TRAFFICABILITY OF SOILS

TESTS ON COARSE-GRAINED SOILS WITH SELF-PROPELLED AND TOWED VEHICLES 1958-1961

TECHNICAL MEMORANDUM NO. 3-240

SEVENTEENTH SUPPLEMENT

May 1963

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

REPORTS OF THE SERIES ENTITLED "TRAFFICABILITY OF SOILS"
TECHNICAL MEMORANDUM NO. 3-240

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PREFACE

The tests reported herein are part of the studies conducted by the U. S. Army Engineer Waterways Experiment Station (WES) under Corps of Engineers Task No. 1-T-0-21701-A-046-02, "Surface Mobility." Tests were financed in part by the Bureau of Yards and Docks, Department of the Navy.

Acknowledgment is made to consultants and representatives of various Government agencies who attended a trafficability conference held at the Waterways Experiment Station on 12 May 1955 and offered guidance for the tests on coarse-grained soils. Special acknowledgment is made to Messrs. Sam Gorelick and Fred Knoop, U. S. Navy Bureau of Yards and Docks, who assisted in formulating priorities for conduct of coarse-grained soil testing reported herein.

These tests were conducted by personnel of the Army Mobility Research Center, Soils Division, WES, under the general supervision of Messrs. W. J. Turnbull, S. J. Knight, and A. A. Rula. Engineers actively engaged in the study were Messrs. A. A. Rula and E. S. Rush. This report was written by Mr. Rush.

Directors of the WES during the conduct of this study and the preparation and publication of this report were Col. A. P. Rollins, Jr., CE, Col. E. H. Lang, CE, and Col. Alex G. Sutton, Jr., CE. Technical Director was Mr. J. B. Tiffany.

CONTENTS

SUMMARY

Standard and special vehicle tests were conducted with 21 military vehicles over a range of vehicle weights, tire pressures, and sand strengths and conditions to pursue investigations recommended in the 15th Supplement of this series. Standard tests were of three kinds: self-propelled, towing, and towed. Special tests included tests on: "honeycomb" sand; gravel beaches; drawbar pull-slip; a truck-trailer combination; the effects of a traction device, tire tread, and wheel load; and the Airoll.

Coarse-grained soil tests were made in five locations in the United States and France. Principal conclusions were that: (a) maximum towing force of self-propelled wheeled vehicles on level sand (for the same sand and vehicle conditions) was about 2% greater than maximum slope negotiable, and these data can be correlated; (b) vehicle performance tended to improve with decreasing contact pressure; (c) 6x6 vehicles generally had higher tractive coefficients than 4x4 vehicles with the same contact pressure on the same sand conditions; and (d) vehicle performance on wet sand that tended to liquefy under the vehicle load was similar to that on fine-grained soils.

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PART I: INTRODUCTION

Purpose and Scope of Test Program

1. The tests reported herein are part of a comprehensive study to quantify the trafficability of coarse-grained soils. The specific objectives of these tests were to:

   a. Establish slope-climbing and towing abilities of a range of self-propelled wheeled and tracked vehicles operating on sands of various strengths (cone index) and moisture contents.

   b. Establish towing force required to tow vehicles over sands of various strengths and moisture contents.

   c. Investigate the effects of such vehicle characteristics as wheel load, tire tread, and special traction devices on vehicle performance in sand.

   d. Establish suitable vehicle performance-sand relations for truck-trailer combinations.

   e. Investigate the trafficability of gravel beaches.

Previous Investigations

2. Since 1945 the Waterways Experiment Station (WES) has conducted a large number of traffic tests with military vehicles on a variety of soil conditions. Results of this work have been published in a series of reports with the general title "Trafficability of Soils," Technical Memorandum No. 3-240, which are listed on the inside of the front cover of this volume. Most of the reports present the results of tests conducted on fine-grained soils, since these soils cover a major portion of the earth's land surface and their behavior under traffic depends to a great extent on their moisture content. The development of instruments and techniques for measuring the trafficability of these soils is considered to be essentially complete.

3. Work to develop methods for predicting, without physical contact, the trafficability of fine-grained soils is another phase of the trafficability studies. Results of this work have been published in a series of reports with the general title "Forecasting the Trafficability of Soils," Technical Memorandum No. 3-331. Work on this prediction phase is continuing.

Background of WES Testing of Coarse-Grained Soils

4. In October 1953, a joint Army-Navy ad hoc committee assigned the responsibility for studying means of determining the trafficability of coarse-grained soils to WES. The first phase of this project was a pilot study to provide background information concerning mobility problems on sands, and to determine whether instruments and techniques that have been successful in defining trafficability of fine-grained soils would also be successful in coarse-grained soils. This study was accomplished in 1954 and is reported in Technical Memorandum No. 3-240, 13th Supplement.

5. In May 1955, a conference was held at WES with consultants and representatives of various Government agencies to discuss results of the pilot study and outline a program for future work. As a result of this conference, additional trafficability tests on a variety of beaches were suggested; subsequently, tests were conducted on beaches of various Pacific islands and at Camp Lejeune, North Carolina, and on desert dune sands near Yuma, Arizona, during 1956 and 1957. These tests are reported in Technical Memorandum No. 3-240, 15th Supplement.

Important findings of pilot study (13th Supplement)

6. All vehicle tests reported in the 13th Supplement were conducted with self-propelled vehicles on quartz sands found on inland areas and beaches of the United States. The important findings are summarized as follows:

- a. Sand categories. Two distinct sand categories were identified, each requiring a different trafficability measurement technique. The two categories are: (1) clean sands that react as a frictional material under the action of traffic with little change in trafficability with changes in moisture content, and (2) sands with fines, poorly drained, that react in a plastic manner when wet.

b. Instruments. The cone penetrometer was found to be as accurate an instrument for measuring sand trafficability as any tested, and was recommended for future use in sands, mainly on the basis of its simplicity and its ability to determine profile conditions, and also because it had been previously accepted for use in fine-grained soils.

c. Remolding effects. No necessity was found for predicting strength changes under vehicle traffic for most sands (see subparagraph d). For sands with fines, poorly drained, a test technique was developed to indicate such strength changes.

d. Repetitive traffic. In general, the first pass was found to be the most difficult for a wheeled vehicle in a clean sand area. An exception to this finding occurred in some crusted sands. The surface crust supported the vehicle for one pass (or a few) but suddenly broke on a subsequent pass, causing the vehicle to become immobilized or making operation more difficult in the much softer underlying sand and deeper ruts. Because only a few tests were conducted on crusted sands, a test for predicting the strength change thereof was not devised.

e. Tire pressure. Tire-inflation pressure was found to be the most significant single vehicle characteristic affecting the performance of wheeled vehicles in sand.

f. Critical layer. For all vehicles tested, the critical layer for clean sands appeared to be the top 6 in. For sands with fines, poorly drained, the critical layer appeared to be the same as that for fine-grained soils (i.e. the 6- to 12-in. layer).

Important findings of subsequent tests (15th Supplement)

7. Test results reported in the 15th Supplement are based on self-propelled, towing, and towed tests. The important results and conclusions from these tests are summarized in the following paragraphs.

8. Tests with single, self-propelled, wheeled vehicles. These tests resulted in the following conclusions:

a. Self-propelled vehicle performance can be defined by means of cone index-slope climbing relations provided cognizance is taken of the general wetness of the sand.

b. Wet sands are more trafficable than dry-to-moist sands. Saturated or near-saturated sands, however, are likely to become quick under vehicular traffic and therefore are the least trafficable.

c. Self-propelled vehicle performance on dry-to-moist sands, as defined by the cone index-slope climbing relations, is the same regardless of sand source (quartz, volcanic, or coral) or location (beach or desert).

d. Payload variation from empty to 1.5 times the rated load has no major effect on the slope-climbing ability of self-propelled vehicles when operated at the same tire pressures.

9. Towing tests with self-propelled vehicles. Pilot towing tests were conducted on natural and harrowed sand. The tests on undisturbed sand were inconclusive; however, harrowed-sand tests showed the following results:

a. Maximum drawbar pulls on level sand ranged between 20 and 40% of the gross vehicle test weight for wheeled vehicles, and between 50 and 60% of the gross vehicle test weight for tracked vehicles.

b. Tests with wheeled vehicles having the same payload capacities but differing in wheel arrangement and tire size resulted in differences in performance. Single-rear-tandem, all-wheel-drive vehicles appeared to have approximately 5% higher drawbar-pull ability than dual-rear-tandem vehicles.

c. The maximum slope-climbing ability of vehicles can be estimated from maximum-drawbar-pull determinations on level sands with reasonable accuracy if the level and sloping surfaces have the same strength.

10. Towed tests with wheeled trailers. These tests produced the following conclusions:

a. Sand disturbance by the towing vehicle has little effect on towing-force requirements when the towed and towing vehicles are operated at the same tire pressures.

b. Towing-force requirements for wheeled trailers can be correlated with cone index and tire pressure.

Recommendations from 15th Supplement

11. From the findings mentioned in the above paragraphs, certain recommendations were made which have been used as a guide for the current studies; however, the recommendations were not in order of priority for proposed studies. Some of the recommendations have not been followed as yet, but it is expected they will be considered in preparation of subsequent reports on sand trafficability.

12. It was recommended in the 15th Supplement that:

a. A rapid method be developed for confident recognition of the three moisture conditions of sand that are important from the trafficability standpoint--dry to moist, wet to inundated, and quick condition.

b. Additional single self-propelled vehicle tests be made, with emphasis on wheeled vehicles of more than 5-ton capacity.

c. Detailed studies of the effect of wheel load, tire pressure, and other vehicle characteristics on performance of vehicles in sand be continued.

d. Towing tests on undisturbed sand with a range of military vehicles be conducted.

e. Additional towed-vehicle tests, including tests with tractor-trailer combinations, be conducted.

f. Work be conducted on procedures to derive means of evaluating performance of vehicles not tested.

g. Vehicle tests on gravel beaches be conducted.

h. Work on estimating the trafficability of untested beaches be continued.

Definitions

13. Certain terms used in this report are defined below.

Soil terms

Fine-grained soil. A soil of which more than 50% of the grains, by weight, will pass a No. 200 U. S. standard sieve (smaller than 0.074 mm in diameter).

Coarse-grained soil. A soil of which more than 50% of the grains, by weight, will be retained on a No. 200 sieve (larger than 0.074 mm in diameter).

Sand. A coarse-grained soil with the greater percentage of the coarse fraction (larger than 0.074 mm) passing the No. 4 sieve (4.76 mm).

Sand with fines, poorly drained. A sand that contains some fine-grained soil and is slow-draining. When wet, such sands behave in a manner similar to very wet fine-grained soils under vehicular traffic.

Density. The unit weight of the soil in pounds per cubic foot. Unless otherwise stated, the density is the dry unit weight.

Moisture content. The ratio, expressed as a percentage, of the weight of water in the soil to the dry weight of the solid particles.

Cone index. An index of shearing resistance of soil obtained with the cone penetrometer. The value represents the resistance of the soil to penetration of a 30-degree cone of 0.5-sq-in. base or projected area. The number, although considered dimensionless, actually denotes pounds of force on the handle divided by the area of the cone base in square inches.

Trafficability. The capacity of a soil to support the traffic of military vehicles.

Bearing capacity. The ability of a soil to support a vehicle without undue sinkage.

Traction capacity. The ability of a soil to provide sufficient resistance to the tracks or wheels of the vehicle to furnish the necessary thrust to move it forward.

Critical layer. The layer of soil regarded as being most pertinent to establishing the relation between soil strength and vehicle performance. (For coarse-grained soils, this appears to be the 0- to 6-in. layer.)

Liquefaction. The puddling and drastic reduction in strength of saturated (although initially firm) sand under the action of repetitive loading. The combined effects of wetness, structure, and fineness of the sand may prevent the sand from draining fast enough to maintain intergranular friction when a dynamic load is applied, thus causing pore pressure to develop and the sand to liquefy.

Beach terms

Foreshore (FS).* That part of the beach ordinarily traversed by the uprush and downrush of waves as the tide rises and falls.

Backshore (BS).* That part of the beach between the foreshore and the forward dune apron (if present) of the coastline.

Berm crest (BC).* The seaward limit of the backshore; usually a relatively flat area paralleling the foreshore and occasionally wetted by waves at high tide.

Berm backslope (BBS). A backshore area between the berm crest and the forward dune apron, usually sloping gently downward and landward.

Backshore flat (BSF). A backshore area between the berm crest and

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* Terms marked with an asterisk were extracted from Appendix A, Beach Erosion Board Bulletin, Special Issue No. 2, March 1953. Other terms pertain to specific areas in which vehicular tests were conducted but which are not defined in the above-mentioned reference.

the tidal flat, usually on the seaside of barren islands. The elevation is approximately 1 ft higher than that of the tidal flat.

Forward dune apron (FDA). The concave seaward slope of a line of dunes.

Dune area (DA). An area of wind-deposited sand between the forward dune apron and the coastline. Coastal dunes may be active or partially stabilized by vegetation.

Tidal flat (TF). A large low-lying area that is affected by tidal action of a body of water. Portions of the area may be inundated at high tides, and other portions, though not inundated, may have fluctuating water tables that are influenced by tidal action.

Spit.* A small point of land or submerged ridge running into a body of water from the shore.

Sand conditions

Dry sand. Sand that was light-colored, loose, and free-flowing when poured from the hand. Dry sand usually occurred on the surface of all components of the beaches except the foreshore, but never extended deeper than about 5 in. before becoming moist. Sand classed as dry on the basis of visual observation usually contained less than 1.5% moisture by weight.

Moist sand. "Moist" sand usually lay directly beneath the dry sand layer. It was usually darker in color, showed slight cohesion, and was cool to the touch. In general, moist coarse sand was found to contain about 1.5 to 5.0% moisture, and moist fine sand about 10 to 12% moisture.

Wet sand. Sand on the foreshore that was being wetted by waves, but was not under a finite depth of water during the time of testing. Wet sand exhibited a considerable amount of cohesion, and free water could be squeezed out of it.

Honeycomb sand. A term tentatively used to identify a particular sand condition encountered at Padre Island (see paragraph 122).

Inundated sand. Sand covered by water during the time of testing. NOTE: A spot on the foreshore "inundated" at one moment during the uprush of a wave might become "wet" a few seconds later when the wave receded.

Quick-condition sand. Loose, yielding, wet, or more commonly,

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* See footnote on preceding page.

inundated sand that had water flowing through it vertically upward and became liquefied under a moving vehicle (thereby causing its immobilization) was termed sand in a "quick condition."

Vehicle terms

Vehicle performance. In this report, the maximum drawbar pull that a vehicle can exert, or the maximum slope it can climb, on a given soil condition.

Pass. One trip of the vehicle over the test course.

Multiple passes. More than one pass of the vehicle in the same path over the test course.

Immobilization. In this report, failure of a self-propelled vehicle to travel forward over sand, although it could possibly back up in its ruts; immobilizations of wheeled vehicles were also considered to have occurred whenever the drive wheels began to jerk violently and the vehicle progressed forward very slowly.

Maximum drawbar pull (maximum towing force). The maximum amount of sustained towing force a self-propelled vehicle can produce at its drawbar under given test conditions.

Towing-force requirements. The amount of force required to tow a given vehicle in neutral gear under given test conditions.

Tractive coefficient. The ratio of the drawbar pull to the gross weight of a vehicle under given test conditions.

Total tractive effort. The maximum towing force or drawbar pull developed by a vehicle plus the force required to tow it (in neutral gear) under given test conditions.

Slip. The percentage of track or tire movement ineffective in thrusting the vehicle forward.

Ply rating (PR).* A term used to identify a given tire with its maximum recommended load when used in a specific type of service. It is an index of tire strength and does not necessarily represent the number of cord plies in the tire.

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* American Tire and Rim Association Yearbook, 1955.

PART II: TEST PROGRAMS

14. The tests reported herein were conducted at five widely separated locations: at Padre Island, near Corpus Christi, Tex. (plate 1), during November-December 1958; at La Turballe and Suscinio Beaches, Brittany, France (plate 2), during May-June 1959; on Mississippi River sand, near Vicksburg, Miss. (plate 3), during September-October 1959 and February 1961; in the vicinity of Cape Cod, Mass. (plate 4), during June 1960; and at Warren Dunes State Park on Lake Michigan (plate 5), during October 1960. Tests included the operation of wheeled and tracked vehicles over beach, tidal flat, coastal dune, and river sands, and over beach gravel. Measurements of vehicle performance were made and pertinent sand data were obtained for each test. Details of the various test programs are described in the following paragraphs together with the appearance of each test area at the time the tests were conducted. The sand or gravel classifications (according to the Unified Soil Classification System) discussed in the following paragraphs are based on laboratory analyses performed on representative samples taken from the 0- to 6-in. depth. Cone index data presented are for the same depth.

Test Areas

Padre Island test areas

15. Padre Island (plate 1) is one of the chain of barren islands that lies parallel to the Texas coast in the vicinity of Corpus Christi. It varies in width from a few hundred yards to 3 to 4 miles, and is approximately 100 miles long. The major portion of the island consists of sand that has not been stabilized by vegetation. The east or gulfside sand beaches are firm with a few exceptions; automobiles can be driven along the foreshore with ease. The west or lagoonside is for the most part a tidal flat area that remains constantly wet because of tidal fluctuations. Active dune areas occur between the east and west shorelines.

16. Tests were conducted on the gulfside and lagoonside of the island. Test areas are described below. Representative grain-size curves and supplementary physical property data are presented in fig. 1 of plate 6.

17. Gulfside test areas. Most of the tests on the gulfside were conducted on a flat (less than 1% slope) area (fig. 1) between the Gulf to the east and an inland water area, known as Packery Channel, to the west. At the time of the tests, Packery Channel was connected to the Gulf; thus, tidal fluctuations of the Gulf affected the water level in the channel. Tests were conducted in the surf, on the wet foreshore 50 to 200 ft wide, along the berm and backshore 25 to 100 ft wide, and in the tidal flat area (approximately 20 acres) near Packery Channel. The soil was a uniform fine sand (SP). Cone index for this area ranged from 25 in the tidal flat area to over 500 on the wet foreshore.

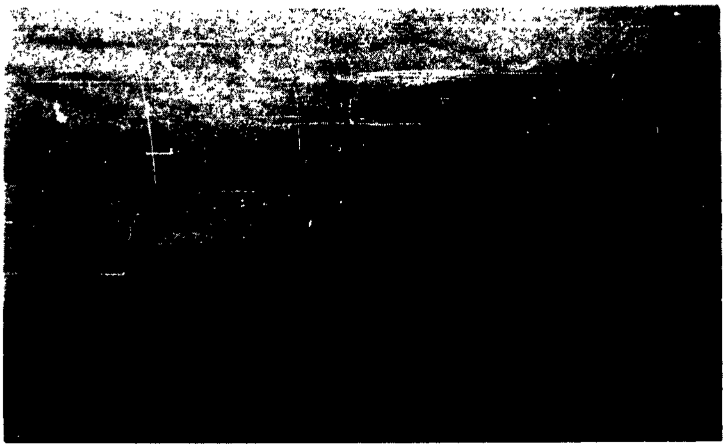


Fig. 1. Gulf foreshore, Padre Island, Texas

18. A few vehicle tests were run on a shell beach, approximately 30 miles south of the area described above and on the gulfside of the island. This beach was composed largely of a mixture of loose shell fragments and sand, which resulted in a softer foreshore than the sand test area mentioned in the preceding paragraph. The soil was a uniform, medium to fine sand (SP).

Fig. 2. Lagoonside (west side) test area, Padre Island, Texas

19. Lagoonside test area. Tests on the lagoonside of the island were conducted in a level area (fig. 2) approximately 2-1/2 miles

southwest of the Gulf foreshore area. The lagoonside testing covered an area from near the sand dunes into the tidal flats of sand and mud; however, the testing was done on areas where the sand was level and fairly clean to a depth of 3 ft. The soil was a uniform fine sand (SP) with about 2% fines. Cone indexes ranged from 20 close to the lagoon to about 75 near the dunes.

Brittany, France, test areas

20. La Turballe Beach. This beach (fig. 3) is located on the Brittany coast of France near the town of La Turballe, between the cities of Vannes to the north and St. Nazaire to the south (plate 2). The beach area utilized for testing was about 2000 yd long. The foreshore averaged 125 ft in width and had an average slope of 15%; cone index ranged from 45 to 143. The backshore was 55 ft wide with an average slope of 10%; cone index ranged from 26 to 72. The forward dune apron, partially stabilized with vegetation, averaged 45 ft in width and had an average slope of 25%; cone index was 150+. Inland from the forward dune apron was a series of small dunes stabilized with grass and weeds. The soil on the foreshore was a uniform coarse to medium sand (SP), and that on the backshore a uniform medium sand (SP). Representative grain-size curves and supplementary data are presented in fig. 2 of plate 6.

Fig. 3. La Turballe Beach, France

21. Suscinio Beach. This beach (plate 2 and fig. 4) is also located on the Brittany coast, north of La Turballe, southeast of Vannes. The test area was about 1/2 mile long. The foreshore averaged 150 ft in width and had an average slope of 9%; cone index ranged from 51 to 156. The backshore was 15 ft wide with an 8% slope; the cone index ranged from 77 to 145. The forward dune apron was almost entirely covered with vegetation, and the

Fig. 4. Suscinio Beach, France

cone index ranged from 93 to 197. The foreshore and backshore were non-uniform gravelly sand (SW). Representative grain-size curves and supplementary data are presented in fig. 2 of plate 6.

Mississippi River test areas

22. During low water, areas of sand suitable for vehicle testing were found in the form of sandbars and beaches along the banks of the Mississippi River. Tests were conducted on two such beaches (plate 3) near Vicksburg, Miss.; the test areas are described below. Representative grain-size curves and supplementary data are presented in fig. 3 of plate 6.

23. Vicksburg Bridge area. This test area (fig. 5), located on the west bank of the river, extended from the Vicksburg Bridge to approximately 2000 ft south of the bridge; it varied in width from about 50 ft on the north end to about 500 ft on the south end. The beach surface was gently undulating with an average slope of about 1%. Inland from the beach was a flat terraced area of sand and silt that was partially stabilized with small willow and cottonwood trees. Cone index ranged from 100 to approximately 160. The soil was a uniform fine sand (SP).

Fig. 5. Vicksburg Bridge area, Mississippi River

24. Marshall Cutoff area. This area (fig. 6) of approximately 50 acres was located on the west top bank of the river about 10 river miles north of the Vicksburg Bridge. Because of its higher elevation, this area was available for testing for longer periods than the Vicksburg Bridge area.

Fig. 6. Marshall Cutoff area, Mississippi River

The Marshall Cutoff area consisted of long, flat sections with very little undulation. The soil was a uniform medium to fine sand (SP). The cone index ranged from 85 to 147.

Cape Cod test areas

25. Camp Wellfleet. Camp Wellfleet Military Reservation is situated on the Atlantic Ocean (east) side of Cape Cod, Mass., approximately 16 miles south of the northern point of the Cape (plate 4). Vehicle tests were conducted on beach areas (fig. 7) representative of beaches along the east coast of the Cape. Foreshore width varied considerably with the tide. At low tide, the foreshore was generally 60 to 100 ft wide; at high tide the foreshore was completely inundated. The backshore was generally about 50 ft wide with some areas about 150 ft wide. The beach was bordered on the inland side by a cliff or forward dune apron (50 to 70% slope) that was approximately 25 to 50 ft high. Tests in this area (fig. 8) were conducted

Fig. 7. Camp Wellfleet beach, Cape Cod, Mass.

Fig. 8. Camp Wellfleet dune area, Cape Cod, Mass.

adjacent to a cliff in an area that had been leveled by construction equipment several years before. Check tests were conducted in the disturbed area to determine its suitability for the traffic testing. The surrounding undisturbed dune area was partially covered with vegetation. Cone index ranged from 57 to 140 in the beach area and from 57 to 230 in the dune area. The beach soil, foreshore and backshore, was uniform medium sand (SP), whereas the soil in the dune area was nonuniform gravelly sand (SW). Representative grain-size curves and supplementary physical property data are presented in fig. 1 of plate 7.

26. Duxbury Beach. Duxbury Beach (plate 4 and fig. 9) is a narrow spit approximately 2 miles long extending south from the coast near Duxbury, Mass., on the northwestern boundary of Cape Cod Bay. Tests were conducted on gravel portions of this beach. The foreshore areas on the east side were predominantly sand, while the foreshore areas on the west side were sand and gravel mixtures. No tests were conducted on foreshore areas on the east side. Backshore areas were largely gravels of various sizes. Some vegetation existed on portions of the backshore. A representative grain-size

Fig. 9. Duxbury Beach area, Mass.

curve with supplementary data for each test series is shown in fig. 2 of plate 7. The soil tested ranged from coarse gravel (GP) with cobbles to gravelly sand (SW). Reliable cone index measurements could not be taken in the gravel areas where trafficability tests were conducted.

Fig. 10. Lake Michigan beach, Warren Dunes State Park

Lake Michigan test areas

27. Tests were conducted on the beach and unstabilized dunes at Warren Dunes State Park (plate 5 and figs. 10 and 11) located approximately 10 miles north of the Michigan-Indiana state line on the east bank of Lake Michigan. Slopes ranged from level to 75%, and cone index ranged from 16 to 110. The soil in the dune area was uniform fine sand (SP). The beach soil, foreshore and backshore, was medium to fine sand (SP). The foreshore had a slope of approximately 10%, whereas the backshore surface was level. Representative grain-size curves and supplementary data are presented in fig. 3 of plate 7.

Fig. 11. Lake Michigan dunes, Warren Dunes State Park

Instruments Used to Obtain Test Data

28. The cone penetrometer and moisture-density cylinder were used in all test areas. A level was used for measuring slopes. Laboratory-type

test gages were used to check tire pressures of all wheeled vehicles; dynamometers and related equipment were used to measure towing forces. The various items of equipment are described in the following paragraphs.

Sand data

29. Cone penetrometer. The cone penetrometer is a field instrument which consists of a 30-degree cone with a 0.5-sq-in. base area mounted on a 5/8-in.-diameter shaft (fig. 12). The cone is forced into the soil slowly and a proving ring and calibrated-dial assembly are used to measure the load applied. The penetration resistance is termed cone index (see "Definitions"). The standard cone penetrometer permits cone index readings to be taken up to 300; however, to obtain measurements in firm sands that exceeded 300 cone index, a 30-degree cone with a 0.2-sq-in. base area and a 3/8-in.-diameter shaft was used. The 0.2-sq-in. cone permitted taking cone index readings up to 750.

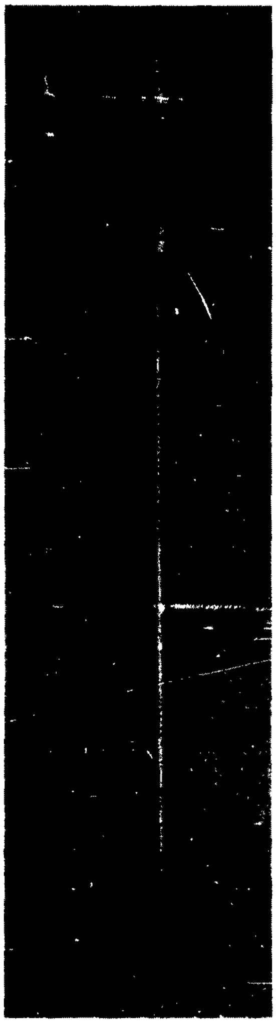


Fig. 12. Cone penetrometer

30. Moisture-density cylinder. A 2-3/4-in.-diameter, 3-in.-high, thin-walled, stainless steel cylinder was used in obtaining all moisture-density samples in sand. Fig. 13 shows a moisture-density sample taken with the cylinder.

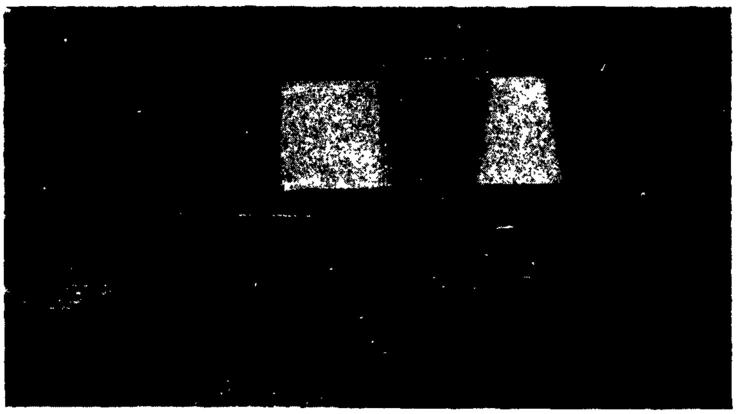


Fig. 13. Moisture-density sample

31. Mechanical analysis sieves. Normally the mechanical analysis of a soil was determined in the laboratory by drying approximately 400 g of the material and passing it through a set of U. S. standard sieves mounted

in a mechanical shaker. For the Duxbury Beach gravel areas, the majority of the sieve analyses were conducted on the beach because of the large gravel sizes and the large quantity of material needed for a representative sample. Standard sieves were used but the material was hand-screened. Any material less than 1/4 in. in diameter was analyzed in the laboratory in the usual manner.

32. Levels. A hand level accurate to 0.5% was used for determining slopes of test lanes that were fairly steep; a rod and a level mounted on a tripod were used to measure shallow slopes.

Vehicle data

33. Tire-inflation pressure gage. A laboratory-type test gage, accurate to 0.25 psi throughout the range of tire pressures tested, was used to measure tire-inflation pressures.

34. Dynamometers. The dynamometers used were electrically recording load cells that measured forces in tension by translating changes in force into changes in electrical energy. The load cells are hermetically sealed and operate without mechanically moving parts. The sensing element is a high-strength load-carrying member to which are bonded special SR-4 strain gages that undergo resistance changes precisely proportional to the applied strain. The dynamometers were used to measure the amount of drawbar pull during the towing and towed tests; they were connected between the test vehicle and the load vehicle. Dynamometers ranged in capacity from 5000 to 20,000 lb, depending upon the amount of force to be measured.

35. Slip meter. The distance a point on the periphery of a wheel or track traveled during a given time and the distance the vehicle traveled during the same time were determined by a slip meter. The meter indicated the number of revolutions the vehicle wheel made while propelling the vehicle, and the number of revolutions made by a nonslipping bicycle wheel trailing the test vehicle and attached to it.

36. Recorder for dynamometer and slip meter. During the tests, the force exerted on the dynamometer and the events experienced by the slip meter were recorded simultaneously as traces on a direct-inking recorder.

37. The system for measuring drawbar pulls contained a recorder, amplifier, power supply, cables, and dynamometers. The recorder, amplifier, and power supply were mounted in the rear of the load vehicle or in a third

Fig. 14. 2-1/2-ton truck instrumented for drawbar pull-slip test

vehicle. Fig. 14 shows a drawbar pull-slip test being conducted.

Vehicles Tested

38. Detailed data for wheeled and tracked vehicles of the types tested are given in table 1. Vehicles tested are shown in figs. 15 through 19. The following tabulation lists the vehicles tested at each test area along with pertinent vehicle data.

Wheeled Vehicles

Vehicle	Empty Weight lb	Test Weight lb
Padre Island		
1/4-ton M38A1, 4x4 truck	2,690	2,690
		2,860
		3,200
3/4-ton M37, 4x4 truck	5,687	5,687
		6,407
		7,187
2-1/2-ton M135, 6x6 truck	12,450	14,750
		17,450
5-ton M41, 6x6 truck	19,070	23,070
		28,170
France		
1/4-ton M38A1, 4x4 truck	2,625	2,625
3/4-ton M37, 4x4 truck	5,687	5,687
		6,887
2-1/2-ton M34, 6x6 truck	11,775	11,775
		16,775
2-1/2-ton DUKW 353, 6x6 truck	14,670	14,670
		19,670
5-ton M51, 6x6 truck	22,663	32,663

Vehicle	Empty Weight lb	Test Weight lb
Mississippi River		
2-1/2-ton M211, 6x6 truck	12,792	18,470
2-1/2-ton M135, 6x6 truck	12,450	18,750
		18,100
	12,000*	17,610
		17,610
Bucket loader, 4x4 tractor	13,595	13,595
Tournadozer, 4x4 tractor	31,070	31,070
5-ton XM520 GOER, 4x4 carrier	16,670	26,670
Cape Cod		
3/4-ton M37, 4x4 truck	5,687	5,687
2-1/2-ton M135, 6x6 truck	12,450	12,450
2-1/2-ton DUKW 353, 6x6 truck	15,285	15,285
5-ton M52, 6x6 truck	18,310	18,310
		22,310
12-ton M127A1 semitrailer	10,400	10,400
Lake Michigan		
5-ton M704 Jumbo, 4x4 truck	13,000	20,100

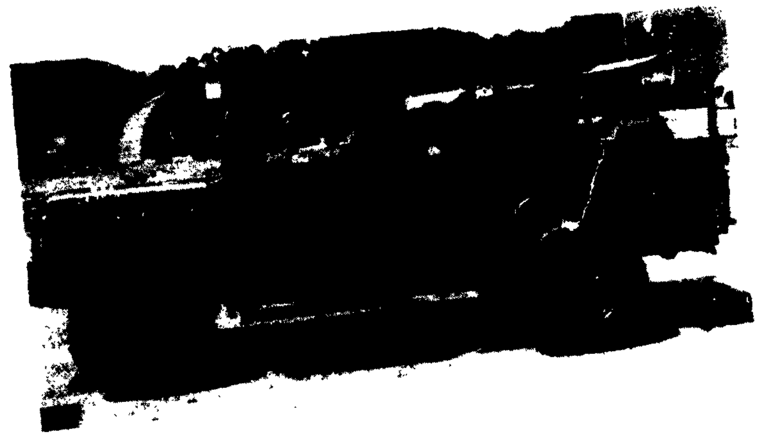
Tracked Vehicles

Vehicle	Gross Weight lb
Mississippi River	
1/4-ton M29C weasel	5,560
Standard D4 engineer tractor	14,870
Standard D7 engineer tractor	27,000
13-ton M5A4 hi-speed tractor	25,230
18-ton M4 hi-speed tractor	28,700

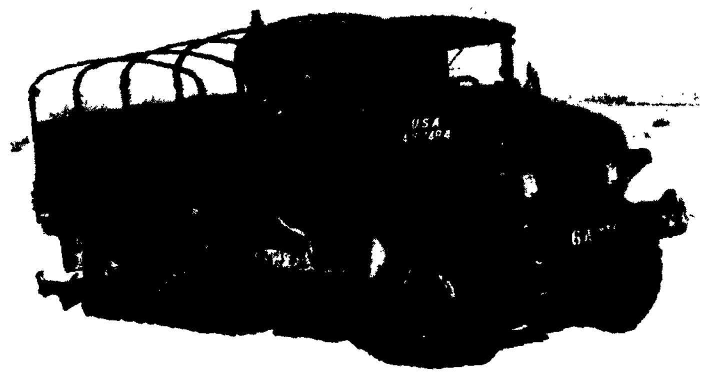
Vehicle	Gross Weight lb
Cape Cod	
Standard D6 engineer tractor	22,667
18-ton M4 hi-speed tractor	30,250
Lake Michigan	
1/4-ton M29C weasel	4,200
Airoll	19,100

* M135 tested with front tandem wheels removed, reducing number of tires to 4.

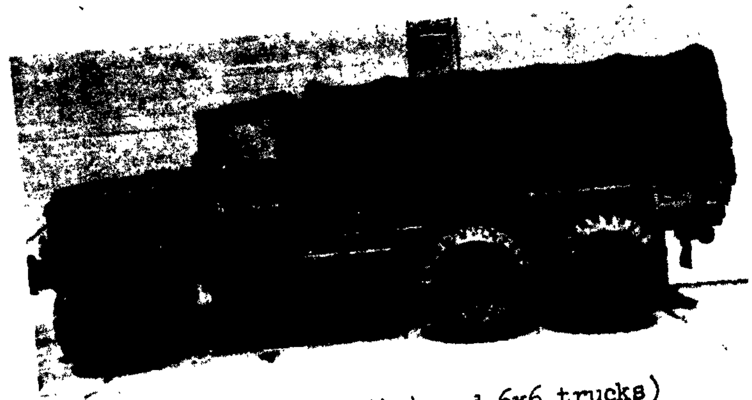
a. 1/4-ton M38A1
4x4 truck



b. 3/4-ton M37
4x4 truck

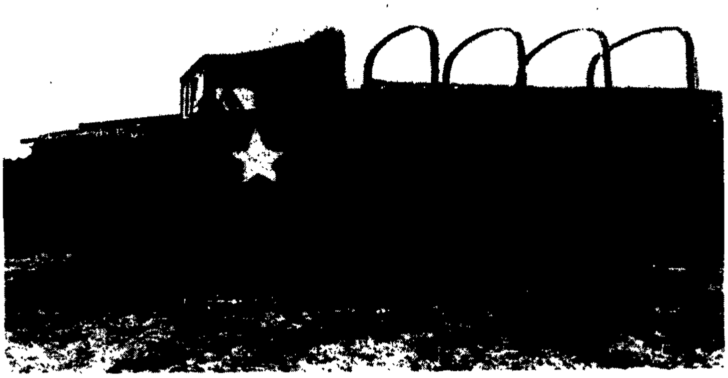


c. 2-1/2-ton M135
6x6 truck

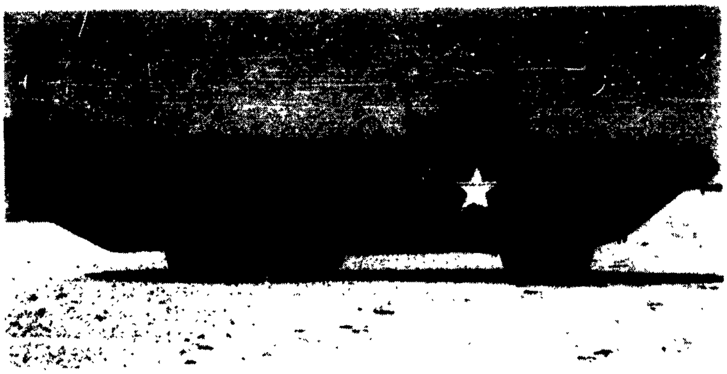


d. 5-ton M41
6x6 truck

Fig. 15. Self-propelled wheeled vehicles (4x4 and 6x6 trucks)
used in tests

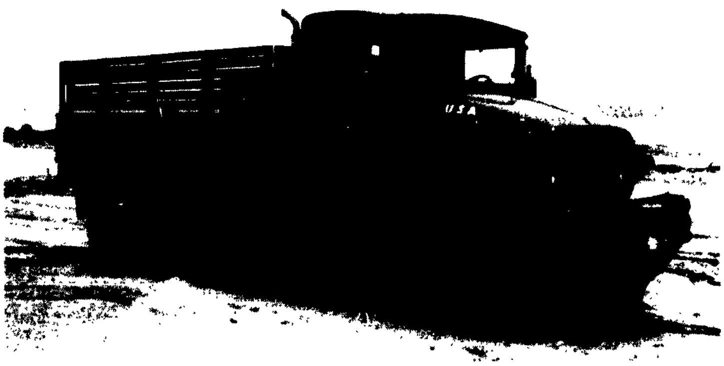


a. 2-1/2-ton M34
6x6 truck



b. 2-1/2-ton DUKW
353, 6x6 truck

c. 5-ton M51
6x6 truck

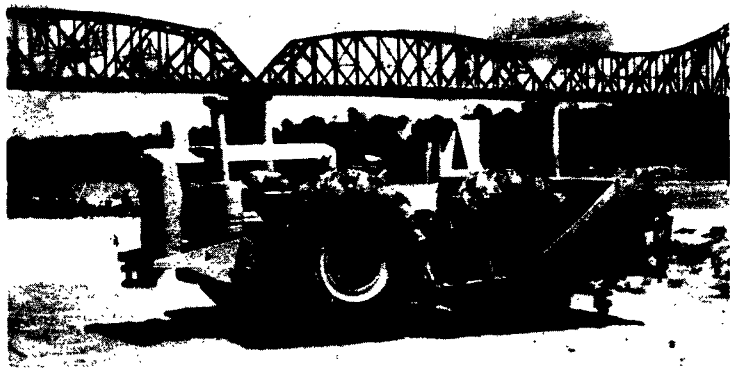


d. 2-1/2-ton M211
6x6 truck

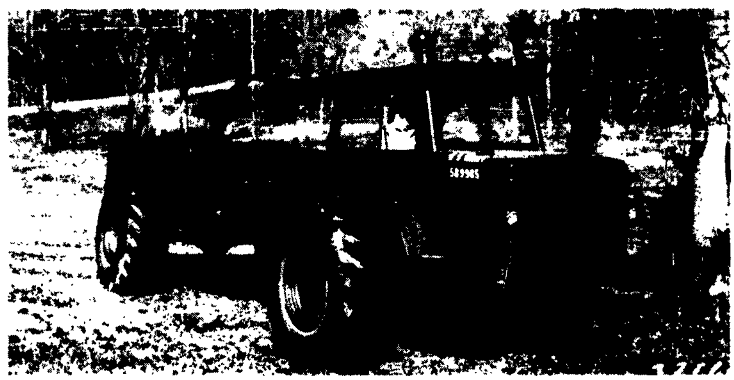
Fig. 16. Self-propelled wheeled vehicles (6x6 trucks) used in tests

a. Bucket loader
4x4 tractor

b. Tournadozer
4x4 tractor



c. 5-ton XM520 GOER
4x4 cargo carrier. (18.00-26,
10-PR tires)



d. 1/4-ton M29C
weasel

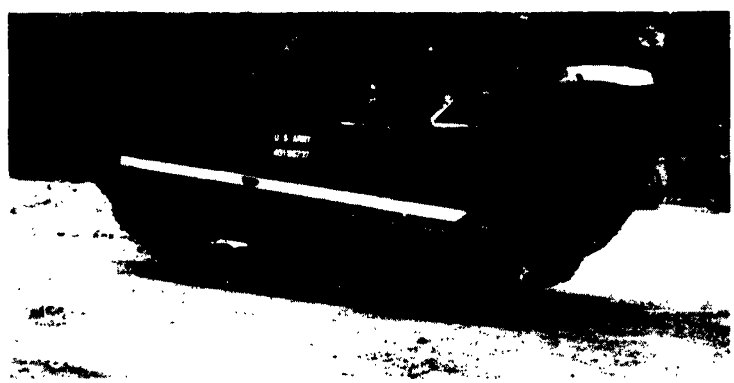


Fig. 17. Self-propelled wheeled and tracked vehicles (construction-type and cargo carriers) used in tests

a. Standard D4 engineer tractor

b. Standard D7 engineer tractor

c. 13-ton M5A4 hi-speed tractor

d. 18-ton M4 hi-speed tractor

Fig. 18. Self-propelled tracked vehicles (tractors) used in tests

a. 5-ton M52, 6x6 truck tractor

b. 12-ton M127A1 dual tandem semitrailer

c. 5-ton M704 Jumbo 4x4 truck

d. Standard D6 engineer tractor

Fig. 19. Self-propelled and towed wheeled vehicles, and self-propelled tracked vehicle used in tests

Tests Conducted

39. The following tabulation summarizes the standard vehicle tests and special tests conducted in this investigation.

Standard Tests

Vehicle	Location	Test Type: Self-propelled Tests (Table 2)	Towing Tests (Table 3)	Towed Tests (Table 5)	Total Tests
		Wheeled Vehicles			
M38	France	20	0	0	20
M38A1	Padre Island	0	42	0	42
M37	Padre Island	0	60	8	68
M37	France	40	0	0	40
M37	Cape Cod	0	11	0*	11
M211	Mississippi River	0	20	0	20
M34	France	32	10	0	42
M135	Padre Island	0	24	8	32
M135	Mississippi River	0	20	2**	22
M135	Cape Cod	17	0	0	17
DUKW 353	France	29	27	0	56
DUKW 353	Cape Cod	8	24	4	36
M41	Padre Island	0	27	8	35
M51	France	11	11	0	22
M52	Cape Cod	0	8	5†	13
Bucket loader	Mississippi River	0	11	4	15
Tournadozer	Mississippi River	0	25	4	29
XM502 GOER	Mississippi River	0	49	8	57
M704 Jumbo	Lake Michigan	36	0	0	36
	Total	193	369	51	613
		Tracked Vehicles			
M29C weasel	Mississippi River	0	19	1	20
M29C weasel	Lake Michigan	9	0	0	9
Std D4	Mississippi River	0	6	1	7
Std D6	Cape Cod	3	8	2	13
Std D7	Mississippi River	0	2	1	3
M5A4	Mississippi River	0	5	1	6
M4	Mississippi River	0	8	1	9
M4	Cape Cod	2	7	1	10
	Total	14	55	8	77

Special Tests

Vehicles	Location	Special Test Conducted	Test Type	Table No.	Total Tests
M38A1, M37, and M135	Padre Island	Quick-condition sand	Multiple-pass, self-propelled	6	40
M135, D7, and M5A4	Mississippi River	Drawbar pull-slip	Towing	7	95
M135	Mississippi River	Traction device	Towing	8	19
M135	Mississippi River	Tire tread and wheel load	Towing and towed	8 and 5	79
M52 towing M127A1	Cape Cod	Truck-trailer	Towing and towed	9 and 5	48
M37 and M135	Cape Cod	Gravel	Self-propelled, towing, and towed	10 and 5	49
Airoll	Lake Michigan	Airoll	Self-propelled and towing	11	63
				Total	393
				Grand total	1083††

* Two tests in table 5 are gravel tests.
** Six tests in table 5 are special tests (tire tread and wheel load).
† Six tests in table 5 with trailer are special tests (truck-trailer).
†† Also total of tests in tables 2-11.

40. All tests, standard or special, followed one or more of the three basic test types or methods of operation: single self-propelled, towing, and towed. They are described in the following paragraphs. For all tests, sand and vehicle performance data were obtained, and pertinent

notes were recorded describing the action of the vehicle.

Single self-propelled tests

41. All single self-propelled tests were performed in the same manner insofar as possible. Each test was conducted with the vehicle traveling in a straight-line path in low gear and low range, at track or wheel speeds of approximately 2 mph. In the wheeled vehicle tests, all wheels were driving and great care was taken to ensure that the pressure in all tires was at the desired level. Two types of single self-propelled tests were employed:

a. Single-pass tests. Usually the first pass of a vehicle is the most difficult to make in sand. Nearly all single-pass, single self-propelled tests were conducted on sloping terrain because level terrain produced few, if any, immobilizations. A test was conducted by running the vehicle up a preselected sand slope to a point where it became immobilized or until it reached the top of the slope. It was found that if the vehicle could negotiate the slope on the first pass, it could also negotiate the slope on subsequent passes in the same path. For tests where first-pass sinkage was slight and the vehicle traveled with ease, only one-pass traffic tests were conducted to expedite testing.

b. Multiple-pass tests. If excessive sinkage occurred on the first pass because of soft sand conditions, additional passes were made in the same ruts until it was established whether the vehicle could negotiate 40 to 50 passes.

Towing tests

42. These tests were of the two general types described in the following subparagraphs.

a. Maximum-drawbar-pull (maximum-towing-force) tests. These tests were performed on level sand with the test vehicle towing a load vehicle by means of a cable. The test was performed with the vehicle moving forward about 2 mph. To obtain the maximum drawbar pull, brakes were gradually applied to the load vehicle while the towing vehicle was simultaneously accelerated. Measurements were made of the load being towed at a time when it appeared that a further increase of load would cause the test vehicle to become immobilized. For each test, three or four runs were made and the data were averaged.

b. Drawbar pull-slip tests. Drawbar pull-slip tests were conducted in the same manner as the maximum-drawbar-pull tests, except that at several stages between no drawbar pull and maximum drawbar pull, measurements were made of the distance the wheels or tracks moved and the distance the test vehicle traveled. These latter measurements were used in the determination of slip.

Towed-vehicle tests

43. In these tests, measurements were made of the force required to tow self-propelled vehicles on level sand and an asphalt road. For one series of special tests, a 12-ton M127A1, dual-tandem semitrailer was used. For the sand tests, the test vehicle was offset slightly to straddle the ruts created by the towing vehicle, thus permitting the test vehicle to travel on undisturbed sand.

Sand Data Obtained

44. Sand data collected for each test included cone index, moisture content, density, and slope. The data collected are described in the following paragraphs. A representative bulk sample from the 0- to 6-in. depth was obtained for each test area for laboratory determinations of grain-size distribution, shown in plates 6 and 7.

Cone index

45. For each test, five sets of before-traffic cone index readings were usually made along the center line of the test lane between the path of the wheels or tracks. Test lanes ranged in length from 50 to 100 ft. A set of cone index readings consisted of measurements made at the surface and at 3-in. vertical increments to a depth of 24 in. unless 300+ cone index readings were obtained before reaching this depth. For some of the tests, after-traffic cone index measurements were made in the ruts, usually after 1 and 10 passes.

Moisture content and density

46. Moisture content-density samples were collected at the center of the test lane. Firm sands were sampled in 3-in. increments to a depth of 6 in.; soft sands were sampled in 3-in. increments to a depth of 18 in.

Slopes

47. The slope of the test lane was determined along its center line and also perpendicular to traffic.

PART III: ANALYSIS OF DATA

Effect of Driver Proficiency and Vehicle Mechanical Features

48. Since varying driver proficiency and vehicle mechanical features may influence significantly results of the "go" or "no-go" type of testing performed in this program, every attempt was made to eliminate or minimize these factors. Driver proficiency was believed to have been virtually eliminated as a factor by conducting all tests in a straight line, at a speed of approximately 2 mph, and in lowest gear at low range. No shifting of gears was permitted. Vehicle mechanical features were somewhat harder to control, since the vehicles used were those made available by various agencies at various times. Nevertheless, care was taken to "warm up" the vehicle before the test was conducted, to use no vehicle with an engine that sounded as though it were not tuned properly, and to regulate and check tire pressures. When mechanical features of the vehicle could not be controlled fully, this fact was noted and allowance was made in analysis of the data, where feasible. For example, paragraph 61 mentions the difficulty of control of tire pressures in the DUKW, paragraph 64 refers to the uneven load distribution of the Jumbo, and paragraph 99 points out the severe buckling that occurred in the tires of the bucket loader.

Single Self-propelled (Slope-Climbing) Tests

49. Vehicles used in the single self-propelled tests conducted during the France, Cape Cod, and Lake Michigan test programs were mainly of the type for which performance (maximum-slope-negotiable) curves had been established and reported in the 15th Supplement; however, a few vehicles for which there were no previously established curves also were tested. During these test programs, tests were conducted on soils coarser than any previously tested. The coarsest soil previously tested was medium sand, whereas the majority of slope-climbing tests reported herein were conducted on soil ranging from coarse sand to gravelly sand; however, some tests were conducted on fine sand at Lake Michigan. Single self-propelled tests also were conducted on gravel; these are discussed under "Special Tests."

Data analysis procedures

50. Analysis of data consisted of plotting slope versus cone index for each tire pressure of a given vehicle, and then drawing a line that separated immobilizations from nonimmobilizations. Where applicable for analytical purposes, data reported in the 15th Supplement were combined with data reported herein. (The 15th Supplement reported data for the 1/4-ton M38A1, 3/4-ton M37, 2-1/2-ton M211, M135 and other 2-1/2-ton trucks with 11.00-20 tires, and 5-ton M41.) Current data were combined with data on similar vehicle types from the 15th Supplement, and used to draw revised slope-cone index-tire pressure curves. For vehicles not previously tested, slope-cone index-tire pressure curves were established from the data reported herein. Where data are limited, these curves were shaped according to curves developed for other vehicles for which sufficient data were available. Limited slope-climbing tests were conducted with the 2-1/2-ton DUKW 353, 5-ton M51, 5-ton M704 Jumbo, M29C weasel, M4 hi-speed tractor, and D6 engineer tractor.

51. Where applicable, the slope-climbing tests and the maximum-towing-force tests are plotted on the same graphs (plates 8 through 14). The scale for the slope-climbing tests may be read from the right side of each graph, while the scale for the maximum-towing-force tests may be read from the left side of each graph. In this manner the data were combined to develop the performance curves shown. The relation of maximum slope negotiable to maximum towing force is explained in the discussion of maximum-towing-force tests (paragraph 78).

Moisture classification

52. All except four of the single self-propelled vehicle tests were conducted on sand in the dry-to-moist category. Backshore and dune areas are usually in the dry-to-moist category, while the foreshore areas washed by surf are usually in the wet-to-inundated category. The four tests on wet sand were conducted on the foreshore of the French beaches; however, coarseness of the beach material and moderate slopes of the foreshores at these test sites contributed to fast drainage after inundation.

Presentation of test results

53. The following paragraphs discuss self-propelled test results. Test data are summarized in table 2 and plotted in plates 8 through 15.

(No plots are shown for the tracked vehicles.) Tests were plotted as open symbols if vehicles negotiated the slope-cone index conditions measured, and as closed symbols if vehicles were immobilized. The curve drawn to separate open symbols from closed symbols represents the line of best visual fit.

54. 1/4-ton M38, 4x4 truck. This vehicle is an early model of the M38A1. It was tested only in France, and since the earlier model is not used as often as the M38A1, but has the same essential vehicle characteristics, the data for both vehicle types were combined in plate 8. Twenty tests were conducted at 30- and 20-psi tire pressures on Suscinio and La Turballe Beaches in France (see table 2, items 1 through 20, and figs. 1 and 2 of plate 8). In 4 tests (items 13, 14, 16, and 17) at 20-psi tire pressure, the vehicle climbed slopes steeper than it was expected to climb. In the remaining 16 tests, the vehicle test results were as expected. The M38 operated easily on the French beaches at 15-psi tire pressure; therefore, tests were not conducted at tire pressures less than 20 psi.

55. 3/4-ton M37, 4x4 truck. Forty tests were conducted in France at tire pressures of 30, 20, 15, and 10 psi, and at gross weights of 5687 and 6887 lb. (Tests of the M37 at Cape Cod were on gravel beaches and are therefore discussed separately.) Test data are summarized in table 2, items 21 through 60, and plots of cone index versus slope-climbing performance are shown in figs. 1 through 4 of plate 9.

56. Three tests (items 25, 42, and 55) were immobilizations on slopes that the vehicle was expected to climb; however, one of these tests (item 25) was conducted in an area where old ruts were present, and the vehicle became immobilized while crossing the ruts. In three tests (items 43, 48, and 54) the vehicle climbed slopes steeper than it was expected to climb. Item 43 was conducted on sand with an 8.1% moisture content, which probably explains the improved vehicle performance. In the remaining 34 tests the vehicle performed as expected.

57. 2-1/2-ton M211, 6x6 truck. Single self-propelled tests were not conducted with this vehicle; however, curves for maximum slope negotiable taken from the 15th Supplement are shown in plate 10 for purposes of comparison with maximum-towing-force test results.

58. 2-1/2-ton M135 and M34, 6x6 trucks. These trucks have similar features, such as weights and tire sizes, and their performance appears to

be similar; therefore, test data are comparable and are plotted together in plate 11. Test data for each vehicle are summarized in table 2.

59. Seventeen tests (table 2, items 61 through 77) were conducted with the M135 at Camp Wellfleet during the Cape Cod test program. (Slope-climbing tests conducted with the M135 on gravel beaches at Duxbury are discussed under "Special Tests.") Thirty-two tests (items 78 through 109) were conducted with the M34 in France. Only one immobilization (item 69) occurred on a cone index-slope condition which previous data had indicated the vehicle should have been able to travel. In six tests (items 63, 68, 98, 101, 107, and 108), the vehicle climbed slopes greater than expected from the curves; however, in three of these tests (items 98, 107, and 108) the differences between actual slopes climbed and those expected to be climbed were negligible. In the remaining 42 tests vehicles performed as expected.

60. <u>2-1/2-ton DUKW 353, 6x6 truck.</u> This truck was tested in France and at Cape Cod. Test data are summarized in table 2 (items 110 through 146), and plots of cone index versus slope-climbing performance are shown in plate 12. Twenty-nine tests were conducted in France, 25 on dry-to-moist sand and 4 on wet sand. The wet sand tests (table 2, items 111, 113, and 126) are indicated by an asterisk in plate 12. (Item 117 was a test at 25 psi and was not plotted in this plate.) Eight tests were conducted at Cape Cod, all on dry-to-moist sand.

61. Curves for maximum slope-climbing performance (plate 12) were determined from the tests reported herein. They are tentative because of the small number of tests conducted and the considerable scatter of data. Also, it is pointed out that the DUKW 353 is equipped with an internal tire-inflation system operated from the instrument panel, and although this system is extremely useful for field operation, it was not amenable to close control or measurement of tire pressures. For these reasons curves were drawn to be conservative, i.e. with a large number of "go" tests plotted to the left of the curve. Despite their conservativeness, the curves indicate that the DUKW performed better than the 2-1/2-ton M135 and M34 trucks.

62. <u>5-ton M41, 6x6 truck.</u> Slope-climbing tests were not conducted with this vehicle; however, the curves for maximum slope negotiable taken from the 15th Supplement are presented in plate 13 for comparison with maximum-towing-force test results.

63. 5-ton M51, 6x6 truck. Single self-propelled tests with this vehicle were conducted only in France, at two tire pressures, 20 and 15 psi. Test data are summarized in table 2, items 147 through 157; plots of cone index versus slope-climbing performance are shown along with maximum-towing-force tests of the M52 in plate 14. Tentative curves for maximum performance are also shown for both tire pressures.

64. 5-ton M704, 4x4 Jumbo truck. Thirty-six tests at four tire pressures were conducted during the Lake Michigan test program. Test data are summarized in table 2, items 158 through 193; plots of cone index versus slope-climbing performance are shown in plate 15. Tentative performance curves are shown for each tire pressure. The Jumbo was unevenly loaded, with over twice as much weight on the rear wheels as on the front. This unevenly distributed load undoubtedly affected the performance of the vehicle.

65. Standard D6 engineer tractor. Only three tests were conducted with this tracked vehicle. Test data are summarized in table 2, items 194 through 196. Results are inconclusive since all three tests were immobilizations. Flatter slopes were not available to determine the cone index-slope combination that would permit the vehicle to travel. Results of these tests are not shown graphically.

66. 18-ton M4 hi-speed tractor. Two tests were conducted with this tracked vehicle; the data are summarized in table 2, items 197 and 198. Results show that the tractor was able to climb a 51% slope on a cone index of 48 in the 0- to 6-in. layer, but it became immobilized on a 53% slope on a cone index of 37. Results of these tests are not shown graphically, and maximum-performance curves were not determined.

67. 1/4-ton M29C weasel. Nine tests were conducted with this tracked vehicle during the Lake Michigan test program, and data are summarized in table 2, items 199 through 207. The results are not shown graphically but indicate that the weasel can climb a 44 to 50% slope on a sand with cone index of 20 to 40 in the 0- to 6-in. layer. The vehicle was able to continue up the slopes even while considerable track slip was occurring. At high slips the tracks were digging through the 0- to 6-in. layer, which is normally used for correlations with vehicle performance in sand. Therefore, data obtained from these tests with the weasel are considered inconclusive.

Discussion of test results

68. Results of slope-climbing tests indicate that the maximum-slope-negotiable curves reported in the 15th Supplement for the 1/4-ton M38A1, 3/4-ton M37, 2-1/2-ton M135 and M211, and 5-ton M41 trucks are applicable to similar vehicles operating on coarse sand and gravelly sand consisting of up to 28% fine gravel.

69. Results of tests with the 2-1/2-ton DUKW are not as consistent as results of tests with the other vehicles. It is believed that the inconsistency of results was caused by lack of proper control of tire-inflation pressures rather than by the coarseness of the test materials, although this vehicle was not tested on fine and medium sands.

70. It was observed that coarseness of the soil caused some difficulty in obtaining cone index measurements. Occasionally the cone would hit a large stone and could not be pushed into the soil. When this happened, the penetrometer was moved, usually just a few inches, to an undisturbed area and a new set of measurements was made.

71. In France, the coarseness of the beach material and the slope (approximately 15% on La Turballe and 8% on Suscinio) allowed fast drainage of the sand after it was washed by waves. Only four single self-propelled vehicle tests were conducted (with the DUKW 353) on wet, coarse sand; therefore, a comparison between slope-climbing performance on wet-to-inundated sand and on dry-to-moist sand was not made. It was observed, however, that when a vehicle was operating on gravelly sand being washed by waves, the gravelly sand appeared to be in a quick condition after passage of the vehicle. Fig. 20 shows ruts created by the 2-1/2-ton DUKW on the wet foreshore. At the time this quick condition was observed, the affected sand was not deep enough to cause immobilizations, but it is believed that beaches of

Fig. 20. Partial liquefaction in ruts of 2-1/2-ton DUKW

this type could be difficult to traverse during periods of a highly active surf.

72. In determining the curves for maximum slope negotiable, reliable curves were derived for slopes up to about 20%; however, curves for slopes above about 20% are not as reliable because of the small number of tests. Suitable test areas having steep slopes with high strengths are difficult to find. In order to guide the shape of curves for the maximum slope negotiable at slopes above about 20% it was necessary to conduct maximum-towing-force tests with similar vehicles on level, firmer sands. When expressed as a percentage of the test weight of the vehicle, maximum towing force is a close approximation of maximum slope-climbing ability of the vehicle; therefore, an indication of the shape of the curves for maximum slope negotiable can be determined from maximum-towing-force tests, which are discussed in the following paragraphs.

Maximum-Towing-Force Tests

73. Maximum-towing-force tests were conducted at four of the five test locations with major emphasis on determination of the maximum towing force of vehicles for which maximum-slope-negotiable curves have been established for only a limited range of sand strengths and slopes. By combining results from slope-climbing tests with results of maximum-towing-force tests, reliable vehicle performance curves can be determined for a range of sand strengths likely to be encountered on any sand beach.

74. Results of maximum-towing-force tests with wheeled vehicles are summarized in table 3, and results of tests with tracked vehicles in table 4. Data in table 3 are plotted in plates 8 through 14 and 16 through 19. Data in table 4 are plotted in plate 20.

Basis of analysis

75. Mathematical computations to determine maximum towing force on a given slope. The maximum towing force a vehicle can develop on a level surface can be used to estimate, for similar conditions, the maximum towing force a vehicle can develop on a given slope, and vice versa. A complete review of the principles involved is given in TM 3-240, 8th Supplement. Briefly, the maximum towing force on a slope, expressed in pounds, can be determined from the formula:

$$P' = P \cos \phi - W \sin \phi$$

where

P' = maximum towing force on slope, lb

P = maximum towing force on level, lb

W = test weight of vehicle, lb

ϕ = angle of the slope, deg

The maximum towing force on a slope, expressed in percentage of vehicle weight, can be determined from the formula $\frac{P'}{W} \times 100$.

76. Mathematical computations to correct for side slope. The above formula is applicable provided the vehicle is operating straight up or down the slope and not tilting to either side, in which case an adjustment is necessary to correct for the side slope before an estimate of the amount of towing force for a given sand condition can be made.

77. Such a correction was necessary in the tests on Suscinio Beach, France. Due to the absence of level sand surfaces and the narrowness of this beach, maximum-towing-force tests were conducted by operating the vehicle on a given straight-line contour of a slope. For these tests, the vehicle was operating in a tilted position with a tendency to slide down the slope; therefore, an adjustment was necessary to estimate the amount of towing force that could have been generated on level sand. This adjustment was made by means of the formula:

$$P = \frac{\sqrt{(P')^2 + (W \sin \phi)^2}}{\cos \phi}$$

where

P = maximum (computed) towing force on level, lb

P' = maximum (measured) towing force on the side slope, lb

W = test weight of vehicle, lb

ϕ = angle of the slope, deg

78. Relation of maximum towing force to maximum slope negotiable. Theoretically, the maximum towing force a vehicle can develop on a given surface, expressed as a percentage of the vehicle's weight (maximum tractive coefficient), is the same as the maximum slope (expressed in percent) it can climb on the same surface. However, in the drawbar testing on clean sands performed with wheeled vehicles in this program, it was found that maximum tractive coefficients were usually higher (about 2%) than maximum

slopes for the same cone index at low strength ranges, and appeared to be about 2% higher at high strength ranges than the slope the cone index-slope curve would indicate if the curve were extended to higher cone indexes. (Few actual data were available for slope-climbing tests on high slopes and high cone indexes.) Accordingly, to provide a reasonable basis for extending vehicle performance-cone index relations to higher cone indexes than before possible, it was decided to plot both parameters of vehicle performance against cone index; this was done by arbitrarily shifting the slope scale (on the ordinate) 2 units higher than the towing force scale, as shown in plates 8 through 14. The scale for towing force is shown on the left, that for slope on the right.

79. The fact that maximum towing forces were found to be higher than corresponding maximum slopes is attributable to the deeper rutting that occurred on the slope (thus increasing rolling resistance), and the tendency for the rear wheels to settle somewhat more than the front ones (thus making the actual slope of the vehicle somewhat steeper than that of the surface). A shift in the center of gravity of the vehicle on the slope also was probably significant to this difference.

Moisture classification

80. Since previous tests had shown that performance of vehicles on sand was influenced by the moisture content of the sand, all tests were separated into tests on dry-to-moist sand and tests on wet-to-inundated sand. The assignment to categories was made by observation of the sand's condition during each test; however, actual moisture content determinations were made where possible.

81. All of the tests on wet-to-inundated sand reported herein were conducted during the Padre Island test program. In plates 8 through 20 all maximum-towing-force tests on wet-to-inundated sand are plotted as an upright triangle symbol, while similar tests on dry-to-moist sand are plotted as an inverted triangle symbol. Performance curves are shown for wet-to-inundated sand and dry-to-moist sand where data permit.

Sand strength measurements

82. During the Padre Island and Cape Cod programs, it was necessary to deviate slightly from the usual procedures for obtaining sand strength measurements. In some wheeled-vehicle tests conducted on the wet foreshore

of Padre Island and the dune area of Camp Wellfleet, sand strength in the 0- to 6-in. depth was beyond the capacity of the cone penetrometer mounted with a 0.5-in. cone. For these tests, a penetrometer with a 0.2-in. cone was used, and cone index readings were multiplied by 2.5, based on previous correlation studies reported in TM 3-240, 13th Supplement. Tests for which the 0.2-in. cone was used (and whose cone index values have therefore been multiplied by 2.5) are indicated by two asterisks in table 3.

Presentation of wheeled-vehicle test results

83. Data from 369 tests with 12 wheeled vehicles are presented in table 3. These data were used to determine the maximum towing force-cone index-tire pressure curves presented in plates 8 through 14 and 16 through 19. Data points have been plotted for each vehicle and tire pressure, and performance curves have been drawn for wet-to-inundated sand and dry-to-moist sand where applicable. In cases where data are lacking or scattered, the final position of the performance curves was influenced by curves for the same vehicle at other tire pressures, or similar vehicles at the same tire pressures. Where possible, the curves of maximum slope negotiable and maximum towing force have been combined into one by staggering the vertical scales.

84. Evaluation of the test results was made by determining the deviation of the maximum towing force, in percentage of test weight, from the average curve. Comparisons of test results with the performance curves were made at equal cone index. Results of the evaluation are shown in the tabulation below, followed by a discussion of results for each vehicle.

			Deviations of Maximum Towing Force			
			Wet-to-Inundated Sand		Dry-to-Moist Sand	
Vehicle	Plate*	Tire Pressure psi	Number of Tests	Avg Dev of Points from Performance Curves, %	Number of Tests	Avg Dev of Points from Performance Curves, %
1/4-ton M38A1 and 1/4-ton M38	8	30	8	4.8	3	0.6
		20	7	5.6	3	2.4
		15	7	2.7	3	0.6
		10	8	3.8	3	2.0
			Avg	4.2	Avg	1.4

(Continued)

* Plate on which towing-force data are plotted.

Vehicle	Plate	Tire Pressure psi	Deviations of Maximum Towing Force: Wet-to-Inundated Sand: Number of Tests	Wet-to-Inundated Sand: Avg Dev of Points from Performance Curves, %	Dry-to-Moist Sand: Number of Tests	Dry-to-Moist Sand: Avg Dev of Points from Performance Curves, %
3/4-ton M37	9	30	10	5.9	9	0.9
		20	9	6.3	8	2.1
		15	9	1.1	8	0.6
		10	10	2.7	8	1.0
			Avg	4.0	Avg.	1.1
2-1/2-ton M211	10	30	0	---	5	0.3
		20	0	---	6	0.7
		15	0	---	4	0.3
		10	0	---	5	1.0
					Avg	0.6
2-1/2-ton M135 and M34	11	60	0	---	5	0.7
		30	4	1.8	6	0.7
		20	5	1.2	7	0.2
		15	5	1.7	9	1.6
		10	5	5.1	8	1.4
			Avg	2.5	Avg	0.9
2-1/2-ton DUKW	12	30	0	---	12	2.3
		20	0	---	14	3.2
		15	0	---	15	1.5
		10	0	---	10	1.9
					Avg	2.2
5-ton M41	13	30	5	8.6	3	1.8
		20	6	3.5	1	0.8
		15	5	4.1	2	0.8
		10	4	3.8	1	3.2
			Avg	5.0	Avg	1.6
5-ton M51 and M52	14	20	0	---	4	1.8
		15	0	---	15	1.5
					Avg	1.6
Bucket loader	16	30	0	---	4	0.1
		20	0	---	2	0.3
		15	0	---	3	0.4
		10	0	---	2	0.3
					Avg	0.3

(Continued)

Vehicle	Plate	Tire Pressure psi	Deviations of Maximum Towing Force: Wet-to-Inundated Sand: Number of Tests	Wet-to-Inundated Sand: Avg Dev of Points from Performance Curves, %	Dry-to-Moist Sand: Number of Tests	Dry-to-Moist Sand: Avg Dev of Points from Performance Curves, %
Tournadozer	17	30	0	---	5	1.6
		20	0	---	7	1.2
		15	0	---	8	0.6
		10	0	---	5	0.8
					Avg	1.0
5-ton XM520 GOER (18.00-26 tires)	18	30	0	---	7	0.9
		20	0	---	6	0.3
		15	0	---	6	1.3
		10	0	---	4	0.8
					Avg	0.8
5-ton XM520 GOER (15.00-34 tires)	19	30	0	---	6	0.5
		20	0	---	7	0.3
		15	0	---	8	0.2
		10	0	---	5	0.4
					Avg	0.4

85. 1/4-ton M38A1, 4x4 truck. All tests with this vehicle were conducted on Padre Island and are listed in table 3, items 1 through 42. Twenty-nine tests were run on wet sand, one test (item 39) was run on inundated sand on the foreshore, and 12 tests were conducted on moist sand. Average deviations of test results from the performance curves are large for tests on wet sand, but there is good agreement for tests on moist sand.

86. It should be noted that four wet-sand tests (items 3, 6, 27, and 31), plotting well below the performance curves in plate 8, were run on a backshore flat area with an abnormal cone index profile, as shown in fig. 21. Also shown in fig. 21 is a normal cone index-depth profile of backshore flat areas for the two backshore flat tests (items 9 and 12) that plot nearer the performance curves. Vehicle performance for items 3, 6, 27, and 31 was probably influenced by the weaker layer below 9 in. However, examination of the average moisture contents of the 0- to 6-in. layer for these four items shows that the lower performance may have been a result of a lower moisture content (15.6) as well as the weak layer below 9 in. The moisture contents for the other wet-sand tests are over 19%.

87. The 12 tests on moist sand were performed on the berm crest area, the only area suitable for towing tests where dry or moist sand could be found. The sand was moist (about 3.0% moisture content), at least to a depth of 12 in., with a 1/2-in. layer of dry sand at the surface.

88. Observation of maximum-towing-force tests indicated that the M38A1 develops much higher wheel slip than most other vehicles in maintaining approximately 1 to 2 mph forward speed.

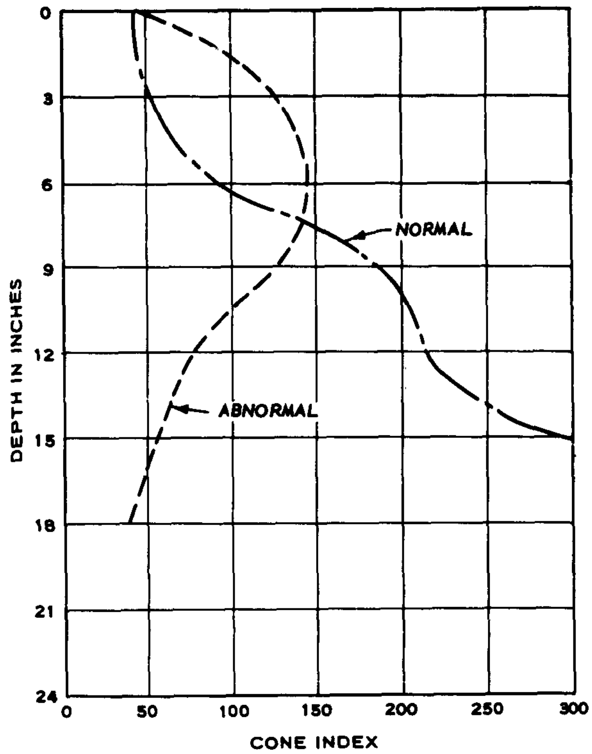


Fig. 21. Average profiles of backshore flat area, gulfside of Padre Island

89. <u>3/4-ton M37, 4x4 truck.</u> Tests with this vehicle were conducted at Padre Island and Cape Cod, and are listed in table 3, items 43 through 113. Thirty-four tests were run on wet sand, 4 (items 77, 84, 91, and 99) on inundated sand (see fig. 22), and 33 on moist sand. The tabulation in paragraph 84 shows rather large deviations of towing force for wet-sand tests at tire pressures of 30 and 20 psi (figs. 1 and 2 of plate 9). The high deviations were caused partially by items 45, 56, and 76 in fig. 1 of plate 9, and items 48, 60, and 83 in fig. 2 of plate 9; these were tests conducted in the backshore flat area on wet sand with a cone index profile similar to the abnormal one shown in fig. 21.

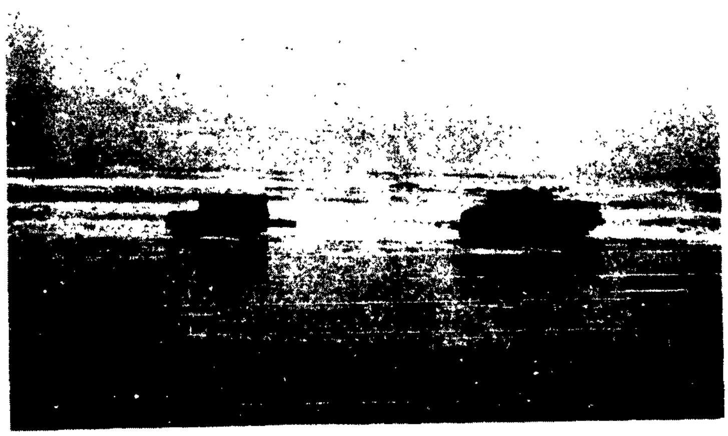


Fig. 22. Towing test on inundated sand, Padre Island

The backshore flat tests in fig. 1 of plate 9 (items 45, 56, and 76) were conducted on wet sand with an average moisture content of 17.2%, while the backshore flat tests in fig. 2 of plate 9 (items 48, 60, and 83) were conducted on sand with an average moisture content of about 22%. Since the moisture contents of all six of these tests were not as low as those of the M38A1 backshore flat tests, it is believed that the abnormal cone index profile caused the poor performance of the M37 truck.

90. In thirty-three tests conducted on moist sand there was an average deviation of towing force of only 1.1% from the performance curve for all tire pressures tested.

91. <u>2-1/2-ton M211, 6x6 truck.</u> This vehicle was tested only during the Mississippi River test program. Twenty tests were conducted on moist sand at tire pressures of 30, 20, 15, and 10 psi. These tests are summarized in table 3, items 114 through 133, and plots of maximum towing force versus cone index are shown in plate 10. Also shown in plate 10 are curves of maximum slope negotiable from tests reported in the 15th Supplement.

92. From the tabulation in paragraph 84, it can be seen that the average deviation of maximum towing force is only 0.6% from the performance curves; however, the range of cone index for these tests was narrow, from about 110 to about 150 for the 0- to 6-in. layer.

93. <u>2-1/2-ton M135 and M34, 6x6 trucks.</u> Both of these vehicles are equipped with 11.00-20, 12-PR tires (single); therefore, data from tests thereof are comparable and are plotted together in plate 11.

94. Fifty-four tests were conducted on wet and moist sands and are listed in table 3, items 134 through 187. Plots of cone index versus maximum towing force are shown in plate 11, with performance curves for each tire pressure tested. Maximum-towing-force tests were conducted during the Padre Island, France, and Mississippi River test programs. Wet-sand tests of the M135 were conducted at Padre Island; the average deviation of these test results from the performance curves was 2.5%, which is much smaller than deviation of test results for other vehicles on wet sand. The average deviation for all tire pressures on dry-to-moist sand was 0.9%, with the largest deviation of individual tests occurring in the tests made in France (items 178 through 187). It is believed these large deviations were a result of unsuitable test areas, i.e. absence of level or nearly level areas.

95. 2-1/2-ton DUKW 353, 6x6 truck. Fifty-one tests were conducted with the DUKW, equipped with 11.00-18, 10-PR tires (single), during the France and Cape Cod test programs and are summarized in table 3, items 188 through 238, and plotted in plate 12. From the tabulation of deviations between test results and performance curves in paragraph 84, it can be seen that the 2.2% deviation is higher than deviations for any other vehicle on dry-to-moist sand. As stated earlier, it is believed that the central tire-inflation system, controlled from the instrument panel, does not permit tire pressures as accurate as those obtained by adjusting the pressures at individual wheels. The DUKW was the only vehicle tested that had such an internal inflation system.

96. 5-ton M41, 6x6 truck. Tests with this vehicle were conducted at Padre Island; they are summarized in table 3, items 239 through 265, and plotted in plate 13. Twenty tests were conducted on wet sand and seven on moist sand. The average deviation of the towing force from the maximum curves (tabulated in paragraph 84) is 5.0% for the wet sand and 1.6% for the moist sand. High deviations for the wet-sand tests were partially caused by tests (items 246, 259, and 264) conducted on the backshore flat area where the abnormal strength profile existed (fig. 21).

97. In the Padre Island test program, the 2-1/2-ton M135 truck was the largest vehicle available to serve as a load vehicle for the M41. Considerable difficulty was experienced when an attempt was made to determine maximum drawbar pull of the M41 on the wet foreshore (a front axle was broken on the M135 during one of these tests); therefore, some of the large deviations for tests on wet sand may have been caused by lack of proper control of the load vehicle.

98. 5-ton M51 and M52, 6x6 trucks. These vehicles, tested in France and at Cape Cod, respectively, were both equipped with 11.00-20, 12-PR tires (dual). The M52 was tested at tire pressures of 20 and 15 psi, the M51 only at 15 psi. Test data are summarized in table 3, items 266 through 284, and plotted in plate 14. Because of lack of sufficient data over a range of cone indexes and tire pressures, the performance curves shown in plate 14 are tentative. Average deviation of test results from performance curves was 1.6% of vehicle weight.

99. Bucket loader, 4x4 tractor. This vehicle, tested during the

Mississippi River test program, was equipped with 14.00-24, 8-PR tires (single), and was tested at tire pressures of 30, 20, 15, and 10 psi and at a gross weight of 13,595 lb. Eleven maximum-towing-force tests, summarized in table 3, items 285 through 295, were conducted on sand with little variation in cone index (109 to 128); therefore, the range of maximum pulls for a given tire pressure was small; however, tentative performance curves are shown in plate 16. Severe buckling of the sidewalls of the tires was noted at 10-psi tire pressure, especially on the rear tires. Average deviation of test results from performance curves was 0.3%.

100. Tournadozer, 4x4 tractor. This vehicle was equipped with 21.00-25, 16-PR tires (single), and was tested at tire pressures of 30, 20, 15, and 10 psi and at a gross weight of 31,070 lb. Twenty-five maximum-towing-force tests, summarized in table 3, items 296 through 320, were conducted during the Mississippi River test program, on sand with little variation in cone index (103 to 147). Therefore, the range of maximum pulls for a given tire pressure was small; however, tentative curves for performance are shown in plate 17. Average deviation of test results from performance curves was 1.0%. The shape of the tentative performance curves was influenced by the shape of the curves for other wheeled vheicles for similar test conditions.

101. 5-ton XM520 GOER, 4x4 cargo carrier. The 5-ton GOER was tested during the Mississippi River test program. Maximum-towing-force tests were conducted with the vehicle equipped first with 18.00-26, 10-PR tires and then with 15.00-34, 10-PR tires; the tests were conducted at inflation pressures of 30, 20, 15, and 10 psi and at a gross weight of 26,670 lb. Results from 23 tests with the 18.00-26 tires and 26 tests with the 15.00-34 tires are summarized in table 3, items 321 through 369. For a given tire pressure, the range of maximum pulls and cone indexes is small; however, tentative curves were drawn through the data shown graphically in plates 18 and 19. The shape of the tentative curves was influenced by the shape of performance curves for other vehicles tested on a more complete range of sand conditions. Examination of performance curves for the GOER shows that the 18.00-26 tires resulted in better performance than the 15.00-34 tires at all tire pressures tested. Average deviation of test results from performance curves was 0.8% with 18.00-26 tires and 0.4% with 15.00-34 tires.

102. Effects of vehicle load. Several of the vehicles were tested at various loads (see tabulation, paragraph 38) to determine the effect of load on vehicle performance. However, no clear-cut change in performance resulted when tire pressure remained constant, and all tests with the same vehicle at the same tire pressure were analyzed together. The explanation for the fact that no difference in performance was discernible, aside from the crudity of performance measurement employed in this program, is that at the same tire pressure, the tire contact area is greater for greater loads, and over a range of loads the average contact pressure probably remains fairly constant. Since ground-contact pressure is apparently highly significant (see paragraph 111), its effect probably obscured any effects due to changes in contact area, load per wheel or axle, etc. Further testing, with more sophisticated instrumentation, is required to obtain reliable data on load effects.

Discussion of wheeled-vehicle test results

103. Three hundred and sixty-nine tests were conducted with twelve wheeled vehicles at various vehicle weights, tire sizes, tire-inflation pressures, and sand conditions. Sufficient data were collected to draw reasonably accurate curves for maximum towing force for the 1/4-ton M38A1, 3/4-ton M37, 2-1/2-ton M211, 2-1/2-ton M135 and M34, 2-1/2-ton DUKW, and 5-ton M41 trucks. Limited data were also collected for the 5-ton M51 and M52 trucks, the bucket loader tractor, the Tournadozer, and the GOER; and tentative curves for maximum towing force were determined for these vehicles. Where applicable, the curves for maximum towing force were combined with the curves for maximum slope negotiable to present performance curves for ranges of tire pressures, sand moisture categories, and sand strengths. For the vehicles not tested for all conditions of moisture, strength, tire pressure, etc., reasonable estimates can be made of their expected performance.

104. Generally, the deviations of individual results of maximum-towing-force tests from the performance curves are low. Highest deviations for the wet-sand tests were probably caused by the unusual strength profile encountered in some of the tests (see fig. 21). The deviation in test results for the 2-1/2-ton DUKW could probably be lowered by more accuracy in tire pressures, and test results with the 1/4-ton M38A1 truck could

possibly be improved with better control of the vehicle speed in low range, low gear.

Presentation of tracked-
vehicle test results

105. Fifty-five tests were conducted with six tracked vehicles during the Mississippi River and Cape Cod test programs. Test data and results are summarized in table 4 and shown graphically in plate 20. Because of the limited range of sand strengths tested with a given vehicle, performance curves are not shown; but for each vehicle, average maximum towing force was determined and is shown in the following tabulation. Also shown are the average deviations of individual maximum-towing-force results from the total average for each vehicle, and the cone index range and average for the 0- to 6-in. depth.

Vehicle	Weight lb	No. of Tests	Maximum Towing Force, % of Vehicle Test Weight		Cone Index 0- to 6-in. Depth	
			Avg	Deviation from Avg	Range	Avg
M29C	5,560	19	49.4	0.6	89-151	130
Std D4	14,870	6	55.1	1.2	133-144	141
Std D6	22,667	8	55.3	0.9	57-112	85
Std D7	27,000	2	57.6	0.5	127-132	130
M5A4	25,230	5	49.0	2.2	118-127	122
M4	28,700	7*	50.7	1.4	103-130	119
M4	30,250	5**	47.6	1.2	38-91	61

* Item 34 not included.
** Items 49 and 50 not included.

106. Plots of test results, maximum towing force versus cone index, are shown in figs. 1 through 6 of plate 20; a plot of average maximum towing force versus cone index for all tracked vehicles is shown in fig. 7 of plate 20. Figs. 8 and 9 of plate 20 correlate vehicle performance and vehicle test weights. Results of these tests are discussed in the following paragraphs.

Discussion of tracked-
vehicle test results

107. With the exception of tests with the 18-ton M4 hi-speed tractor, ranges of cone indexes tested for each vehicle were too limited to determine relations between maximum vehicle performance and cone index similar to the performance curves for wheeled vehicles. Tests with the 18-ton M4

tractor indicated a reduction in maximum towing force with a reduction in sand strength in the 0- to 6-in. layer (fig. 6 of plate 20).

108. The tabulation in paragraph 105 shows that deviations of individual maximum-towing-force test results from the average are larger for the two hi-speed tractors (M4 and M5A4) than for the standard engineer tractors. This larger deviation is probably caused by (a) difficulty in maintaining a constant vehicle speed when a load is gradually applied, and (b) difficulty in determining, through observation of track slippage, when the maximum sustained pull is occurring. (The curve for towing force versus track slip for the 13-ton M5A4 tractor, fig. 3 of plate 24, indicates at what percentage of slip the maximum sustained pull is considered to have occurred.) More elaborate instrumentation is needed for closer control over test procedures, and such instrumentation would probably reduce the amount of variation in test results.

109. It can be seen from fig. 7 of plate 20 that the standard engineer tractors are able to produce higher maximum sustained pulls than the hi-speed tractors and the M29C weasel. This can also be seen in fig. 8 of plate 20, which correlates vehicle test weight in pounds with maximum pull in pounds. Data for the engineer tractors, D4, D6, and D7, plot in such a manner that a straight line drawn through the origin best fits the data when making an angle whose tangent is 0.56 with the horizontal, and a similar straight line through the origin best fits the data for the M29C, M5A4, and M6 when making an angle whose tangent is 0.50. Maximum drawbar-pull data are combined with towing-force-required data for further analysis in paragraph 117.

Summary of Self-propelled Vehicle Performance

110. A summary of vehicle performance curves for both tracked and wheeled vehicles is shown in plate 21; figs. 1 through 4 of this plate show curves for wheeled vehicles at the various tire-inflation pressures, and fig. 5 shows curves for tracked vehicles, including the curves for the Airoll which are discussed in the section on "Special Tests," paragraphs 148 through 154.

111. The GOER with 18.00-26 tires, the same vehicle with 15.00-34

tires, and the Tournadozer, which is equipped with 21.00-25 tires, performed better at every tire pressure than the more conventional wheeled vehicles. The principal reason for this is probably the fact that these vehicles were equipped with tires which were larger in proportion to the weight of the vehicles than those of the more conventional vehicles, thus affording comparatively larger contact areas and smaller ground-contact pressures. The effect of ground pressure on wheeled vehicle performance in sand apparently is highly significant, as can be seen from plate 22. In this plate the maximum towing force in percent of vehicle weight, selected arbitrarily at cone index = 100, is plotted against the average ground-contact pressure. Maximum-towing-force values were taken from figs. 1 through 4 of plate 21, extrapolating when necessary. Average ground-contact pressures are taken from table 1. There is a reasonably good correlation between maximum towing force and contact pressure for 6x6 vehicles with single wheels, and an equally good one for 6x6 vehicles with dual wheels and 4x4 vehicles (together).

112. All tracked vehicles attained maximum towing forces considerably higher than those attained by the best wheeled vehicle (see fig. 5 of plate 21). It is noted that change in cone index does not appear to influence maximum towing force significantly; however, the data are sparse. The superiority in maximum towing force can be attributed at least partly to the lower ground pressures of the tracked vehicles. If data for tracked vehicles were shown in plate 22 they would plot in the upper left-hand corner. The three vehicles with rigid tracks (D7, D6, and D4), although higher in ground pressure, attained higher maximum towing forces than the four vehicles (two M29C's, M5A4, and M4) with more flexible tracks, indicating, at least superficially, that rigidity of track is of significant benefit for vehicle performance in sand.

113. No further analysis of the effects of ground-contact pressure, number of wheels and axles, and rigidity of tracks on vehicle performance will be made in this report. However, studies are under way, using the data reported herein and elsewhere, which are expected to provide rational, but not necessarily mathematically rigorous, explanations for the superiority of one vehicle over another in terms of vehicle characteristics. If this study is successful, it will produce the means for evaluating the

performance of other vehicles of similar types on the basis of their physical characteristics without the necessity of testing the vehicles. These data are also being studied, in conjunction with other data measured in the laboratory in other studies, for the purpose of developing general, mathematically rigorous relations between vehicles and sand which should apply to all ground vehicles, whether similar to those actually tested or not.

Towed-Vehicle Tests

114. Towed-vehicle tests were conducted to determine the force required to tow vehicles as trailers. Towed tests conducted with wheeled trailers on sand and on asphalt pavement were reported in the 15th Supplement. In the tests reported herein self-propelled wheeled and tracked vehicles, with transmissions disengaged, were towed as trailers on sand and asphalt. The tests on sand are summarized in table 5; data collected during the tests on asphalt pavement are not included in the data tables but are summarized below, following the discussion of the sand tests.

Sand tests

115. Wheeled vehicles. Data for this analysis are presented in table 5 and shown graphically in plate 23. All items are discussed below except items 19 through 24, and items 42 through 47, which are discussed under "Special Tests." Fifty-one tests were conducted with seven wheeled vehicles at tire pressures ranging generally between 30 and 10 psi.

116. The performance curves of towing force required (in percentage of test weight) versus cone index (plate 23) are similar to those in the 15th Supplement, plate 16, but they were adjusted slightly to accommodate the additional data for a greater range of cone indexes. Fig. 5 of plate 23 shows curves for 45- and 60-psi tire pressures taken from the 15th Supplement; no data at these tire pressures were collected during the current test programs. As can be seen from examination of figs. 1 through 4 of plate 23, some scatter of test results around the average curves occurs for all tire pressures, but test results are not consistently higher or lower than the average curves that were drawn using both trailer tests (from the 15th Supplement) and self-propelled vehicle tests. The average deviation of test results from the average curves for equal cone indexes is

1.9%, while the average deviation of trailer test results (from the 15th Supplement) was only 1.0%. (Further analysis of these results is needed to take into account basic vehicle factors.)

117. Tracked vehicles. Eight towed tests (table 5, items 64 through 71) were conducted with six tracked vehicles. Poor correlations exist between force required to tow the tracked vehicles and cone index, and between required towing force and vehicle weight; however, when required towing force in pounds is added to the maximum towing force in pounds, the resulting total tractive effort shows good correlation with vehicle weight (fig. 9 of plate 20). For example, total tractive effort for the D4 was obtained by adding the maximum drawbar pull of 8193 lb (from paragraph 105, 55.1% of 14,870 lb) and the towing force required, 1487 lb (from table 5, item 65), to obtain a total of 9680 lb. Total tractive efforts for the other vehicles were obtained in a similar manner. The data for all vehicles plot so that a straight line drawn through the origin best fits the data when making an angle with the horizontal whose tangent is 0.64. Direct shear tests (consolidated and drained) performed on oven-dry Mississippi River sand show the sand to have an angle of internal friction of 32 degrees. The tangent of 32 degrees is 0.625. Direct shear tests on sand at the moisture content prevailing during the vehicle tests (3%) shows the tangent of the angle of internal friction to be 0.543.

Asphalt pavement tests

118. Towed-vehicle tests on asphalt pavement were conducted with self-propelled vehicles to obtain a measure of the force required to overcome internal resistance of the vehicle and external resistance between the pavement and the wheels or tracks.

119. Wheeled vehicles. Limited tests were conducted with three wheeled vehicles at four loads and four tire pressures. The vehicles used were the 3/4-ton M37, 2-1/2-ton M135, and 5-ton M41 trucks. Results of these tests indicated that the force required to tow, in pounds, was directly proportional to the increased load for a given vehicle and tire pressure. This relation allowed force required to tow to be expressed as a percentage of vehicle weight, and comparisons could be more easily made between force required to tow and tire pressure for a given vehicle, or

between required towing forces of different vehicles at equal tire pressures. Comparisons of results of the three vehicles indicate that the force required to tow any of the vehicles at a given tire pressure was the same if force was expressed in percent of vehicle weight. The following tabulation summarizes the results and shows a comparison with similar results for trailers from the data reported in the 15th Supplement.

Tire Pressure psi	Avg Force (% of Test Weight) Required to Tow: Self-propelled Vehicles	Trailers
30	2.1	1.3
20	2.8	1.3
15	3.3	1.5
10	4.1	2.3

As can be seen above, towing force required on asphalt pavement tends to increase with decrease in tire pressure, and the force required to tow trucks is greater (on the average, 1.5% of vehicle weight) than the force required for trailers.

120. Tracked vehicles. Limited tests with three vehicles--a 1/4-ton M29C weasel, an 18-ton M4 hi-speed tractor, and a 38-ton M6 hi-speed tractor--indicate that the force required to tow tracked vehicles on asphalt pavement is about 5.5% of their test weight. This is slightly higher than that required for wheeled vehicles at 10-psi tire pressure (4.1%) on asphalt, and lower than that for tracked vehicles (8.7%) on sand with a cone index of about 100 in the 0- to 6-in. layer.

Special Tests

121. Major emphasis of the tests reported herein was on the development of performance curves for a range of vehicles, tire pressures (where applicable), and dry-to-moist and wet-to-inundated sand conditions. However, during conduct of these test programs opportunities arose to perform some special studies pertinent to the investigation of vehicle performance on coarse-grained soils. These special studies included tests on a sand that will be identified in this report as a "honeycomb" sand; drawbar pull-slip tests; tests of the effects of traction devices and tire treads; a special vehicle test in which a 6x6 vehicle was converted to a 4x4 vehicle;

truck-trailer combination tests; and tests on gravel. These studies are discussed below.

Tests on honeycomb sand

122. On the lagoonside of Padre Island there occurred tidal flat areas which were nearly level and composed of a very fine sand with little or no fines (plate 6), a pronounced honeycomb structure (fig. 23), high moisture content (table 6), and a water table usually within 15 in. of the surface. Forty tests were conducted on this sand using three vehicles: the 1/4-ton M38A1, 3/4-ton M37, and 2-1/2-ton M135 trucks. A test consisted of running a vehicle back and forth in the same path until it became immobilized or until it appeared capable of running indefinitely. In some tests vehicles were immobilized; in others they were not. Results of the tests are summarized in table 6. Scenes of typical tests are shown in figs. 24 through 26. The behavior of the honeycomb sand differed somewhat under the traffic of vehicles from that of sands previously tested. This is discussed in the following paragraphs.

Fig. 23. Profile of sand, lagoon test area, Padre Island, Tex.

123. Immobilization of vehicles. Immobilization occurred as a result of progressive deepening of ruts with repetitive traffic until the vehicle rested on its undercarriage. Cone index measurements made in the ruts during the test indicated that in nearly every test a progressive softening of the sand was occurring. In this sense, the honeycomb sand behaved like fine-grained soils or sands with fines, poorly drained, and unlike other sands of approximately the same grain size and moisture content. The strength of the latter sands usually remained the same or was increased by repetitive traffic; thus, if a vehicle was able to make one pass, it was able to make a large number of passes. The behavior of the

Fig. 24. M135 ruts after 1st pass (not immobilized). Honeycomb sand

Fig. 26. M37 ruts after 2d-pass immobilization. Honeycomb sand

Fig. 25. M38A1 immobilized on 3d pass. Honeycomb sand

honeycomb sand also differed from that of similar sands identified as "quick-condition" sands in a previous report (Technical Memorandum No. 3-240, 15th Supplement). Whereas the honeycomb sand always allowed at least one pass of a vehicle, the quick-condition sand would not allow even one pass.

124. Remolding. Undoubtedly, the reduction in strength caused by repetitive traffic was a primary factor in determining the trafficability of the honeycomb sand. Unfortunately, only limited opportunity was available to study this feature. A few remolding tests of the types that are successfully applied to fine-grained soils and sands with fines, poorly drained, were attempted, but their results were inconclusive and they were abandoned.

125. Effect of tire-inflation pressure. The tire pressure was varied in the first few tests on honeycomb sand; however, the test engineers felt that tire pressure was not significant, and thereafter conducted all vehicle tests with tires at the same inflation pressure, 15 psi.

126. Correlation of vehicle performance and condition of honeycomb sand. An attempt was made to correlate the performance of the vehicles with the various measurements and combinations of measurements made in the honeycomb sand. The results were negative. Cone index measured before traffic did not clearly indicate whether or not the vehicles would be immobilized. Cone index measured after one pass showed a crude relation; however, even a measurement made after only one pass of a vehicle had little practical value for prediction purposes. Neither moisture content nor percent saturation of the sand provided a good index of its trafficability. A combination of before-traffic cone index with percent saturation showed some correlation with "go" and "no go," as it had in a previous study (Technical Memorandum No. 3-240, 4th Supplement), but the correlation was far from satisfactory.

127. Summary. The tests performed on honeycomb sand at Padre Island revealed that this sand behaved differently from sands previously tested. The tests were not adequate to develop a good technique for the assessment of the trafficability of the sand. Observations and results indicated that the remolding phenomenon is probably the key to measurements of the trafficability of this sand. Additional field testing is required to define

proper means of measuring the trafficability of this sand.

Drawbar pull-slip tests

128. During the Mississippi River test program, 95 drawbar pull-slip tests were conducted with three vehicles to obtain a comparison of vehicle performance for three different traction systems. The three vehicles used were the 2-1/2-ton M135 truck, the standard D7 engineer tractor, and the 13-ton M5A4 hi-speed tractor. All three vehicles were tested on similar sands with cone index of the 0- to 6-in. layer ranging between 117 and 132. Data and test results are summarized in table 7, and plots of drawbar pull versus slip are shown in plate 24.

129. 2-1/2-ton M135, 6x6 truck. Tests with this truck (table 7, items 1 through 44) were conducted at tire pressures of 30 and 10 psi; drawbar pull-slip curves are presented in fig. 1 of plate 24. Results of these tests show that maximum drawbar pull (maximum towing force) occurred at about 12% slip for 10- and 30-psi tire pressures; as the percentage of slip increased, drawbar pull decreased until about 75% slip, after which the drawbar pull tended to increase again with an increase in wheel slip. The drawbar pull at 100% slip was higher than at 12% slip; however, pull at 100% slip is not a suitable value for expressing vehicle performance.

130. Observations of wheel slip during the tests indicated that maximum pull occurred when shear planes such as those in fig. 27 first appeared in the ruts behind the wheels (at 12% slip for these tests). (Tests reported in the 15th Supplement indicate maximum pull on harrowed sand occurred at higher slips, usually 20 to 25%.) In the current tests, when wheel slip increased beyond 12%, the wheeled vehicles usually developed a "jerking" and "bouncing" motion, which is undoubtedly harmful to the vehicle.

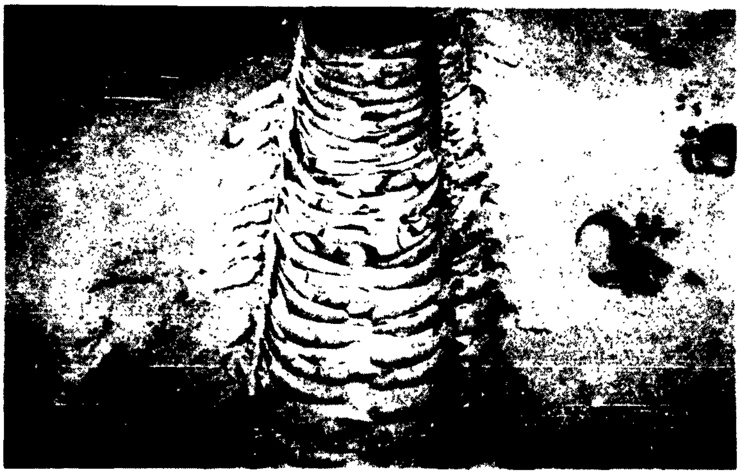


Fig. 27. 2-1/2-ton M135 rut pattern after maximum drawbar-pull test. Moist sand

131. Standard D7 engineer tractor. Fig. 2 of plate 24 shows the results of 25 drawbar pull-slip tests conducted with the D7 tractor during the Mississippi River test program (table 7, items 45 through 69). Maximum drawbar pull (maximum towing force) first occurred at about 25% slip and remained constant up to a track slip of almost 90%.

132. 13-ton M5A4 hi-speed tractor. Fig. 3 of plate 24 shows results of 26 drawbar pull-slip tests and the average curve for tests conducted with the M5A4 tractor during the Mississippi River test program (table 7, items 70 through 95). The M5A4 tractor's drawbar pull continued to increase as track slip increased, up to 100% slip; however, the maximum drawbar pull was considered to have occurred at about 45% slip while the vehicle was moving approximately 1 to 2 mph. Since maximum towing force occurred at a much higher percentage of slip with the M5A4 than with the D7 engineer tractor, it is considered that the D7 is a better performer on sand. This may be a result of differences in track systems, grouser shearing action, and other features.

Effects of traction devices

133. A set of snap-tracs* was mounted on the 2-1/2-ton M135 truck (fig. 28) during the Mississippi River test program to determine their effect on the performance of the truck. To obtain the photograph in fig. 28, the moving truck was halted abruptly, and the sand alongside the wheel was shoveled away carefully without disturbing the position of the grousers of the snap-tracs. Test results are summarized in table 8, items 30 through 48, and presented graphically in

Fig. 28. Snap-tracs on M135 wheel

* U. S. Army Engineer Waterways Experiment Station, CE, A Limited Study of Snap-tracs, Miscellaneous Paper No. 4-322 (Vicksburg, Miss., February 1959).

plate 25. Nineteen tests were conducted at tire pressures of 60, 30, 15, and 10 psi and at a vehicle weight of 19,188 lb. Tentative curves for average performance were drawn for each tire pressure. The shape of the curves was guided by the shape of curves for the same vehicle operating without snap-tracs.

134. A comparison of maximum towing force of the vehicle equipped with snap-tracs with that of the vehicle without snap-tracs is shown in fig. 3 of plate 29. Tests indicated that towing force was reduced by use of snap-tracs at tire pressures of 10 to 30 psi, those normally used on sand, but that towing force was increased slightly by the use of snap-tracs at a tire pressure of 60 psi. Maximum towing force is the difference between gross tractive effort and motion resistance. While the snap-tracs undoubtedly increased the gross tractive effort, they also increased the motion resistance. At the low tire pressures where the tire deflects and sinkage is low, the effect of the snap-tracs was more significant in increasing motion resistance than at the higher tire pressures where sinkage is greater.

Effects of tire tread

135. Standard 11.00-20, 12-PR, NDCC tires, purposely devoid of tread, were mounted on the 2-1/2-ton M135 truck during the Mississippi River test program to determine the effects of tire tread on performance. Fifty-three tests were conducted with smooth tires; for 29 of the tests (table 8, items 1 through 29) the vehicle was operated as a 6x6 (fig. 29), and for 24 tests

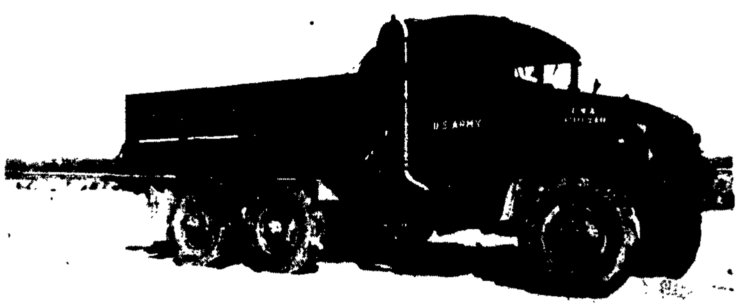


Fig. 29. M135 tested as a 6x6 with smooth tires

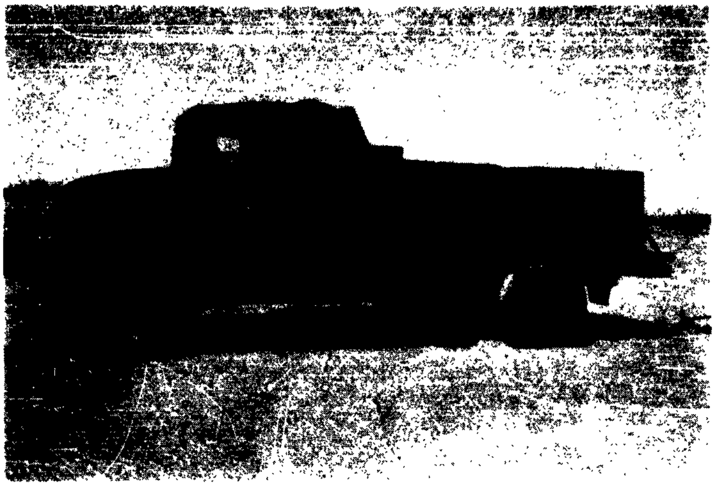


Fig. 30. M135 tested as a 4x4 with smooth tires

(table 8, items 69 through 92) the vehicle was operated as a 4x4 (fig. 30). Test data are shown graphically in plates 26 through 28.

136. Comparisons can be made in plate 29 of the tire contact area, fig. 1, and tire contact pressure, fig. 2, for both the treaded and smooth tires. A comparison of performance on sand can be made in fig. 3 of plate 29. Maximum towing force was increased at a given tire pressure when smooth tires were used on the vehicle tested both as a 6x6 and as a 4x4. Improved performance is probably explained by the fact that contact area of the tires was substantially increased (fig. 1 of plate 29) and ground-contact pressure decreased (fig. 2 of plate 29) when the treads were removed.

<u>6x6 versus 4x4</u>

137. As can be seen from fig. 3 of plate 29, the M135 produced a higher maximum force at a given tire pressure when it was operated as an aborted 4x4 than when it was operated as a normal 6x6. On the basis of average ground-contact pressure, superiority of the 4x4 configuration over that of the 6x6 also is evident. This is directly the reverse of the general relation between 6x6's and 4x4's that has been found for the other vehicles (see plate 22). A reasonable explanation for this is that when the M135's weight was distributed to four wheels (4400 lb per wheel versus 2950 lb per wheel as a 6x6), the tires bulged so much that the bulging sidewalls may have carried a significant part of the load in shallow ruts. Thus the average contact pressure measured on a hard surface was probably significantly higher than the actual contact pressure that prevailed during the test in the sand. This brief investigation, while inconclusive because of the lack of reliable and detailed data on tire-to-soil contact areas and

pressures, at least serves to illustrate that, in an emergency, a 6x6 vehicle will perform satisfactorily as a 4x4 in soft sands.

Truck-trailer combination tests

138. Maximum-towing-force tests. These tests with the 5-ton M52 truck towing the M127A1 semitrailer were conducted at Camp Wellfleet. The force required to tow the truck-trailer combination and the maximum drawbar pull the truck-trailer combination could develop were measured in a few tests. The towing force required for the semitrailer alone was not measured because instrumentation and equipment for this purpose were not available.

139. Truck and trailer tire pressures were varied, and tests were conducted on a range of sand strengths. Test results are summarized in table 9, and plots of maximum towing force in pounds versus cone index and tire pressure are shown in figs. 1 through 4 of plate 30. (Force in pounds was used instead of percent of test weight, as was the case with the single self-propelled vehicles, since all wheels of the combination were not driving.)

140. Results of these tests indicate that at 60-psi tire pressure (fig. 1 of plate 30) for both truck and trailer, a cone index of about 180 was required to permit the combination to travel, but when the truck tire pressure was reduced to 30 psi (fig. 2 of plate 30) and the trailer tires remained at 60 psi, for the same cone index the combination could move forward and have about 2100 lb of excess towing force. When the tire pressure of the truck and trailer was reduced to 15 psi (fig. 4 of plate 30), the combination for the same cone index could move forward with an excess towing force of about 3500 lb. Further tests with this and other truck-trailer combinations are needed before any definite conclusions can be drawn.

141. Towed-vehicle tests. Limited tests were conducted by towing the combination at various tire pressures. Test results are summarized in table 5, items 42 through 47, and are also shown in figs. 1 through 4 of plate 30. Because of differences in tire pressures within the combination, direct comparisons could not be made with towed-vehicle tests in plate 23 for item 65. For this test the force required to tow the combination was approximately 2.5% of vehicle weight higher than the average 15-psi curve

for the same cone index. Results are inconclusive because of the small number of tests conducted.

Tests on gravel beaches

142. Self-propelled (slope-climbing) and maximum-towing-force tests were conducted on gravel to determine the effects of a range of sand-gravel sizes on vehicle performance, and also to determine the approximate limits in sand-gravel sizes that can be measured accurately with the cone penetrometer. Vehicle tests were conducted with the 3/4-ton M37 and 2-1/2 ton M135 trucks on Duxbury Beach during the Cape Cod test program. Summary of data and test results are presented in table 10, gradation curves for the range of soils tested are shown in plate 7, and test results are shown graphically in plate 31, in which maximum-towing-force and maximum-slope-negotiable data are plotted as in plates 8 through 14.

143. Significance of cone index in gravel. When the cone penetrometer is pushed into a coarse gravel, it may bear directly on a large stone and thus yield a very high reading, well above the capacity of the instrument, at a small penetration depth. It may then slip off this stone and move downward between other stones, giving finite readings on the dial before abruptly being stopped again. The whole action is jerky, and the readings are erratic. If the penetrometer operator ignores the very high readings and considers only those "between stones," a mental average of the readings will give him a rough estimate of the tightness or compactness of the gravel, and thus a rough estimate of its trafficability. In a fine gravel the penetration action is much smoother, and the readings apparently reflect the trafficability with a greater degree of accuracy.

144. The column of average cone indexes in the 0- to 6-in. layer in table 10 (Duxbury Beach) shows that the readings vary between 69 and 188+. The plus sign indicates the occurrence of one or more readings beyond the capacity of the instrument. The dashes indicate that the penetrometer could not be pushed more than 6 in. into the soil by the weight of the operator. The three values of 69, in tests 185, 186, and 187 (items 43, 44, and 34, respectively, of table 10), proved to have been measured in a gravelly sand in which the gravel (about 40% of the total) was fine gravel. Subsequently it was shown that these three tests could

be plotted with tests on dry-to-moist sands conducted with the same vehicle and tire pressure (plate 31).

145. The cone index values assigned to the remaining tests covered only a narrow range and were not believed to be truly indicative of the strength of the gravel. For these reasons, no attempt was made to draw a performance versus cone index curve. Instead, a semiquantitative estimate of the trafficability afforded by the gravel on Duxbury Beach was sought by indicating the drawbar pulls measured, the slopes climbed, and the slopes failed against the background of the appropriate curve for dry-to-moist sand. This analysis is indicated in plate 31. Drawbar-pull tests shown on the left are bounded by horizontal lines extending to the sand performance curves. An arbitrary horizontal line is drawn separating "go" and "no go" on the right and extending to each curve. On this basis it may be said that the trafficability of the gravel beach at Duxbury was similar to that of dry-to-moist sands with cone indexes ranging from about 70 to 130.

146. Obviously, the cone penetrometer does not provide a good means of quantifying the trafficability of a coarse gravel. However, it apparently does distinguish gravels that can be classed with sands (by a comparatively smooth penetration) from those that must be classed separately. For the latter it provides a rough estimate of maximum vehicle performance, based on known performance of similar vehicles on dry-to-moist sands at cone indexes of 70 to 130.

147. Observations of vehicle performance. Observations of vehicles operating in gravel revealed the following: (a) Once the wheels begin to slip in loose gravel, wheel action is similar to action in sand in that wheels alternately grip and shear in their attempt to gain traction. (b) Lowering of tire pressure improves vehicle performance in gravel as in sand. (c) Vehicle performance is improved on the passes after the first pass as in sand, but the degree of improvement is not as great as in sand. (d) Clean gravel (no sand sizes present) tends to be slippery when wet; on occasion, if silt or other materials such as vegetal matter are present, it can become difficult for wheeled vehicles to move.

Tests with the Airoll

148. During the Lake Michigan test program, tests were conducted

with the Airoll (fig. 31) on dune slopes and level backshore. The Airoll has a unique propulsion system, and movement can occur under two different and distinct actions of the tires on the ground; these are considered as rolling-wheel track and stationary-wheel track actions. Movement as a rolling-wheel track can occur on level or only moderately sloping, firm surfaces when the tires are made to roll beneath the platform by the tangential force being applied by the platform. In this case, the friction force between platform and tires is greater than the rolling resistance between tires and ground. Movement as a stationary-wheel track occurs when rolling resistance offered by soft soil or steep slopes exceeds the frictional force between the platform and the tires. In this case, the tires remain stationary or rotate in place and the platform slides along on top of the tires. Immobilization occurs when the force necessary to move the vehicle is greater than the shearing resistance of the soil. In this case, the tires are forced to slide beneath the platform, shearing soil as they slide. A more complete description of the Airoll is contained in a separate report.*

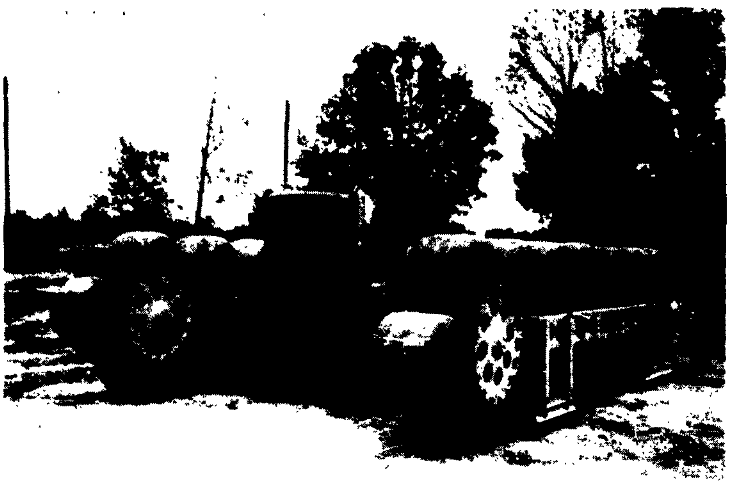


Fig. 31. Airoll used in tests

149. Slope-climbing tests. Self propelled (slope-climbing) tests were conducted in the usual manner. In a typical run, the Airoll began its climb as a rolling-wheel track. At some point during its climb the Airoll shifted from a rolling-wheel to a stationary-wheel track performance (see arrow in fig. 32), and continued to climb (as a conventional tracked vehicle) until steepness of the slope finally immobilized it or it reached the top of the slope. On each test run, test lane sections were marked to

* U. S. Army Engineer Waterways Experiment Station, CE, Trafficability Tests with the Airoll on Organic and Mineral Soils, Miscellaneous Paper No. 4-439 (Vicksburg, Miss., August 1961).

identify the maximum slope on which the Airoll operated as a rolling- and as a stationary-wheel track, and the slope on which it became immobilized. Thus one run up a slope usually provided several tests. Fig. 32 illustrates a typical test with the Airoll.

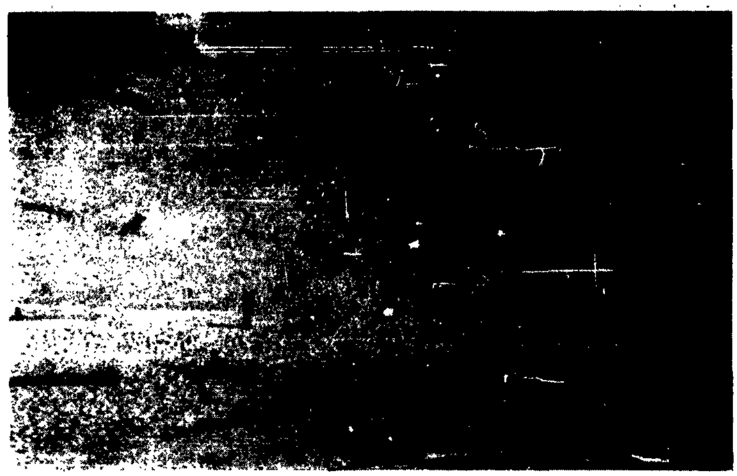


Fig. 32. Typical test with Airoll

150. Slope-climbing test results are summarized in table 11, items 1 through 50, and shown graphically in figs. 1 through 3 of plate 32. Tests were conducted at tire pressures of 15, 10, and 5 psi. Analysis of data indicates that slope-climbing ability as a rolling-wheel track is unchanged between 15 and 10 psi, but increases when tire pressure is reduced to 5 psi, as shown in the lower portions of figs. 1 through 3 of plate 32. Nominal tire pressure recommended for these tires is 2 to 8 psi. Slope-climbing ability as a stationary-wheel track is increased with increased tire pressure, as shown in the upper portions of figs. 1 through 3 of plate 32.

151. Airoll performance is compared with the performance of two wheeled vehicles (2-1/2-ton M135 and 5-ton Jumbo trucks) and one tracked vehicle (M29C weasel) in fig. 4 of plate 32. The performance curves for the M135 and Jumbo trucks are from plates 11 and 15, respectively. The performance curve for the weasel was developed from test results, table 2, items 199 through 207. Examination of fig. 4 of plate 32 shows Airoll performance as a rolling-wheel track to be similar to the performance of conventional wheeled vehicles, and its performance (at 15 and 10 psi) as a stationary-wheel track to be slightly better than that of conventional tracked vehicles such as the weasel.

152. Towing tests. Drawbar pull-slip tests were conducted on the backshore area at Warren Dunes State Park at 5-psi tire pressure. Results of these tests are summarized in table 11, items 51 through 63. The Airoll

was instrumented for slip measurements in the same manner as conventional tracked vehicles. A zero-slip datum was established from measurements made when the Airoll was operating with no drawbar pull. On the sand tested it traveled as a rolling-wheel track on the "no-load" run. When drawbar pull-slip runs were made the Airoll traveled as a rolling-wheel track until at some drawbar load the rolling-wheel action changed to stationary-wheel action. This change was noted on the records. Determining slip in this manner resulted in rolling-wheel track operation from 0 to -100% slip, and stationary-wheel track operation from 0 to 100% slip.

153. Test results are shown graphically in fig. 5 of plate 32. Two curves are shown, to represent rolling- and stationary-wheel performances. The Airoll developed a maximum drawbar pull of 24% of its weight at -20% slip operating as a rolling-wheel track, and a maximum drawbar pull of 50% of its weight at 100% slip operating as a stationary-wheel track. The two curves shown tend to break at about -15% slip instead of 0 as would be expected. This is probably a result of lack of refinement of instrumentation for slip measurements of an unconventional vehicle. From the slope-performance curves of fig. 4 of plate 32, it is apparent that the maximum drawbar pull of the Airoll as a stationary-wheel track would have been greater at tire pressures of 15 and 10 psi.

154. <u>Towed-vehicle tests.</u> Limited towed tests were conducted at 5-psi tire pressure to determine the amount of force necessary to tow the Airoll on asphalt pavement and clean sand. Results of these tests are not shown graphically herein, but they indicated that a towing force of 4.5 and 6.6% of vehicle weight is required on asphalt pavement and sand, respectively.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

155. The following conclusions are based on analysis of the data collected in the five test programs reported herein. The basic guide for these test programs was the findings and recommendations in the 15th Supplement of the "Trafficability of Soils" report series.

a. The maximum tractive coefficient a vehicle can develop in a given sand condition, multiplied by 100 to express it in percent, is usually about 2% higher than the maximum slope it can climb, expressed in percent.

b. The maximum towing force of self-propelled wheeled vehicles is higher on wet-to-inundated sands (e.g. on the foreshore of flat beaches) than on dry-to-moist sands through the range of cone indexes and tire pressures tested.

c. The maximum towing force on a given sand condition increased generally with a decrease in average ground-contact pressure. 6x6 vehicles attained higher maximum towing forces than 4x4's at the same average ground-contact pressures.

d. Limited tests with tracked vehicles on sand show that the engineer tractors have a higher performance (expressed as a percentage of the test weight) than the hi-speed tractors and the M29C weasel, despite the fact that the average ground-contact pressures of the engineer tractors also are higher.

e. Drawbar pull-slip curves for the 2-1/2-ton M135 truck show that maximum sustained drawbar pull occurs at about 12% slip.

f. Drawbar pull-slip curves for the standard D7 engineer tractor and the 13-ton M5A4 hi-speed tractor have different shapes; maximum sustained drawbar pull occurs at about 25% slip for the D7 and at about 45% slip for the M5A4.

g. Vehicle performance is better with smooth tires than with treaded tires or traction devices, and limited tests with the 2-1/2-ton M135 truck indicate that increasing wheel load by removing two wheels improves its performance slightly, although probably not enough to offset the adverse effects of overloading the tires.

h. The towing force required to tow self-propelled wheeled vehicles as trailers is similar to the towing force required for wheeled trailers, but deviations of individual test results from the average curves are larger for the self-propelled vehicles.

i. Results of 40 tests at Padre Island on honeycomb sand indicate that this sand behaved somewhat differently from other sands. However, testing was not adequate to permit development of reliable techniques for assessing its trafficability.

j. Results of tests with a truck-trailer combination indicate that performance of such a combination can be estimated (with reasonable accuracy) from the performance curves developed for towing and towed vehicles.

k. Sands containing as much as about 40% fine gravel (and little or no coarse gravel) exhibit essentially the same characteristics as sands containing no gravel, i.e. test data for all these sands can be plotted and analyzed together. Sands containing more than 40% fine gravel (and little or no coarse gravel) have not yet been tested.

l. The trafficability of coarse gravels cannot be measured with the same degree of accuracy as that of sands. However, the trafficability of coarse gravels (regardless of cone index) was found to be similar to that of dry-to-moist sands in which cone index varied from 75 to 125. The maximum slope or towing force that could be developed on coarse gravels by the vehicles tested in this program was approximately equal to that developed by the same vehicles on dry-to-moist sands with cone indexes between 100 and 125.

m. On sand slopes the Airoll performs better than wheeled vehicles, and appears to perform on a par with tracked vehicles.

Recommendations

156. It is recommended that:

a. Additional studies be conducted to determine the effects of wheel arrangements and loads, tire sizes, and tread design on the performance of wheeled vehicles on sands.

b. A study be conducted and a report prepared on procedures for evaluating performance of vehicles on sands without the necessity for actual tests.

c. Investigations be made of differences in vehicle performance on "natural" and "prepared" sand conditions; the reason why vehicle performance is better on wet sand than on dry sand with the same cone index; a method for identifying quick-condition sand areas; and the probable cone index necessary to permit vehicles to execute difficult maneuvers.

d. Studies be conducted of methods of estimating trafficability of untested beaches.

e. Additional tests be made on sands with tracked vehicles and truck-trailer combinations.

f. Additional tests (including towed-vehicle tests) be made on gravel beaches when opportunities arise, and instruments other than the cone penetrometer be considered for measuring the trafficability of gravel beaches.

g. Test sites with broader ranges of cone index be found and utilized in expanding performance-cone index relations where necessary.

h. A special program be conducted at Padre Island for the purpose of development of adequate means of measuring the trafficability of honeycomb sand.

i. Additional testing be done on vehicles equipped with low-profile, low-silhouette tires similar to those used on the 5-ton XM520 GOER vehicle.

j. Search for an explanation of the better performance of the 2-1/2-ton, 6x6 vehicle with its middle wheels removed be continued.

Table 1

Vehicle Data

Vehicle	Empty Weight lb	Gross Weight lb	Tire Description: Nominal Width in.	Rim Diameter in.	Ply Rating	No. of Tires	Tire Pressure psi	Total Contact Area sq in.*	Avg Contact Pressure psi**	Tire Print in.† Length	Tire Print in.† Width	Ground Clearance in.	Engine Type	Engine Brake, hp	Transmission
Wheeled Vehicles															
1/4-ton M38A1†† 4x4 truck	2,475	2,975‡	7.00	16	6	4	30	98.6	30.2	6.7	4.4	9.0	Gasoline	72 at 4000 rpm	Synchromesh
							20	121.7	24.4	7.5	4.7				
							15	141.3	21.1	8.2	4.8				
							10	167.5	17.8	9.2	5.0				
1/4-ton M38 4x4 truck	2,625	2,625‡	7.00	16	6	4			No data			9.25	Gasoline	60 at 4000 rpm	Synchromesh
3/4-ton M37†† 4x4 truck	5,645	5,645‡‡	9.00	16	8	4	30	178.7	31.6	7.8	6.7	11.0	Gasoline	78 at 3200 rpm	Synchromesh
							20	217.4	26.0	8.6	7.2				
							15	247.3	22.8	9.1	7.5				
							10	290.9	19.4	10.2	7.6				
		7,085‡‡					30	223.1	31.8	9.0	7.2				
							20	265.7	26.7	9.9	7.5				
							15	301.0	23.5	10.7	7.6				
							10	338.8	20.9	11.6	7.6				
		7,805‡‡					30	241.2	32.4	9.0	7.2				
							20	281.1	27.8	10.2	7.6				
							15	317.4	24.6	10.7	7.6				
							10	363.6	21.5	12.2	7.7				
2-1/2-ton M211 6x6 truck	12,792	12,792‡‡	9.00	20	8	10	30	340.2	37.6	7.6	5.1	12.0	Gasoline	130 at 3400 rpm	Hydramatic
							20	409.7	31.2	8.5	5.4				
							15	465.0	27.5	9.1	5.7				
							10	584.0	21.9	10.5	5.9				
		17,960‡‡					30	465.8	38.6	9.2	5.9				
							20	561.4	32.0	10.3	6.2				
							15	649.7	27.6	11.2	6.5				
							10	789.3	22.8	12.5	6.9				
		20,034‡‡					30	526.0	38.1	9.9	6.2				
							20	639.5	31.3	11.2	6.6				
							15	745.6	26.9	12.2	6.8				
							10	904.9	22.1	13.7	7.2				
2-1/2-ton M34 6x6 truck	11,775	11,775‡ 16,775‡	11.00	20	12	6			No data			12.5	Gasoline	127 at 3200 rpm	Synchromesh
2-1/2-ton M135†† 6x6 truck	12,450	12,450‡‡	11.00	20	12	6	30	324.9	38.3	9.9	6.3	12.0	Gasoline	130 at 3200 rpm	Hydramatic
							20	372.8	33.4	10.7	6.6				
							15	436.9	28.5	11.8	6.9				
							10	499.8	24.9	12.9	7.1				
		17,330‡‡					30	419.4	41.3	11.7	6.8				
							20	494.0	35.1	12.8	7.2				
							15	566.1	30.6	13.9	7.5				
							10	637.7	27.2	15.1	7.8				

(Continued)

Note: Weights shown here are the weights of the vehicles when tire prints were made. Test weights for the vehicles, which sometimes differed, are shown in data tables and plates. Wheel and axle loads were not measured.

* Determined from tire prints on a hard surface.
** Computed by dividing gross weight by total contact area.
† Average dimensions for all tires on vehicle.
†† Data from table 2 of TM 3-240, 15th Supplement, but considered applicable for this report.
‡ Estimated.
‡‡ Measured.

Table 1 (Continued)

Vehicle	Empty Weight lb	Gross Weight lb	Tire Description: Nominal Width in.	Rim Diameter in.	Ply Rating	No. of Tires	Tire Pressure psi	Total Contact Area sq in.	Avg Contact Pressure psi	Tire Print in.: Length	Width	Ground Clearance in.	Engine: Type	Brake, hp	Transmission
							Wheeled Vehicles (Continued)								
2-1/2-ton M135†† 6x6 truck (Cont'd)		22,705**					30	550.0	41.3	13.6	7.5				
							20	638.3	35.6	14.9	7.7				
							15	710.4	32.0	15.9	8.0				
							10	823.8	27.6	17.4	8.4				
2-1/2-ton M135 6x6 truck	12,450	19,188**	11.00	20	12	6	Tested with Snap-tracs					12.0	Gasoline	130 at 3200 rpm	Hydramatic
2-1/2 ton M135 (tested as 6x6)	12,450	18,100**	11.00 (tread removed)	20	12	6	30	527.4	34.3	13.6	7.5		Gasoline	130 at 3200 rpm	Hydramatic
							20	662.3	27.3	15.4	8.2				
							15	783.7	23.1	17.1	8.4				
							10	995.9	18.2	19.1	9.5				
2-1/2-ton M135 (tested as 4x4)	12,000	17,610**	11.00	20	12	4	30	383.8	45.9	13.9	7.6		Gasoline	130 at 3200 rpm	Hydramatic
							20	468.3	37.6	16.0	7.9				
							15	541.1	32.5	17.7	8.2				
							10	---	--	--	---				
2-1/2-ton M135 (tested as 4x4)	12,000	17,610**	11.00 (tread removed)	20	12	4	30	457.1	38.5	15.8	8.3		Gasoline	130 at 3200 rpm	Hydramatic
							20	623.1	28.3	18.2	9.5				
							15	---	--	--	---				
							10	---	--	--	---				
2-1/2-ton DUKW 353, 6x6 truck	15,285	15,285*	11.00	18	10	6	30	402.1	38.0	11.1	7.3	11.0	Gasoline	92 at 2750 rpm	Constant-mesh
							20	479.1	31.9	12.4	7.7				
							15	569.3	26.9	13.7	7.9				
							10	683.5	22.4	15.3	8.1				
5-ton M41†† 6x6 truck	18,115	18,115**	14.00	20	12	6	30	568.0	31.9	11.9	8.9	13.0	Gasoline	196 at 2800 rpm	Synchromesh
							20	684.6	26.5	13.3	9.4				
							15	788.8	23.0	14.6	9.5				
							10	915.9	19.8	16.3	9.9				
		28,175**					30	795.7	35.4	14.8	10.0				
							20	955.3	29.5	16.5	10.3				
							15	1062.4	26.5	17.8	10.7				
							10	1289.2	21.8	20.5	11.1				
		32,380**					30	909.9	35.6	16.0	10.4				
							20	1078.3	30.0	18.2	10.6				
							15	1211.1	25.7	19.8	10.9				
							10	1480.2	21.9	22.6	11.3				
5-ton M51 6x6 truck	22,663	32,663*	11.00	20	12	10	No data					10.5	Gasoline	196 at 2800 rpm	Synchromesh
5-ton M52 6x6 truck	18,310	22,310*	11.00	20	12	10	30	608.7	36.7	10.6	7.1	12.0	Gasoline	196 at 2800 rpm	Synchromesh
							20	760.4	29.3	11.9	8.1				
							15	862.2	25.9	13.4	7.9				
							10	1045.6	21.3	15.5	8.2				
Bucket loader 4x4 tractor	13,595	13,595**	14.00	24	8	4	30	514.0	26.4	13.4	11.7	15.0	Gasoline	77 at 2200 rpm	Clark power-shift
							20	597.0	22.8	14.2	12.4				
							15	701.0	19.4	15.9	12.7				
							10	866.0	15.7	18.4	12.8				

(Continued)

†† Data from table 2 of TM 3-240, 15th Supplement, but considered applicable for this report.
* Estimated.
** Measured.

Table 1 (Concluded)

Vehicle	Empty Weight lb	Gross Weight lb	Tire Description: Nominal Width in.	Rim Diameter in.	Ply Rating	No. of Tires	Tire Pressure psi	Total Contact Area sq in.	Avg Contact Pressure psi	Tire Print in. Length	Tire Print in. Width	Ground Clearance in.	Engine Type	Engine Brake, hp	Transmission
Wheeled Vehicles (Continued)															
Tournadozer 4x4 tractor	31,070	31,070**	21.00	25	16	4	30	1114.0	27.9	19.1	18.8	14.0	Gasoline	127 at 3400 rpm	Tournamatic, constant-mesh, clutch-operated
							20	1286.0	24.2	20.8	19.4				
							15	1493.0	20.8	22.8	20.2				
							10	1814.0	17.1	25.7	20.6				
5-ton XM520 GOER 4x4 cargo carrier	16,670	26,670**	18.00	26	10	4	30	1241.0	21.5	21.9	19.0	21.0	Diesel	110 at 2200 rpm	Torque converter
							20	1465.2	18.2	24.1	20.1				
							15	1605.9	16.6	25.2	20.3				
							10	1891.8	14.2	27.8	21.6				
			15.00	34	10	4	30	1085.7	24.6	22.2	15.7				
							20	1258.1	21.2	25.6	16.8				
							15	1423.9	18.7	26.8	18.0				
							10	1777.4	15.0	30.0	18.9				
5-ton M704 Jumbo 4x4 truck	13,000 (est)	20,100**	18.00	26	10	4	30	745.7	27.0	16.5	13.5	16.5	Gasoline	160 at 2800 rpm (est)	Mechanical
							20	827.3	24.3	16.5	14.3				
							15	956.1	21.0	18.6	14.8				
							10	1162.7	17.3	20.5	16.2				
12-ton M127A1 dual-tandem semitrailer	10,400	10,400*	11.00	20	12	8	60	209.0	49.8	6.9	4.7	--	--	--	--
							30	266.1	39.1	7.8	5.2				
							20	319.0	32.6	8.6	5.5				
							15	362.9	28.7	9.2	5.8				

Vehicle	Test Weight lb	Contact Length in.	Contact Width in.	Shoe Length in.	Both Tracks Total Contact Area sq in.	Avg Contact Pressure psi	Bogies per Side	Ground Clearance in.	Engine Type	Engine hp	Transmission Type	Remarks
Tracked Vehicles												
1/4-ton M29C weasel	4,200**	78	20	4.25	3,120	1.3	8	11.0	Gasoline	65 at 3600 rpm	Mechanical	Brake horsepower
1/4-ton M29 weasel	5,560**	78	20	4.25	3,120	1.8	8	11.0	Gasoline	65 at 3600 rpm	Mechanical	Brake horsepower
Standard D4 engineer tractor	14,870**	61	13	6.00	1,586	9.4	6	11.0	Diesel	44 at 1400 rpm	Mechanical	Net horsepower
Standard D6 engineer tractor	22,667**	86	16	6.75	2,752	8.2	6	12.5	Diesel	55 at 1400 rpm	Mechanical	Net horsepower
Standard D7 engineer tractor	27,000**	95	20	8.00	3,800	7.1	7	15.0	Diesel	80 at 1000 rpm	Mechanical	Net horsepower
13-ton M5A4 hi-speed tractor	25,230**	117	17	5.50	3,878	6.5	5	20.0	Gasoline	207 at 2900 rpm	Mechanical	Brake horsepower
18-ton M4 hi-speed tractor	28,700**	131	17	6.00	4,454	6.4	5	20.0	Gasoline	190 at 2100 rpm	Torque converter	Brake horsepower
18-ton M4 hi-speed tractor	30,250**	131	17	6.00	4,454	6.8	5	20.0	Gasoline	190 at 2100 rpm	Torque converter	Brake horsepower
Airoll	19,100**	213§	24§	--	10,224	1.9	7	26.0	Gasoline	187 at 4400 rpm	Allison XTG-90 converter	Brake horsepower

* Estimated.
** Measured.
§ Contact length and width based on projected track area.

Table 2

Summary of Data and Test Results, Single Self-Propelled (Slope-Climbing) Tests with Wheeled and Tracked Vehicles

Item No.	Test Program	Location	Test Area*	Test No.	Slope %	Tire Pressure psi	Immobilized	Before Traffic Average Cone Index 0- to 6-in. Depth	Before Traffic Average Cone Index 6- to 12-in. Depth	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Content % by Weight 6- to 12-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth	Dry Density lb/cu ft 6- to 12-in. Depth
							Wheeled Vehicles							
							1/4-ton M38, 4x4 Truck, Test Weight 2,625 lb							
1	France	Suscinio	FDA	174	27	30	Yes	152+	---	3.0	---	Moist	100.9	--
2			FDA	176	17		Yes	151+	---	3.0	---	Moist	100.9	--
3			FDA	175	16		Yes	166+	---	3.0	---	Moist	100.9	--
4			FS	172	11		Yes	83	249+	4.3	---	Moist	103.7	--
5			FS	177	10		Yes	60	---	1.4	---	Moist	104.2	--
6			FS	178	9		No	126	---	1.4	---	Moist	104.2	--
7			FS	173	7		No	104	---	2.4	---	Moist	109.5	--
8		La Turballe	BS	22	11.5	20	Yes	43	131	5.7	6.3	Moist	92.8	88.5
9			BS	25	10.5		Yes	27	125	5.7	7.3	Moist	89.2	87.9
10			BS	26	10		Yes	49	180	3.5	4.5	Moist	93.0	93.1
11			BS	28	10		Yes	49	159	3.5	4.5	Moist	93.0	93.1
12			BS	23	9.5		No	59	189	5.4	2.9	Moist	89.0	92.3
13			BS	24	6.5		No	30	85	1.6	6.0	Moist	92.1	85.5
14			BS	27	6.5		No	37	96	4.6	5.6	Moist	86.6	90.6
15			BS	29	5.5		No	59	160	4.6	5.6	Moist	86.6	90.6
16		Suscinio	FDA	179	25		No	127+	---	2.4	---	Moist	106.7	--
17			FDA	180	25		No	162+	---	2.4	---	Moist	106.7	--
18			FS	171	10		No	62	223+	4.3	---	Moist	103.7	--
19			FS	169	8		No	75	236+	4.4	---	Moist	102.4	--
20			FS	170	6.5		No	107	---	2.7	---	Moist	106.2	--
							3/4-ton M37, 4x4 Truck, Test Weight 5,687 lb							
21	France	Suscinio	FDA	95	15.5	30	Yes	142	---	4.4	---	Moist	97.8	--
22			FDA	100	15		Yes	140	---	4.4	---	Moist	97.8	--
23			BS	93	8		No	77	245+	2.2	---	Moist	104.4	--
24			BS	98	8		No	87	256+	2.2	---	Moist	104.4	--
25			FS	96	7		Yes	118	---	2.2	---	Moist	102.6	--
26			BS	92	6		No	124+	---	2.3	---	Moist	106.4	--
27			BS	94	6		No	145	---	1.7	---	Moist	104.9	--
28			BS	97	6		No	133	---	2.3	---	Moist	106.4	--
29			BS	99	4		No	123	---	1.7	---	Moist	104.9	--
30			FDA	105	26	20	Yes	99	---	4.4	---	Moist	97.8	--
31			FS	101	10		No	109	---	2.1	---	Moist	102.9	--
32			BS	104	9		No	113	---	1.7	---	Moist	104.9	--
33			BS	103	8		No	81	241+	2.2	---	Moist	104.4	--
34			BS	102	7		No	118	---	2.3	---	Moist	106.4	--
35			FDA	108	23	15	Yes	165	---	4.4	---	Moist	97.8	--
36			FS	106	9		No	99	---	2.2	---	Moist	102.6	--
37			FS	107	8		No	150	---	3.9	---	Moist	108.0	--
38			FDA	110	23	10	No	131	---	4.4	---	Moist	97.8	--
39			FS	109	7		No	113	---	2.2	---	Moist	102.6	--
							3/4-ton M37, 4x4 Truck, Test Weight, 6,887 lb							
40	France	La Turballe	FS	18	18.5	15	No	128	---	2.6	7.7	Moist	95.5	93.4
41			FS	17	13		No	132	---	5.8	3.7	Moist	93.9	96.4
42			FS	20	12		Yes	66	205	4.8	3.2	Moist	96.0	97.3
43			BS	14	11		No	51	179	8.1	2.1	Moist	90.8	89.8
44			BS	19	11		Yes	53	208	3.1	3.9	Moist	92.1	89.6
45			BS	15	10.5		Yes	40	153+	5.7	3.8	Moist	87.4	87.9
46			BS	11	10		Yes	42	166	---	---	Moist	--	--
47			BS	13	8		Yes	37	146	4.5	4.1	Moist	87.3	87.6
48			BS	12	5		No	31	105	3.1	5.0	Moist	86.4	86.0
49			FS	3	20.5	10	No	101	---	3.2	4.4	Moist	96.7	93.7
50			FS	8	18.5		No	122	---	3.2	4.4	Moist	96.7	93.7
51			BS	16	16		Yes	28	169	3.4	5.5	Moist	87.5	88.9
52			BS	4	15		No	70	247+	5.3	3.0	Moist	93.2	93.6
53			BS	9	13		No	72	---	5.3	3.0	Moist	93.2	93.6
54			BS	10	12.5		No	39	185	---	---	Moist	--	--
55			FS	1	12		Yes	57	195	3.1	3.5	Moist	92.7	100.6
56			BS	5	12		Yes	40	155	3.9	4.4	Moist	93.5	91.3
57			FS	21	12		No	66	205	4.8	3.2	Moist	96.6	97.3
58			FS	6	10.5		No	54	219+	3.1	3.5	Moist	92.7	100.6
59			FS	2	10		No	109	---	5.1	2.8	Moist	94.4	94.6
60			FS	7	10		No	119	---	5.1	2.8	Moist	94.4	94.6
							2-1/2-ton M135, 6x6 Truck, Test Weight 12,450 lb							
61	Cape Cod	Wellfleet	FS	150	11	20	Yes	46	178	---	---	Moist	--	--
62			FS	151	11		Yes	43	83	---	---	Moist	--	--
63			BS	152	9		No	47	143	3.0	---	Moist	91.5	--
64			BS	149	14	15	Yes	55	150	---	---	Moist	--	--
65			BS	142	13		Yes	51	111	---	---	Moist	--	--
66			BS	140	12.5		Yes	49	134	---	---	Moist	--	--
67			BS	137	12		Yes	50	140	1.6	---	Moist	92.1	--
68			FS	147	11		No	41	162	3.3	---	Moist	87.6	--
69			BC	138	10.5		Yes	55	117	3.2	---	Moist	92.6	--
70			BC	141	8		No	53	117	---	---	Moist	--	--
71			BS	139	5		No	63	195	---	---	Moist	--	--
72			BS	136	2		No	55	132	2.9	---	Moist	93.1	--
73			BS	143	22	10	Yes	51	111	---	---	Moist	--	--
74			BC	145	14		No	55	131	---	---	Moist	--	--
75			BS	148	14		No	55	150	---	---	Moist	--	--
76			FS	146	11		No	41	162	3.3	---	Moist	87.6	--
77			BC	144	8.5		No	60	134	4.3	---	Moist	89.3	--

(Continued)

* See "Beach Terms" under "Definitions" in text.

Table 2 (Continued)

Item No.	Test Program	Location	Test Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Before Traffic Average Cone Index 0- to 6-in. Depth	Before Traffic Average Cone Index 6- to 12-in. Depth	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Content % by Weight 6- to 12-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth	Dry Density lb/cu ft 6- to 12-in. Depth
							Wheeled Vehicles (Continued)							
							2-1/2-ton M34, 6x6 Truck, Test Weight 11,775 lb							
78	France	Suscinio	FDA	141	27	30	Yes	160+	---	1.3	---	Moist	107.0	--
79			FDA	143	21.5		Yes	197+	---	1.3	---	Moist	107.0	--
80			FS	146	10		Yes	59	220+	2.5	---	Moist	100.9	--
81			FS	145	8.5		Yes	82	252+	3.1	---	Moist	106.3	--
82			FS	144	8		No	94	---	9.3	---	Moist	98.8	--
83			FS	147	8		Yes	68	226+	2.5	---	Moist	106.4	--
84			FS	148	8		No	156+	---	4.8	---	Moist	102.7	--
85			BS	140	6		No	114	273+	2.3	---	Moist	98.6	--
86			BS	142	4.5		No	109	259	2.3	---	Moist	98.6	--
87			FS	149	11	20	Yes	61	220+	2.5	---	Moist	100.9	--
88			FS	151	10		Yes	60	217+	2.5	---	Moist	100.9	--
89			FS	152	8.5		No	114+	---	2.5	---	Moist	106.4	--
90			FS	150	8		No	69	228+	2.5	---	Moist	106.4	--
91			FDA	157	17	15	No	93	---	2.0	---	Moist	105.7	--
92			FS	153	11		No	66	229	2.3	---	Moist	106.5	--
93			FS	155	11		No	57	213+	2.3	---	Moist	106.5	--
94			FS	156	8.5		No	87	253+	3.0	---	Moist	104.6	--
95			FS	154	7		No	95	254+	3.0	---	Moist	104.6	--
96		La Turballe	BS	69	24	10	Yes	41	115	3.1	2.4	Moist	91.4	89.7
97			BS	70	20		Yes	43	218+	2.6	3.8	Moist	92.8	94.4
98			BS	72	18		No	51	224+	2.6	3.8	Moist	92.8	94.4
99			BS	66	17.5		Yes	34	203+	3.5	4.1	Moist	90.9	88.5
100			FS	71	15		No	101	257+	4.8	5.0	Moist	95.6	93.0
101			BS	68	13.5		No	35	159	3.6	4.1	Moist	88.6	89.1
102			BS	67	12.5		No	41	131	3.5	4.1	Moist	90.9	88.5
							2-1/2-ton M34, 6x6 Truck, Test Weight 16,775 lb							
103	France	La Turballe	BS	57	17	15	Yes	42	188	3.4	3.5	Moist	88.3	93.8
104			BS	60	16.5		Yes	41	152	2.9	3.7	Moist	92.4	88.3
105			BS	55	15		Yes	24	154	3.0	3.0	Moist	90.3	91.8
106			BS	58	14		Yes	52	232+	3.4	3.5	Moist	88.3	93.8
107			FS	56	13.5		No	55	237+	3.1	3.5	Moist	93.7	92.4
108			BS	59	12.5		No	49	217+	3.4	3.5	Moist	88.3	93.8
109			FS	54	11		No	79	238+	4.4	3.3	Moist	93.1	95.8
							2-1/2-ton DUKW 353, 6x6 Truck, Amphibian, Test Weight 14,670 lb							
110	France	La Turballe	FS	39	13.5	20	No	60	183	2.6	4.5	Moist	--	--
111			FS	37	12		No	53	199+	2.6	13.4	Wet	--	--
							2-1/2-ton DUKW 353, 6x6 Truck, Amphibian, Test Weight 19,670 lb							
112	France	La Turballe	FS	41	13	30	No	128	---	2.6	4.6	Moist	95.4	90.2
113			FS	34	11.5		Yes	55	178	---	13.1	Wet	--	--
114			BS	43	10.5		Yes	55	176	4.0	4.0	Moist	92.2	89.8
115		Suscinio	FS	111	10		Yes	62	199	2.4	---	Moist	104.8	--
116			FS	113	8		No	134+	---	1.8	---	Moist	97.7	--
117			FS	46	12	25	Yes	54	181	10.5	---	Wet	99.4	--
118		La Turballe	FS	47	23	20	Yes	45	152	4.7	5.0	Moist	90.2	93.1
119			FS	32	16		No	115	---	2.7	3.4	Moist	--	--
120			BS	33	14.5		No	31	145	3.6	4.4	Moist	--	--
121			FS	30	13		Yes	50	154	2.8	6.5	Moist	--	--
122			FS	36	13		No	74	226	3.0	4.4	Moist	--	--
123			FS	38	13		Yes	61	182+	2.8	3.0	Moist	--	--
124			BS	50	12.5		Yes	41	100	3.6	3.8	Moist	90.1	89.7
125			FS	44	11		No	78	241	4.0	3.4	Moist	94.7	93.8
126			FS	45	11		No	58	174	10.6	---	Wet	99.5	--
127			FS	31	10.5		No	67	218+	6.5	3.6	Moist	--	--
128			FS	35	10.5		No	61	202+	4.2	3.0	Moist	--	--
129			BS	42	10.5		No	55	176	4.0	4.0	Moist	92.2	89.8
130			BS	40	10		No	59	211+	3.6	3.9	Moist	91.2	88.8
131		Suscinio	BS	112	9		No	98	---	3.8	---	Moist	103.4	--
132			FS	114	9		No	71	194	2.4	---	Moist	104.8	--
133			FS	115	8		No	111	---	2.1	---	Moist	101.2	--
134		La Turballe	FS	48	21	10	No	57	143	4.7	5.0	Moist	90.2	93.1
135			BS	53	15		No	30	103	2.6	4.1	Moist	92.9	89.3
136			BS	52	12		No	26	92	3.0	3.2	Moist	90.2	89.8
137			BS	49	14		No	32	110	2.9	3.7	Moist	91.2	90.5
138			BS	51	12.5		No	41	100	3.6	3.8	Moist	90.1	89.7
							2-1/2-ton DUKW 353, 6x6 Truck, Test Weight 15,285 lb							
139	Cape Cod	Wellfleet	FS	17	14.5	20	Yes	30	75	---	---	Moist	--	--
140			FS	16	14.5		No	72	---	3.5	---	Moist	97.5	--
141			BS	21	15		Yes	49	151	0.4	---	Dry	96.2	--
142			FS	18	14		Yes	81	---	---	---	Dry	--	--
143			FS	22	13		No	112	---	2.5	---	Dry	94.9	--
144			BS	20	14	15	Yes	49	151	0.4	---	Dry	96.2	--
145			FS	23	13.5		No	112	---	---	---	Dry	--	--
146			FS	19	11		No	32	64	---	---	Dry	--	--
							5-ton M51, 6x6 Truck, Test Weight 32,663 lb							
147	France	Suscinio	FS	160	9	20	Yes	70	203+	6.0	---	Moist	105.1	--
148			FS	159	8.5		No	95	245+	5.0	---	Moist	105.0	--
149			FS	158	8		Yes	51	145	6.0	---	Moist	105.1	--
150		La Turballe	BS	85	17	15	Yes	47	168	2.7	3.6	Moist	91.0	92.1
151			BS	86	17		Yes	41	170	2.7	3.6	Moist	91.0	92.1
152			BS	84	11.5		No	52	161	2.3	3.2	Moist	92.4	91.7
153			FS	81	10.5		No	60	---	2.6	3.9	Moist	91.6	95.5
154			FS	83	10.5		No	81	---	2.6	3.9	Moist	91.6	95.5
155			BS	82	10		No	62	205	2.3	3.2	Moist	92.4	91.7
156		Suscinio	FS	161	9		No	64	164	7.1	---	Moist	107.9	--
157			FS	162	9		No	73	183	7.1	---	Moist	107.9	--

(Continued)

Table 2 (Concluded)

Item No.	Test Program	Location	Test Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Before Traffic Average Cone Index 0- to 6-in. Depth	Before Traffic Average Cone Index 6- to 12-in. Depth	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Content % by Weight 6- to 12-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth	Dry Density lb/cu ft 6- to 12-in. Depth
Wheeled Vehicles (Continued)														
5-ton M704, Jumbo 4x4 Truck, Test Weight 20,100 lb														
158	Lake	Warren	DA	43	19.5	30	Yes	74	188	---	---	Moist	--	--
159	Michigan	Dunes	DA	42	18		No	85	231+	---	---	Moist	--	--
160			DA	46A	17.5		Yes	84	236+	---	---	Moist	--	--
161			DA	47	16.5		No	84	202	---	---	Moist	--	--
162			DA	44	14		Yes	69	185	---	---	Moist	--	--
163			DA	45	10.5		No	75	178	---	---	Moist	--	--
164			DA	49	24	20	Yes	74	189	---	---	Moist	--	--
165			DA	48	23		Yes	89	235	---	---	Moist	--	--
166			DA	50	18.5		No	93	237+	---	---	Moist	--	--
167			DA	46B	17.5		No	84	236+	---	---	Moist	--	--
168			DA	55A	16		Yes	64	120	---	---	Moist	--	--
169			DA	51	15		Yes	63	131	---	---	Moist	--	--
170			DA	52	15		No	64	125	---	---	Moist	--	--
171			DA	56	15		No	71	117	---	---	Moist	--	--
172			DA	53	14		Yes	68	133	---	---	Moist	--	--
173			DA	54	6		No	50	102	---	---	Moist	--	--
174			DA	92	28	15	Yes	64	---	---	---	Moist	--	--
175			DA	59	28		Yes	76	195+	---	---	Moist	--	--
176			DA	60	27		No	98	243+	---	---	Moist	--	--
177			DA	94	24		Yes	73	166	---	---	Moist	--	--
178			DA	96	24		Yes	98	265	---	---	Moist	--	--
179			DA	95	21		No	110	---	---	---	Moist	--	--
180			DA	93	21		No	105	---	---	---	Moist	--	--
181			DA	57	17.5		Yes	57	116	---	---	Moist	--	--
182			DA	97	17.5		No	86	---	---	---	Moist	--	--
183			DA	58	16		No	58	117	---	---	Moist	--	--
184			DA	55B	16		No	64	120	---	---	Moist	--	--
185			DA	98	34.5	10	Yes	96	249	---	---	Moist	--	--
186			DA	104	28.5		Yes	67	142	---	---	Moist	--	--
187			DA	102	27		Yes	67	222	---	---	Moist	--	--
188			DA	99	27		No	91	---	---	---	Moist	--	--
189			DA	100	27		Yes	64	145	---	---	Moist	--	--
190			DA	103	25		No	95	---	---	---	Moist	--	--
191			DA	105	25		No	88	201	---	---	Moist	--	--
192			DA	96	24		No	98	265	---	---	Moist	--	--
193			DA	101	21		No	75	---	---	---	Moist	--	--
Tracked Vehicles														
Standard D6 Engineer Tractor, Test Weight 22,667 lb														
194	Cape Cod	Wellfleet	FDA	115	36-1/2		Yes	59	114	2.3	---	Moist	98.1	--
195			FDA	116	49		Yes	49	80	---	---	Moist	--	--
196			FDA	117	55		Yes	50	101	---	---	Moist	--	--
18-ton M4 Hi-Speed Tractor, Test Weight 30,250 lb														
197	Cape Cod	Wellfleet	FDA	94	51		No	48	101	2.3	---	Moist	98.1	--
198			FDA	95	53		Yes	37	79	---	---	Moist	--	--
1/4-ton M29C Weasel, Test Weight 4,200 lb														
199	Lake	Warren	DA	64	56.5		Yes	23	82	---	---	Moist	--	--
200	Michigan	Dunes	DA	23	51		Yes	39	114	1.0	---	Moist	--	--
201			DA	25	50		Yes	24	111	3.7	---	Moist	--	--
202			DA	86	47.5		No	81	129	---	---	Moist	--	--
203			DA	30	46.5		Yes	16	66	---	---	Moist	--	--
204			DA	82	45.5		No	58	100	2.5	---	Moist	--	--
205			DA	29	44.5		No	25	88	1.0	---	Moist	--	--
206			DA	22	38.5		No	29	70	---	---	Moist	--	--
207			DA	28	37.5		No	23	181+	0.7	---	Moist	--	--

Table 3

Summary of Data and Test Results, Maximum-Towing-Force Tests with Self-propelled Wheeled Vehicles

Item No.	Test Program	Location	Test Area*	Test No.	Tire Pressure psi	Measured Maximum Towing Force on Slopes: Slope %	Measured: lb	Measured: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
1/4-ton M38A1, 4x4 Truck, Test Weight 2,690 lb														
1	Padre Island	Gulf	FS	36	30	0	1,229	45.7	1,229	45.7	300**	23.5	Wet	99.9
2			BC	56		-0.5	667	24.8	653	24.3	377**	3.1	Moist	96.4
3			BSF	73		0	550	20.4	550	20.4	81	15.9	Wet	85.9
4			FS	37	20	0	1,259	46.8	1,259	46.8	310**	24.6	Wet	98.0
5			BC	57		-0.5	875	32.5	861	32.0	365**	3.4	Moist	96.1
6			BSF	74		-0.5	697	25.9	683	25.4	107	15.6	Wet	95.7
7			FS	38	15	0	1,399	52.0	1,399	52.0	262**	24.2	Wet	99.0
8			BC	58		-0.5	968	36.0	955	35.5	370**	2.3	Moist	96.7
9			BSF	75		-0.5	884	32.9	872	32.4	71	23.9	Wet	95.5
10			FS	39	10	0	1,555	57.8	1,555	57.8	300**	26.0	Wet	96.4
11			BC	59		0	1,120	41.6	1,120	41.6	314**	2.0	Moist	97.3
12			BSF	76		-0.5	1,022	38.0	1,009	37.5	56	24.0	Wet	91.2
1/4-ton M38A1, 4x4 Truck, Test Weight 2,960 lb														
13	Padre Island	Gulf	FS	40-1	30	0	1,368	46.2	1,368	46.2	430**	23.1	Wet	100.4
14			FS	40-2		0	1,136	38.4	1,136	38.4	330**	--	Wet	--
15			BC	52		-2.0	707	23.9	648	21.9	357**	3.7	Moist	95.9
16		Lagoon	TF	193		0	610	20.6	610	20.6	52	19.3	Wet	91.3
17		Gulf	FS	41	20	0	1,516	51.2	1,516	51.2	307**	24.0	Wet	98.2
18			BC	53		0	873	29.5	873	29.5	382**	3.1	Moist	95.9
19		Lagoon	TF	194		0	556	18.8	556	18.8	34	20.2	Wet	78.7
20		Gulf	FS	42	15	-1.0	1,636	55.3	1,607	54.3	395**	22.5	Wet	100.2
21			BC	54		-0.5	1,083	36.6	1,069	36.1	352**	3.1	Moist	95.2
22		Lagoon	TF	195		0	838	28.3	838	28.3	29	21.2	Wet	82.1
23		Gulf	FS	43	10	1.0	1,744	58.9	1,773	59.9	380**	23.1	Wet	100.0
24			BC	55		0	1,317	44.5	1,317	44.5	335**	3.0	Moist	96.2
25		Lagoon	TF	196		0	764	25.8	764	25.8	21	21.3	Wet	85.0
1/4-ton M38A1, 4x4 Truck, Test Weight 3,200 lb														
26	Padre Island	Gulf	FS	44	30	0	1,459	45.6	1,459	45.6	362**	23.0	Wet	100.3
27			BSF	69		-0.5	839	26.2	822	25.7	137	12.9	Wet	93.3
28		Lagoon	TF	189		0	996	31.1	996	31.1	65	20.1	Wet	94.2
29		Gulf	BC	48		1.0	681	21.3	714	22.3	290**	2.9	Moist	96.9
30			FS	45	20	-0.5	1,631	51.0	1,616	50.5	415**	23.2	Wet	99.8
31			BSF	70		-1.0	925	28.9	893	27.9	100	18.0	Wet	95.6
32		Lagoon	TF	190		0	941	29.4	941	29.4	37	21.6	Wet	90.5
33		Gulf	BC	49		1.0	742	23.2	774	24.2	285**	3.3	Moist	95.6
34			FS	46	15	0	1,800	56.2	1,800	56.2	515**	22.5	Wet	98.9
35			TF	71		0	1,153	36.0	1,153	36.0	80	24.4	Wet	88.2
36		Lagoon	TF	191		0	522	16.3	522	16.3	35	20.6	Wet	88.1
37		Gulf	BC	50		0	1,114	34.8	1,114	34.8	330**	2.6	Moist	95.3
38			FS	47-1	10	0	1,905	59.5	1,905	59.5	482**	22.5	Wet	98.7
39			Surf	47-2		0	1,813	56.7	1,813	56.7	125	--	Inundated	--
40		Gulf	TF	72		-0.5	1,124	35.1	1,107	34.6	71	23.1	Wet	90.2
41		Lagoon	TF	192		0	648	20.2	648	20.2	33	20.6	Wet	88.1
42		Gulf	BC	51		-2.5	1,319	41.2	1,238	38.7	341**	3.3	Moist	95.6
3/4-ton M37, 4x4 Truck, Test Weight 5,687 lb														
43	Padre Island	Gulf	FS	17	30	0	2,150	37.8	2,150	37.8	477**	22.4	Wet	100.7
44			BC	21		0	1,030	18.1	1,030	18.1	367**	4.7	Moist	95.8
45			BSF	85		1.0	1,123	19.7	1,177	20.7	118	16.7	Wet	92.7
46			FS	18	20	0.5	2,256	39.7	2,286	40.2	420**	22.1	Wet	101.9
47			BC	22		0.5	1,421	25.0	1,450	25.5	347**	4.7	Moist	95.7
48			BSF	86		0	1,320	23.2	1,320	23.2	103	21.8	Wet	93.4
49			FS	19	15	1.0	2,625	46.2	2,684	47.2	407**	22.6	Wet	100.7
50			BC	23		0	1,690	29.7	1,690	29.7	310**	5.5	Moist	95.0
51			TF	87		-0.5	1,711	30.1	1,683	29.6	62	22.6	Wet	91.8
52			FS	20	10	0	2,800	49.2	2,800	49.2	398**	22.7	Wet	99.5
53			BC	24		0.5	2,072	36.4	2,099	36.9	287**	4.5	Moist	97.8
54			TF	88		0	2,186	38.4	2,186	38.4	61	23.3	Wet	95.6
3/4-ton M37, 4x4 Truck, Test Weight 6,407 lb														
55	Padre Island	Gulf	FS	9	30	0	3,008	46.9	3,008	46.9	417**	23.2	Wet	98.4
56			BSF	81		0.5	1,034	16.1	1,064	16.6	87	17.3	Wet	90.0
57		Lagoon	TF	185		-0.5	939	14.7	910	14.2	35	20.8	Wet	73.8
58		Gulf	BC	13		-1.0	1,165	18.2	1,102	17.2	312**	4.6	Moist	96.8
59			FS	10	20	0	2,855	44.6	2,855	44.6	500**	23.2	Wet	97.4
60			BSF	82		1.0	1,313	20.5	1,378	21.5	104	21.8	Wet	96.1
61		Lagoon	TF	186		0	1,675	26.1	1,675	26.1	44	22.2	Wet	87.0
62		Gulf	BC	14		0	1,456	22.7	1,456	22.7	337**	4.5	Moist	95.7
63			FS	11	15	0	2,909	45.4	2,909	45.4	480**	23.4	Wet	99.1
64			TF	83		-0.5	2,225	34.7	2,191	34.2	73	22.4	Wet	91.1
65		Lagoon	TF	187		-0.5	1,484	23.2	1,454	22.7	37	21.9	Wet	86.9
66		Gulf	BC	15		1.5	1,715	26.8	1,813	28.3	330**	4.8	Moist	95.2
67			FS	12	10	0.5	3,270	51.0	3,300	51.5	422**	--	Wet	--
68			TF	84		-0.5	2,268	35.4	2,236	34.9	63	26.5	Wet	87.1
69		Lagoon	TF	188		1.0	1,695	26.5	1,762	27.5	32	21.2	Wet	--
70		Gulf	BC	16		0	2,463	38.4	2,463	38.4	340**	5.0	Moist	98.4

(Continued)

* See "Beach Terms" under "Definitions" in text.
** 0.2-in. cone penetrometer reading multiplied by 2.5.

Table 3 (Continued)

Item No.	Test Program	Location	Test Area	Test No.	Tire Pressure psi	Measured Maximum Towing Force on Slopes: Slope %	Measured Maximum Towing Force on Slopes: lb	Measured Maximum Towing Force on Slopes: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected Maximum Towing Force for Level: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
						3/4-ton M37, 4x4 Truck, Test Weight 7,187 lb								
71	Padre Island	Gulf	FS	1-1	30	0	3,100	43.1	3,100	43.1	378**	26.1	Wet	95.2
72			FS	1-2		0	3,200	44.5	3,200	44.5	510**	24.2	Wet	96.6
73			BC	5-1		0	1,247	17.4	1,247	17.4	272**	--	Moist	--
74			BC	5-2		0.5	1,392	19.4	1,430	19.9	360**	4.8	Moist	96.0
75			BC	5-3		0.5	1,306	18.2	1,344	18.7	360**	--	Moist	--
76			BSF	77		0	1,500	20.9	1,500	20.9	113	17.6	Wet	91.1
77			Surf	141		0	1,550	21.6	1,550	21.6	60	--	Inundated	--
78		Lagoon	TF	181		-0.5	1,615	22.5	1,581	22.0	34	20.1	Wet	94.2
79		Gulf†	BC	205		0	896	12.5	896	12.5	86	3.8	Moist	86.5
80		Gulf†	BC	209		-0.5	850	11.8	812	11.3	96	3.6	Moist	99.1
81		Gulf	FS	2	20	0.5	3,536	49.2	3,572	49.7	490**	23.7	Wet	99.7
82			BC	6		-1.0	1,890	26.3	1,818	25.3	337**	5.0	Moist	96.1
83			BSF	78		0	1,805	25.1	1,805	25.1	129	23.5	Wet	96.8
84			Surf	142		0	1,900	26.4	1,900	26.4	60	--	Inundated	--
85			TF	182		0	1,878	26.1	1,878	26.1	48	21.6	Wet	90.5
86		Gulf†	BC	206		0	1,030	14.3	1,030	14.3	62	4.1	Moist	85.6
87		Gulf†	BC	210		2.0	1,145	15.9	1,286	17.9	122	4.5	Moist	99.2
88		Gulf	FS	3	15	0	3,425	47.7	3,425	47.7	372**	23.9	Wet	99.4
89			BC	7		1.0	2,020	28.1	2,091	29.1	300**	5.1	Moist	96.5
90			TF	79		-1.0	2,053	28.6	1,984	27.6	49	21.4	Wet	76.6
91			Surf	143		0	2,050	28.5	2,050	28.5	60	--	Inundated	--
92			TF	183		-0.5	1,800	25.0	1,761	24.5	38	20.6	Wet	88.1
93		Gulf†	BC	207		2.0	1,082	15.1	1,229	17.1	69	4.2	Moist	87.9
94		Gulf†	BC	211		1.0	1,650	23.0	1,725	24.0	110	3.8	Moist	97.7
95		Gulf	FS	4-1	10	-1.0	3,686	51.3	3,615	50.3	502**	--	Wet	--
96			FS	4-2		0	3,605	50.2	3,605	50.2	472**	24.2	Wet	99.5
97			BC	8		-1.5	2,699	37.6	2,595	36.1	330**	4.6	Moist	95.4
98			TF	80		0	2,943	40.9	2,943	40.9	73	23.1	Wet	94.2
99			Surf	144		0	2,100	29.2	2,100	29.2	60	--	Inundated	--
100			TF	184		0	1,725	24.0	1,725	24.0	49	19.3	Wet	87.7
101		Gulf†	BC	208		0.5	1,900	26.4	1,933	26.9	98	4.2	Moist	88.1
102		Gulf†	BC	212		0	2,050	28.5	2,050	28.5	101	3.6	Moist	95.6
						3/4-ton M37, 4x4 Truck, Test Weight 5,687 lb								
103	Cape Cod	Wellfleet	DA	1	30	2	800	14.1	916	16.1	128	3.3	Moist	96.0
104			DA	2		-1	950	16.7	893	15.7	128	4.2	Moist	97.5
105			DA	3	20	1	950	16.7	1,007	17.7	104	2.7	Moist	102.9
106			DA	4		1	1,150	20.2	1,206	21.2	136	3.1	Moist	100.6
107			DA	5		1.5	1,050	18.5	1,137	20.0	139	3.2	Moist	99.6
108			DA	8	15	3	1,250	22.0	1,422	25.0	138	2.8	Moist	97.2
109			DA	9		1	1,300	22.9	1,359	23.9	131	2.8	Moist	97.2
110			DA	10		3	1,250	22.0	1,422	25.0	131	--	Moist	--
111			DA	11	10	2.5	1,600	28.1	1,740	30.6	120	1.9	Moist	97.9
112			DA	12		-2	1,750	30.8	1,638	28.8	125		Moist	--
113			DA	13		0	1,700	29.9	1,700	29.9	103	--	Moist	--
						2-1/2-ton M211, 6x6 Truck, Test Weight 18,470 lb								
114	Mississippi River	Vicksburg Bridge	--	18	30	0	1,880	10.2	1,880	10.2	132	3.6	Moist	90.7
115			--	19		-1.4	2,122	11.5	1,865	10.1	122	4.3	Moist	89.6
116			--	20		-2.1	2,136	11.6	1,755	9.5	113	4.6	Moist	86.2
117			--	21		-0.4	2,024	11.0	1,958	10.6	121	3.4	Moist	87.9
118			--	22		-2.7	2,325	12.6	1,829	9.9	122	3.8	Moist	91.0
119			--	23	20	-1.0	3,142	17.0	2,955	16.0	126	3.5	Moist	89.5
120			--	24		-1.5	3,081	16.7	2,807	15.2	135	3.7	Moist	89.5
121			--	25		-0.5	3,449	18.7	3,362	18.2	147	3.4	Moist	89.9
122			--	26		-0.5	3,442	18.6	3,343	18.1	140	3.5	Moist	88.2
123			--	27		-1.3	2,946	16.0	2,715	14.7	121	4.0	Moist	96.6
124			--	28		-3.6	3,383	18.3	2,715	14.7	117	3.8	Moist	91.2
125			--	29	15	-3.2	3,950	21.4	3,362	18.2	112	7.8	Moist	90.3
126			--	30		-0.3	3,410	18.5	3,362	18.2	113	3.5	Moist	89.6
127			--	31		-0.4	3,652	19.8	3,583	19.4	131	2.9	Moist	87.7
128			--	32		-0.4	3,588	19.4	3,509	19.0	129	3.2	Moist	87.7
129			--	33	10	1.6	5,017	27.2	5,319	28.8	135	4.4	Moist	90.9
130			--	34		0	5,283	28.6	5,283	28.6	140	5.3	Moist	91.2
131			--	35		-0.2	4,870	26.4	4,839	26.2	138	3.9	Moist	90.2
132			--	36		0.6	5,141	27.8	5,245	28.4	133	1.2	Moist	88.3
133			--	37		0.8	4,739	25.7	4,895	26.5	138	2.4	Moist	86.4
						2-1/2-ton M135, 6x6 Truck, Test Weight 14,750 lb								
134	Padre Island	Gulf	TF	89	30	-0.5	4,022	27.3	3,953	26.8	90	31.3	Wet	87.3
135			FS	93		0	6,958	47.2	6,958	47.2	467**	23.0	Wet	99.4
136		Lagoon	TF	201		0	2,820	19.1	2,820	19.1	42	19.9	Wet	92.8
137		Gulf	TF	90	20	-0.5	3,975	26.9	3,894	26.4	63	23.3	Wet	89.9
138			FS	94		-0.5	7,410	50.2	7,331	49.7	472**	21.8	Wet	99.4
139		Lagoon	TF	202		0	2,855	19.4	2,855	19.4	25	19.8	Wet	89.2
140		Gulf	TF	91	15	0	4,640	31.5	4,640	31.5	51	22.4	Wet	88.6
141			FS	95		-0.5	7,200	48.8	7,124	48.3	442**	24.8	Wet	96.4
142		Lagoon	TF	203		0	3,774	25.6	3,774	25.6	50	35.2	Wet	80.9
143		Gulf	TF	92	10	-0.5	5,333	36.2	5,266	35.7	50	22.8	Wet	83.6
144			FS	96		0	7,250	49.2	7,250	49.2	445**	22.7	Wet	100.0
145		Lagoon	TF	204		0	3,432	23.3	3,432	23.3	32	17.6	Wet	80.6

(Continued)

** 0.2-in. cone penetrometer reading multiplied by 2.5.
† Shell Beach.

Table 3 (Continued)

Item No.	Test Program	Location	Test Area	Test No.	Tire Pressure psi	Measured Maximum Towing Force on Slopes: Slope %	Measured Maximum Towing Force on Slopes: lb	Measured Maximum Towing Force on Slopes: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected Maximum Towing Force for Level: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
						2-1/2-ton M135, 6x6 Truck, Test Weight 17,450 lb								
146	Padre Island	Gulf	FS	101	30	0.5	7,097	40.7	7,189	41.2	312**	23.5	Wet	98.2
147			BC	105		2.0	4,610	26.4	4,956	28.4	325**	6.5	Moist	98.2
148			BSF	109		-1.0	2,488	14.3	2,321	13.3	105	6.7	Moist	86.1
149			FS	102	20	0	8,312	47.6	8,312	47.6	505**	21.7	Wet	99.7
150			BC	106		0	5,970	34.2	5,970	34.2	352**	7.0	Moist	97.4
151			TF	110		0	5,048	28.9	5,048	28.9	62	23.4	Wet	97.5
152			FS	103	15	0.5	8,786	50.3	8,865	50.8	432**	23.0	Wet	99.6
153			BC	107		0	6,500	37.2	6,500	37.2	352**	5.4	Moist	93.9
154			TF	111		0	5,777	33.1	5,777	33.1	69	22.2	Wet	85.6
155			FS	104	10	0	9,400	53.9	9,400	53.9	557**	22.2	Wet	89.9
156			BC	108		0	7,314	41.9	7,314	41.9	317**	6.5	Moist	96.6
157			TF	112		0	6,564	37.6	6,564	37.6	47	22.2	Wet	87.5
						2-1/2-ton M135, 6x6 Truck, Test Weight 18,750 lb								
158	Mississippi River	Vicksburg Bridge	--	60	60	-0.8	1,270	6.8	1,125	6.0	134	3.0	Moist	90.5
159			--	61		-1.3	1,594	8.5	1,350	7.2	144	2.5	Moist	88.8
160			--	62		-1.2	1,378	7.3	1,144	6.1	114	3.1	Moist	87.6
161			--	136		-0.3	1,050	5.6	994	5.3	118	3.6	Moist	97.1
162			--	137		0	1,150	6.1	1,150	6.1	129	3.6	Moist	96.7
163			--	1-3	30	-1.3	3,626	19.3	3,375	18.0	143	8.5	Moist	88.5
164			--	4		-3.5	4,407	23.5	3,750	20.0	160	1.8	Moist	90.8
165			--	5-7		-2.0	3,984	21.2	3,600	19.2	156	10.6	Moist	89.8
166			--	56-59		-1.0	2,953	15.7	2,756	14.7	129	3.8	Moist	87.5
167			--	8	20	0.6	4,020	21.4	4,125	22.0	139	5.7	Moist	87.5
168			--	9		0.7	4,137	22.1	4,275	22.8	152	5.5	Moist	85.7
169			--	10		-1.6	4,182	22.3	3,881	20.7	125	4.8	Moist	90.0
170			--	11		-0.5	4,153	22.1	4,050	21.6	142	4.4	Moist	88.8
171			--	12	15	-1.7	5,099	27.2	4,781	25.5	135	4.5	Moist	85.8
172			--	13		-0.5	5,257	28.0	5,156	27.5	155	5.9	Moist	89.3
173			--	63		0.5	4,792	25.6	4,894	26.1	130	2.6	Moist	89.6
174			--	64		0.8	4,572	24.4	4,725	25.2	134	2.9	Moist	86.1
175			--	65		0.7	4,838	25.8	4,969	26.5	140	2.8	Moist	87.7
176			--	14-17	10	-1.8	6,276	33.5	5,944	31.7	134	4.2	Moist	87.8
177			--	52-55		-0.7	6,100	32.5	5,962	31.8	132	3.9	Moist	89.0
						2-1/2-ton M34, 6x6 Truck, Test Weight 11,775 lb								
178	France	Succinio	FS	132‡	20	9	1,542	13.1	1,871	15.9	78	5.7	Moist	108.1
179			FS	133‡		7.5	1,584	13.5	1,810	15.4	92	3.3	Moist	109.7
180			FS	134‡	15	8	1,600	13.6	1,851	15.7	51	2.2	Moist	105.0
181			FS	135‡		8	1,515	12.9	1,781	15.1	70	2.0	Moist	103.0
182			FS	136‡		8	1,408	12.0	1,691	14.4	92	5.8	Moist	102.1
183			FS	137‡	10	8	2,417	20.5	2,591	22.0	94	4.0	Moist	103.3
184			FS	138‡		10	2,295	19.5	2,581	21.9	64	2.1	Moist	104.3
185			FS	139‡		9.5	2,041	17.3	2,321	19.7	55	2.4	Moist	99.8
						2-1/2-ton M34, 6x6 Truck, Test Weight 16,775 lb								
186	France	La Turballe	FS	61	10	14.5	1,850	11.0	4,278	25.5	66	3.0	Moist	90.9
187			FS	62		15	2,225	13.3	4,747	28.3	125	4.0	Moist	89.6
						2-1/2-ton DUKW 353, 6x6 Truck, Amphibian, Test Weight 14,670 lb								
188	France	La Turballe	FS	63	15	6.5	2,700	18.4	3,653	24.9	103	3.6	Moist	92.6
189			FS	64		7.5	3,200	21.8	4,298	29.3	141	3.5	Moist	94.0
190			FS	65	10	8.5	3,390	23.1	4,636	31.6	86	2.6	Moist	94.1
						2-1/2-ton DUKW 353, 6x6 Truck, Amphibian, Test Weight 19,670 lb								
191	France	Succinio	FS	116‡	30	6	4,058	20.6	4,230	21.5	143	6.9	Moist	103.9
192			FS	117‡		8	2,696	13.7	3,120	15.9	133	5.9	Moist	104.1
193			BS	121‡		8	3,390	17.2	3,730	19.0	105	1.4	Moist	104.6
194			BS	122‡		8	3,481	17.7	3,820	19.4	106	1.2	Moist	105.1
195			BS	123‡		9	3,376	17.2	3,810	19.4	133	0.9	Moist	105.5
196			BS	124‡		9	3,561	18.1	3,970	20.2	140	1.7	Moist	103.0
197			FS	118‡	20	8	4,924	25.0	5,170	26.3	107	1.9	Moist	102.5
198			FS	119‡		8	3,467	17.6	3,800	19.3	67	2.6	Moist	105.4
199			BS	120‡		7	4,018	20.4	4,250	21.6	95	1.3	Moist	104.4
200			FS	125‡		8	4,415	22.4	4,680	23.8	67	3.5	Moist	102.1
201			FS	126‡		8	3,356	17.1	3,700	18.8	92	3.7	Moist	106.3
202			FS	127‡		8	3,423	17.4	3,760	19.1	104	2.4	Moist	106.2
203		La Turballe	FS	76		11	2,000	10.2	4,170	21.2	80	5.9	Moist	96.5
204			FS	77		5	2,860	14.5	3,836	19.5	143	3.5	Moist	93.3
205		Suscinio	FS	128‡	15	9.5	3,318	16.9	3,800	19.3	68	2.5	Moist	104.8
206			FS	129‡		11	3,298	16.8	3,940	20.0	61	2.4	Moist	108.7
207			FS	130‡		10	4,078	20.7	4,520	23.0	68	2.7	Moist	103.9
208			FS	131‡		10.5	4,129	21.0	4,610	23.4	69	3.3	Moist	105.9
209		La Turballe	FS	73		11	3,505	17.8	5,692	28.9	95	3.0	Moist	90.1
210			FS	74		12	2,750	14.0	5,133	26.1	96	3.6	Moist	92.4
211			FS	75		12	2,767	14.1	5,150	26.2	86	4.0	Moist	88.7
212			FS	78	10	12	3,610	18.4	5,999	30.5	78	4.8	Moist	97.1
213			FS	79		12	4,057	20.6	6,449	32.8	117	3.5	Moist	93.3
214			FS	80		12	3,950	20.1	6,341	32.2	86	4.8	Moist	97.1
						2-1/2-ton DUKW 353, 6x6 Truck, Test Weight 15,285 lb								
215	Cape Cod	Wellfleet	DA	24	30	-2.0	3,225	21.1	2,919	19.1	169	2.7	Moist	98.6
216			DA	25		0	2,950	19.3	2,950	19.3	181	---	Moist	--
217			DA	26		1.0	2,900	19.0	3,057	20.0	193	2.1	Moist	100.1
218			DA	27		-0.5	3,125	20.4	3,042	19.9	160	---	Moist	--
219			BS	41		1.0	625	4.1	780	5.1	48	3.2	Moist	92.4
220			BS	42		0.5	750	4.9	825	5.4	44	---	Moist	--

(Continued)

** 0.2-in. cone penetrometer reading multiplied by 2.5.
‡ Indicates tests conducted with vehicle operating on a side slope. See paragraphs 76 and 77.

Table 3 (Continued)

Item No.	Test Program	Location	Test Area	Test No.	Tire Pressure psi	Measured Maximum Towing Force on Slopes: Slope %	Measured Maximum Towing Force on Slopes: lb	Measured Maximum Towing Force on Slopes: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected Maximum Towing Force for Level: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
						2-1/2-ton DUKW 353, 6x6 Truck, Test Weight 15,285 lb (Continued)								
221	Cape Cod	Wellfleet	DA	28	20	-0.5	3,800	24.9	3,730	24.4	185	2.1	Moist	100.2
222			DA	29		-1.0	3,625	23.7	3,470	22.7	159	---	Moist	--
223			DA	30		1.0	3,850	25.2	4,005	26.2	172	1.8	Moist	99.6
224			BS	43		0	1,200	7.8	1,200	7.8	50	2.5	Moist	94.0
225			BS	44		1.5	1,200	7.8	1,422	9.3	49	2.9	Moist	93.6
226			BS	45		0.5	1,300	8.5	1,376	9.0	60	---	Moist	--
227			DA	31	15	-2.5	5,225	34.2	4,845	31.7	172	1.9	Moist	100.6
228			DA	32		-3.0	4,700	30.7	4,234	27.7	182	---	Moist	--
229			DA	33		-1.0	4,625	30.3	4,479	29.3	142	---	Moist	--
230			BS	46		-1.0	1,950	12.8	1,804	11.8	46	2.9	Moist	90.8
231			BS	47		0	1,600	10.5	1,600	10.5	43	---	Moist	--
232			BS	48		0	1,650	10.8	1,650	10.8	40	3.3	Moist	90.7
233			DA	34	10	3.0	5,200	34.0	5,655	37.0	162	2.1	Moist	100.8
234			DA	35		-1.0	5,300	34.7	5,151	33.7	160	2.5	Moist	101.8
235			DA	36		0	5,200	34.0	5,200	34.0	129	---	Moist	--
236			BS	49		0.5	3,200	20.9	3,271	21.4	40	---	Moist	--
237			BS	50		1.0	3,100	20.3	3,256	21.3	39	2.9	Moist	91.5
238			BS	51		-1.5	3,150	20.6	2,919	19.1	44	---	Moist	--
						5-ton M41, 6x6 Truck, Test Weight 23,070 lb								
239	Padre Island	Gulf	FS	60	30	1.0	9,303	40.3	9,528	41.3	355**	22.7	Wet	101.4
240			BSF	117		0	3,910	16.9	3,910	16.9	97	9.8	Moist	85.1
241			BSF	121		0	3,800	16.5	3,800	16.5	76	11.7	Moist	85.8
242		Lagoon	TF	197		0	6,336	27.5	6,336	27.5	52	19.1	Wet	88.0
243		Gulf	BC	64		1.5	7,200	31.2	7,544	32.7	340**	2.2	Moist	90.9
244			FS	61	20	0	11,646	50.5	11,646	50.5	310**	23.9	Wet	100.2
245			TF	118		-1.5	5,976	25.9	5,629	24.4	35	23.6	Wet	82.6
246			BSF	122		0.5	5,052	21.9	5,168	22.4	110	16.8	Wet	94.0
247		Lagoon	TF	198		-1.5	7,231	31.3	6,875	29.8	47	21.2	Wet	85.1
248		Gulf	BC	65		1.5	8,810	38.2	9,159	39.7	305**	3.0	Moist	95.8
249			FS	62	15	0	12,204	52.9	12,204	52.9	290**	24.1	Wet	99.8
250			TF	119		0	7,870	34.1	7,870	34.1	39	23.7	Wet	88.1
251			BSF	123		0.5	6,415	27.8	6,529	28.3	99	9.6	Moist	86.0
252		Lagoon	TF	199		0	5,209	22.6	5,209	22.6	33	19.8	Wet	74.6
253		Gulf	BC	66		1.5	9,840	42.6	10,174	44.1	360**	4.3	Moist	94.9
254			FS	63	10	-1.0	12,960	56.2	12,735	55.2	270**	24.4	Wet	98.4
255			TF	120		0	8,541	37.0	8,541	37.0	30	22.9	Wet	91.3
256			BSF	124		-0.5	9,050	39.2	8,928	38.7	93	19.3	Wet	95.1
257		Lagoon	TF	200		0	6,900	29.9	6,900	29.9	30	20.4	Wet	81.4
258		Gulf	BC	67		2.0	10,600	45.9	11,051	47.9	360**	2.6	Moist	97.7
						5-ton M41, 6x6 Truck, Test Weight 28,170 lb								
259	Padre Island	Gulf	BSF	130	30	0	8,700	30.9	8,700	30.9	189	24.8	Wet	98.1
260			TF	133		0	10,081	35.8	10,081	35.8	40	24.0	Wet	97.8
261			FS	68		0	13,200	46.9	13,200	46.9	455**	24.0	Wet	99.4
262			BSF	131	20	0.5	12,200	43.3	12,338	43.8	162	23.6	Wet	100.5
263			TF	134		-0.5	10,500	37.3	10,367	36.8	89	24.3	Wet	94.7
264			BSF	132	15	0	10,280	36.5	10,280	36.5	140	21.7	Wet	98.6
265			TF	135		-0.5	11,200	39.8	11,071	39.3	88	21.2	Wet	95.2
						5-ton M51, 6x6 Dump Truck, Test Weight 32,663 lb								
266	France	Suscinio	FS	163‡	15	8	4,279	13.1	5,010	15.3	107	2.9	Moist	110.5
267			FS	164‡		8	4,477	13.7	5,180	15.9	100	5.0	Moist	104.3
268			FS	165‡		9.5	2,424	7.4	3,930	12.0	54	1.8	Moist	108.3
269			FS	166‡		10	2,280	7.0	3,970	12.1	61	2.2	Moist	102.3
270			FS	167‡		10	3,525	10.8	4,800	14.7	51	2.9	Moist	103.2
271			FS	168‡		10	3,321	10.2	4,650	14.2	57	2.5	Moist	104.0
272		La Turballe	FS	87		12	2,343	7.2	6,284	19.2	84	3.2	Moist	94.9
273			FS	88		10.5	2,979	9.1	6,428	19.7	99	2.6	Moist	96.1
274			BS	89		10	2,059	6.3	5,340	16.3	66	4.0	Moist	87.9
275			FS	90		10.5	2,619	8.0	6,066	18.6	87	3.2	Moist	94.9
276			FS	91		10.5	3,223	9.9	6,674	20.4	93	2.6	Moist	96.1
						5-ton M52, 6x6 Truck, Test Weight 18,310 lb								
277	Cape Cod	Wellfleet	DA	102	20	-0.5	1,400	7.6	1,300	7.1	53	3.1	Moist	95.7
278			DA	103		0	1,600	8.7	1,600	8.7	51	---	Moist	---
279			DA	104		0.5	1,500	8.2	1,592	8.7	51	3.7	Moist	94.5
280			DA	105		0	2,000	10.9	2,000	10.9	54	---	Moist	--
281			DA	96	15	0.5	2,300	12.6	2,400	13.1	56	3.1	Moist	96.8
282			DA	97		-1.5	2,400	13.1	2,123	11.6	50	---	Moist	--
283			DA	98		0	2,300	12.6	2,300	12.6	52	4.0	Moist	94.5
284			DA	99		0	2,700	14.7	2,700	14.7	70	---	Moist	--
						Bucket Loader, 4x4 Tractor, Test Weight 13,595 lb								
285	Mississippi River	Vicksburg Bridge	--	163	30	1.0	2,600	19.1	2,733	20.1	122	0.3	Moist	99.5
286			--	164		0.3	2,720	20.0	2,760	20.3	128	4.3	Moist	88.5
287			--	165		-0.4	2,800	20.6	2,746	20.2	126	2.8	Moist	93.0
288			--	166		0.2	2,580	19.0	2,610	19.2	112	2.6	Moist	93.4
289			--	169	20	0.8	3,320	24.4	3,426	25.2	125	2.8	Moist	94.5
290			--	170		-0.5	3,300	24.3	3,236	23.8	120	2.6	Moist	95.9
291			--	173	15	-1.0	4,220	31.0	4,078	30.0	124	2.9	Moist	94.6
292			--	174		-0.4	4,180	30.7	4,119	30.3	121	3.1	Moist	92.8
293			--	175		0.6	3,850	28.3	3,929	28.9	117	2.4	Moist	93.8
294			--	180	10	-1.2	4,780	35.2	4,622	34.0	109	5.2	Moist	92.2
295			--	181		0	4,820	35.5	4,820	35.5	123	3.4	Moist	96.5

(Continued)

** 0.2-in. cone penetrometer reading multiplied by 2.5.
‡ Indicates tests conducted with vehicle operating on a side slope. See paragraphs 76 and 77.

Table 3 (Concluded)

Item No.	Test Program	Location	Test Area	Test No.	Tire Pressure psi	Measured Maximum Towing Force on Slopes: Slope %	Measured Maximum Towing Force on Slopes: lb	Measured Maximum Towing Force on Slopes: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected Maximum Towing Force for Level: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
						Tournadozer, 4x4 Tractor, Test Weight 31,070 lb								
296	Mississippi River	Vicksburg Bridge	--	86	30	0.7	6,488	20.9	6,711	21.6	103	2.9	Moist	88.2
297			--	87		-0.8	6,856	22.1	6,618	21.3	130	2.7	Moist	86.8
298			--	88		-1.0	7,000	22.5	6,680	21.5	115	2.8	Moist	84.4
299			--	89		-1.4	7,731	24.9	7,301	23.5	147	3.6	Moist	86.3
300			--	91		-2.2	7,410	23.8	6,711	21.6	141	5.8	Moist	90.6
301			--	92	20	0.7	8,571	27.6	8,793	28.3	136	2.7	Moist	88.2
302			--	93		0.4	8,333	26.8	8,451	27.2	138	3.4	Moist	86.0
303			--	94		-0.4	9,522	30.6	9,383	30.2	136	3.3	Moist	89.3
304			--	95		-0.4	8,850	28.5	8,731	28.1	136	3.3	Moist	89.3
305			--	97		-0.3	9,000	29.0	8,917	28.7	122	2.7	Moist	81.5
306			--	98		-0.3	8,840	28.4	8,731	28.1	136	2.7	Moist	88.3
307			--	99		-1.4	8,890	28.6	8,451	27.2	138	2.3	Moist	87.4
308			--	100	15	-3.0	11,038	35.5	10,098	32.5	125	3.1	Moist	86.6
309			--	101		-1.2	10,520	33.9	10,160	32.7	124	2.7	Moist	88.0
310			--	102		-0.7	10,750	34.6	10,533	33.9	139	2.9	Moist	90.0
311			--	103		-0.3	10,246	33.0	10,160	32.7	135	3.9	Moist	91.2
312			--	104		-0.3	9,913	31.9	9,818	31.6	130	3.4	Moist	86.0
313			--	105		0	10,500	33.8	10,500	33.8	124	3.0	Moist	87.0
314			--	106		0.2	10,250	33.0	10,315	33.2	134	2.7	Moist	89.1
315			--	107		-0.5	10,657	34.3	10,502	33.8	133	3.5	Moist	88.4
316			--	108	10	-0.5	12,500	40.2	12,335	39.7	116	2.5	Moist	88.5
317			--	109		-0.4	12,600	40.6	12,490	40.2	137	3.9	Moist	88.4
318			--	110		-1.7	12,600	40.6	12,086	38.9	116	2.4	Moist	88.1
319			--	111		-0.6	13,000	41.8	12,801	41.2	138	5.2	Moist	84.5
320			--	112		-0.3	12,500	40.2	12,397	39.9	133	2.6	Moist	87.2
						5-ton XM520 GOER, 4x4 Cargo Carrier, Test Weight 26,670 lb 18.00-26, 10-PR Tires								
321	Mississippi River	Vicksburg Bridge	--	1-1	30	-0.3	7,500	28.1	7,413	27.8	143	3.2	Moist	93.8
322			--	1-2		-0.8	7,000	26.2	6,773	25.4	113	6.8	Moist	91.6
323			--	1-3		-1.2	6,750	25.3	6,227	24.1	119	2.5	Moist	92.4
324			--	1-4		-1.6	7,750	29.0	7,307	27.4	132	3.6	Moist	94.9
325			--	1-5		-0.1	7,000	26.2	6,960	26.1	140	3.5	Moist	98.6
326			--	1-6		0.5	7,000	26.2	7,120	26.7	143	9.2	Moist	84.7
327			--	1-7		0.6	7,000	26.2	7,147	26.8	126	8.6	Moist	93.5
328			--	2-1	20	-0.2	9,000	33.7	8,933	33.5	151	---	Moist	--
329			--	2-2		-0.2	9,250	34.7	9,200	34.5	151	5.3	Moist	94.3
330			--	2-3		-3.2	9,000	33.7	8,133	30.5	136	---	Moist	--
331			--	2-4		1.1	8,250	30.9	8,533	32.0	126	---	Moist	--
332			--	2-5		-0.1	8,750	32.8	8,720	32.7	134	7.3	Moist	95.6
333			--	2-6		0.6	8,500	31.9	8,667	32.5	135	---	Moist	--
334			--	3-1	15	0.5	10,000	37.5	10,133	38.0	157	---	Moist	--
335			--	3-2		-0.6	10,500	39.4	10,347	38.8	146	3.7	Moist	95.8
336			--	3-3		-1.2	11,000	41.2	10,667	40.0	136	---	Moist	--
337			--	3-4		-2.0	10,500	39.4	9,973	37.4	142	---	Moist	--
338			--	3-5		1.0	9,500	35.6	9,760	36.6	147	---	Moist	--
339			--	3-6		0.1	9,750	36.5	9,760	36.6	144	5.2	Moist	90.6
340			--	4-1	10	0	11,500	43.1	11,493	43.1	126	3.0	Moist	92.8
341			--	4-2		-0.3	12,000	45.0	11,920	44.7	145	---	Moist	--
342			--	4-3		0.4	11,750	44.0	11,840	44.4	141	---	Moist	--
343			--	4-4		-2.2	12,000	45.0	11,413	42.8	149	---	Moist	--
						5-ton XM520 GOER, 4x4 Cargo Carrier, Test Weight 26,670 lb 15.00-34, 10-PR Tires								
344	Mississippi River	Vicksburg Bridge	--	1-1	30	-0.4	6,500	24.4	6,400	24.0	135	6.0	Moist	94.0
345			--	1-2		-0.3	6,750	25.3	6,667	25.0	132	3.4	Moist	93.0
346			--	1-3		-2.1	7,000	26.2	6,427	24.1	134	3.1	Moist	94.2
347			--	1-4		0.4	6,500	24.4	6,613	24.8	144	7.8	Moist	91.3
348			--	1-5		0.1	6,250	23.4	6,267	23.5	142	3.3	Moist	95.0
349			--	1-6		0.6	6,750	25.3	6,907	25.9	144	3.9	Moist	90.1
350			--	2-1	20	0.4	8,250	30.9	8,347	31.3	130	---	Moist	--
351			--	2-2		-1.0	8,500	31.9	8,240	30.9	136	4.3	Moist	91.6
352			--	2-3		-0.8	8,500	31.9	8,293	31.1	130	---	Moist	--
353			--	2-4		-1.1	8,500	31.9	8,213	30.8	123	3.8	Moist	93.4
354			--	2-5		0.6	8,000	30.0	8,160	30.6	130	---	Moist	--
355			--	2-6		0	8,000	30.0	8,000	30.0	130	---	Moist	--
356			--	2-7		0.3	8,000	30.0	8,080	30.3	129	3.5	Moist	91.6
357			--	3-1	15	0	9,500	35.6	9,493	35.6	145	3.2	Moist	88.2
358			--	3-2		0	9,500	35.6	9,493	35.6	143	---	Moist	--
359			--	3-3		-1.1	9,750	36.5	9,440	35.4	134	3.7	Moist	94.2
360			--	3-4		-1.6	10,000	37.5	9,573	35.9	148	---	Moist	--
361			--	3-5		0.3	9,250	34.7	9,333	35.0	141	3.7	Moist	91.2
362			--	3-6		0.5	9,250	34.7	9,387	35.2	141	---	Moist	--
363			--	3-7		-0.7	9,500	35.6	9,307	34.9	136	---	Moist	--
364			--	3-8		-0.8	9,500	35.6	9,280	34.8	139	3.8	Moist	94.8
365			--	4-1	10	-0.4	11,500	43.1	11,387	42.7	151	7.2	Moist	89.5
366			--	4-2		-0.6	11,500	43.1	11,333	42.5	146	---	Moist	--
367			--	4-3		-0.3	11,000	41.2	10,907	40.9	139	---	Moist	--
368			--	4-4		-0.1	11,000	41.2	10,960	41.1	129	2.9	Moist	90.9
369			--	4-5		-2.2	11,000	41.2	10,400	39.0	126	---	Moist	--

Table 4

Summary of Data and Test Results, Maximum-Towing-Force Tests with Self-propelled Tracked Vehicles

Item No.	Test Program	Location	Test Area*	Test No.	Measured Maximum Towing Force on Slopes: Slope %	Measured Maximum Towing Force on Slopes: lb	Measured Maximum Towing Force on Slopes: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected Maximum Towing Force for Level: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
					1/4-ton M29C Weasel, Test Weight 5,560 lb							
1	Mississippi	Vicksburg	--	66	1.1	2,726	49.0	2,786	50.1	129	2.4	89.1
2	River	Bridge	--	67	-0.4	2,819	50.7	2,797	50.3	147	3.7	89.5
3			--	68	-0.4	2,710	48.7	2,685	48.3	134	3.8	89.2
4			--	69	0	2,657	47.8	2,657	47.8	126	2.7	89.2
5			--	70	-1.9	2,834	51.0	2,730	49.1	133	2.8	87.0
6			--	71	-1.0	2,794	50.2	2,736	49.2	112	3.7	86.5
7			--	72	0	2,733	49.1	2,733	49.1	115	3.3	88.1
8			--	73	-0.9	2,748	49.4	2,697	48.5	131	4.8	89.8
9			--	74	0	2,681	48.2	2,681	48.2	125	4.6	89.2
10			--	75	-1.0	2,835	51.0	2,780	50.0	98	4.3	88.5
11			--	76	-0.6	2,804	50.4	2,769	49.8	127	3.8	90.1
12			--	78	0.0	2,761	49.7	2,761	49.7	151	4.0	89.7
13			--	79	-1.6	2,853	51.3	2,763	49.7	137	4.9	89.9
14			--	80	-1.3	2,767	49.8	2,697	48.5	131	5.0	89.1
15			--	81	0	2,750	49.5	2,750	49.5	142	4.6	87.4
16			--	82	-0.5	2,819	50.7	2,791	50.2	135	5.1	87.5
17			--	83	-1.3	2,829	50.9	2,758	49.6	134	6.7	89.3
18			--	84	-2.4	2,919	52.5	2,786	50.1	141	4.3	88.6
19			--	85	-2.3	2,939	52.8	2,808	50.5	140	4.6	88.8
					Standard D4 Engineer Tractor, Test Weight 14,870 lb							
20	Mississippi	Vicksburg	--	117	-2.5	8,286	55.7	7,911	53.2	141	2.8	94.6
21	River	Bridge	--	118	-0.8	8,139	54.7	8,015	53.9	144	3.1	93.4
22			--	119	-0.6	8,444	56.8	8,357	56.2	144	5.6	93.5
23			--	120	-0.5	8,562	57.6	8,491	57.1	142	3.4	92.6
24			--	121	-0.8	8,225	55.3	8,104	54.5	143	2.4	95.3
25			--	122	-1.1	8,460	56.9	8,297	55.8	133	5.3	95.4
					Standard D7 Engineer Tractor, Test Weight 27,000 lb							
26	Mississippi	Vicksburg	--	125	-0.3	15,500	57.4	15,417	57.1	127	3.1	95.3
27	River	Bridge	--	126	-0.1	15,750	58.3	15,714	58.2	132	2.4	94.8
					13-ton M5A4 Hi-Speed Tractor, Test Weight 25,230 lb							
28	Mississippi	Vicksburg	--	128	-0.4	12,500	49.5	12,388	49.1	124	5.7	95.6
29	River	Bridge	--	129	-0.2	12,000	47.6	11,959	47.4	127	4.8	95.7
30			--	160	0.3	13,250	52.5	13,321	52.8	121	2.8	94.7
31			--	161	1.2	12,500	49.5	12,792	50.7	118	---	--
32			--	162	-0.6	11,500	45.6	11,354	45.0	121	---	--
					18-ton M4 Hi-Speed Tractor, Test Weight 28,700 lb							
33	Mississippi	Vicksburg	--	145	-0.1	14,000	48.8	13,977	48.7	128	2.8	92.0
34	River	Bridge	--	146	0	13,500**	47.0	13,500	47.0	132	2.7	95.1
35			--	147	-0.2	15,000	52.3	14,953	52.1	118	3.3	97.3
36			--	148	-0.1	15,500	54.0	15,469	53.9	115	2.8	89.9
37			--	149	-0.4	14,500	50.5	14,379	50.1	115	2.6	95.6
38			--	150	0.2	14,500	50.5	14,551	50.7	130	2.4	93.5
39			--	151	0	14,500	50.5	14,500	50.5	127	3.3	94.1
40			--	152	-0.2	14,000	48.8	13,948	48.6	103	3.6	95.5
					18-ton M4 Hi-Speed Tractor, Test Weight 30,250 lb							
41	Cape Cod	Wellfleet	FS	127	0.5	9,000**	29.8	9,166	30.3	107	2.8	99.3
42			FS	128	0	12,000**	39.7	12,000	39.7	106	---	--
43			FS	129	-0.5	14,500	47.9	14,338	47.4	91	3.8	103.2
44			BS	131	-2.0	14,750	48.8	14,157	46.8	51	---	--
45			BS	132	2.5	14,500	47.9	15,246	50.4	55	2.8	94.0
46			BS	133	1.0	13,500	44.6	13,794	45.6	70	---	--
47			BS	134	0	14,500	47.9	14,500	47.9	38	---	--
					Standard D6 Engineer Tractor, Test Weight 22,667 lb							
48	Cape Cod	wellfleet	BS	118	1.0	12,500	55.1	12,716	56.1	57	3.3	89.7
49			BS	119	0	12,000	52.9	12,000	52.9	73	---	--
50			BS	120	0.5	12,250	54.0	12,354	54.5	66	3.2	90.4
51			BS	121	0	12,500	55.1	12,500	55.1	63	---	--
52			FS	122	0.5	12,500	55.1	12,603	55.6	98	2.5	100.1
53			FS	123	0.5	12,500	55.1	12,603	55.6	111	---	--
54			FS	124	0.5	12,500	55.1	12,603	55.6	96	2.8	98.2
55			FS	125	0	13,000	57.4	13,000	57.4	112	---	--

Note: All tests performed on moist sand.
* See "Beach Terms" under "Definitions" in text.
** Not maximum towing force.

Table 5

Summary of Data and Test Results, Towed-Vehicle Tests with Self-propelled Vehicles

Item No.	Program	Location	Test Area*	Test No.	Truck Tire Pressure psi	Required Towing Force Measured on Slopes: Slope %	Required Towing Force Measured on Slopes: lb	Required Towing Force Measured on Slopes: % of Test Weight	Corrected Required Towing Force for Level: lb	Corrected Required Towing Force for Level: % of Test Weight	Average Cone Index, 0- to 6-in. Depth: Before Traffic	Average Cone Index, 0- to 6-in. Depth: After Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth	Rut Depth After One Pass, in.
								Wheeled Vehicles								
								3/4-ton M37, 4x4 Truck, Test Weight 7,187 lb								
1	Padre Island	Gulf	BC	28	30	1.0	214	3.0	144	2.0	330**	230**	2.7	Moist	98.1	0.25
2			BC	29	20	2.0	154	2.1	7	0.1	359**	268**	4.3	Moist	95.6	0.25
3			BC	30	15	1.5	274	3.8	165	2.3	372**	277**	4.6	Moist	95.2	0.25
4			BC	31	10	0	467	6.5	467	6.5	309**	282**	2.7	Moist	96.8	0.25
5			BSF	32	30	0	898	12.5	898	12.5	141	97	23.0	Wet	100.0	1.00
6			BSF	33	20	0	546	7.6	546	7.6	170	107	20.5	Wet	97.5	1.50
7			BSF	34	15	1.5	417	5.8	309	4.3	174	143	24.3	Wet	98.4	0.50
8			BSF	35	10	0	366	5.1	366	5.1	164	120	22.5	Wet	96.4	0.50
								2-1/2-ton M135, 6x6 Truck, Test Weight 14,750 lb								
9	Padre Island	Gulf	BSF	97	30	1.0	2574	17.4	2419	16.4	82	---	14.6	Wet	83.3	3.25
10			BSF	98	20	0.5	1347	9.1	1268	8.6	128	---	11.5	Wet	84.2	1.50
11			BSF	99	15	0.5	2002	13.6	1932	13.1	109	88	14.6	Wet	88.3	3.75
12			BSF	100	10	2.5	1268	8.6	899	6.1	78	89	20.4	Wet	89.2	2.75
								2-1/2-ton M135, 6x6 Truck, Test Weight 17,450 lb								
13	Padre Island	Gulf	TF	113	30	1.0	2647	15.2	2478	14.2	124	78	16.5	Wet	90.1	3.25
14			TF	114	20	0.5	2900	16.6	2809	16.1	32	41	23.5	Wet	85.0	3.00
15			TF	115	15	0.5	2502	14.3	2408	13.8	33	36	22.4	Wet	88.6	2.75
16			TF	116	10	0	2583	14.8	2583	14.8	31	47	23.2	Wet	93.5	3.00
								2-1/2-ton M135, 6x6 Truck, Test Weight 18,320 lb								
17	Mississippi River	Vicksburg Bridge	--	154	30	0.6	1760	9.6	1649	9.0	121	---	2.8	Moist	96.8	--
18			--	157	10	-0.4	1600	8.7	1667	9.1	128	---	2.5	Moist	96.1	--
								2-1/2-ton M135, Tested as a 4x4 with 11.00-20, 12-PR Tires (Std NDCC Tread), Test Weight 17,610 lb								
19	Mississippi River	Marshall Cutoff	--	80	30	0	1638	9.3	1638	9.3	127	---	2.6	Moist	97.2	--
20			--	79	20	0	1602	9.1	1602	9.1	100	---	2.6	Moist	96.7	--
21			--	78	15	0	1444	8.2	1444	8.2	112	---	2.4	Moist	95.9	--
								2-1/2-ton M135, Tested as a 4x4 with 11.00-20, 12-PR Tires (Tread Removed), Test Weight 17,610 lb								
22	Mississippi River	Marshall Cutoff	--	53	30	0	1285	7.3	1285	7.3	85	---	2.8	Moist	97.1	--
23			--	52	20	0	1197	6.8	1197	6.8	103	---	2.4	Moist	95.2	--
24			--	51	15	0	1039	5.9	1039	5.9	102	---	2.6	Moist	97.3	--
								2-1/2-ton DUKW 353, 6x6 Truck, Test Weight 15,285 lb								
25	Cape Cod	Wellfleet	DA	40	30	1.5	2250	14.7	2018	13.2	137	---	---	Moist	--	--
26			DA	39	20	1.5	1700	11.1	1467	9.6	112	---	2.2	Moist	99.4	--
27			DA	38	15	2.5	1650	10.8	1269	8.3	114	---	---	Moist	--	--
28			DA	37	10	0	2250	14.7	2250	14.7	88	---	1.8	Moist	102.0	--
								5-ton M41, 6x6 Truck, Test Weight 23,070 lb								
29	Padre Island	Gulf	TF	125	30	-1.0	4453	19.3	4683	20.3	41	54	24.3	Wet	83.0	3.75
30			TF	126	20	-1.0	3467	15.0	3691	16.0	25	37	22.7	Wet	79.1	4.00
31			TF	127	15	0	2745	11.9	2745	11.9	23	35	23.0	Wet	85.3	3.00
32			TF	128	10	0	2884	12.5	2884	12.5	30	47	22.9	Wet	84.7	2.75
								5-ton M41, 6x6 Truck, Test Weight 28,170 lb								
33	Padre Island	Gulf	BSF	136	30	-2.0	3523	12.5	4085	14.5	70	87	10.7	Moist	87.6	2.00
34			BSF	137	20	-2.0	1120	4.0	1690	6.0	186	120	24.7	Wet	98.2	0.50
35			BSF	138	15	2.0	1280	4.5	704	2.5	302**	253**	7.8	Moist	94.7	0.25
36			BSF	139	10	0.5	1381	4.9	1239	4.4	166	124	12.4	Wet	94.8	1.00
								5-ton M52, 6x6 Truck, Test Weight 18,310 lb								
37	Cape Cod	Wellfleet	DA	81	30	0	2000	10.9	2000	10.9	160	---	---	Moist	--	--
38			BS	101	20	1.5	3400	18.6	3131	17.1	51	---	---	Moist	--	--
39			DA	80	20	-1.0	1450	7.9	1630	8.9	135	---	1.7	Moist	100.2	--
40			BS	100	15	-2.0	2000	10.9	2362	12.9	62	---	3.9	Moist	94.3	--
41			DA	79	15	1.0	1200	6.5	1007	5.5	188	---	---	Moist	--	--
								5-ton M52, 6x6 Truck, Test Weight 22,310 lb, Towing 12-ton M127A1 Semitrailer with 10,400 lb on Wheels; Total Weight, 32,710 lb								
42	Cape Cod	Wellfleet	DA	82	30†	-1.5	3400	10.4	3892	11.9	126	---	1.7	Moist	100.2	--
43			DA	83	20†	1.5	2000	6.1	1472	4.6	209	---		Moist		--
44			DA	114	20††	0	1700	5.2	1700	5.2	202	---	2.6	Moist	98.1	--
45			DA	78	15†	0	3300	10.1	3300	10.1	126	---		Moist		--
46			BS	84	15†	0.5	6000	18.3	5822	17.8	66	---	3.3	Moist	96.7	--
47			BS	85	15††	0	5400	16.5	5400	16.5	48	---	3.6	Moist	95.6	--
								Bucket Loader, 4x4 Tractor, Test Weight 13,595 lb								
48	Mississippi River	Vicksburg Bridge	--	168	30	-0.9	680	5.0	802	5.9	135	---	2.4	Moist	95.1	--
49			--	172	20	-0.2	802	5.9	829	6.1	117	---	2.3	Moist	94.1	--
50			--	179	15	-0.7	720	5.3	816	6.0	117	---	2.5	Moist	94.2	--
51			--	183	10	-1.3	880	6.5	1060	7.8	111	---	2.7	Moist	94.0	--

(Continued)

* See "Beach Terms" under "Definitions" in text.
** 0.2-in. cone penetrometer reading multiplied by 2.5.
† Trailer at 60 psi.
†† Trailer at 15 psi.

(Sheet 1 of 2 sheets)

Table 5 (Concluded)

Item No.	Program	Location	Test Area	Test No.	Truck Tire Pressure psi	Required Towing Force Measured on Slopes: Slope %	Required Towing Force Measured on Slopes: lb	Required Towing Force Measured on Slopes: % of Test Weight	Corrected Required Towing Force for Level: lb	Corrected Required Towing Force for Level: % of Test Weight	Average Cone Index, 0- to 6-in. Depth: Before Traffic	Average Cone Index, 0- to 6-in. Depth: After Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth	Rut Depth After One Pass, in.
Wheeled Vehicles (Continued)																
Tournadozer, 4x4 Tractor, Test Weight 31,070 lb																
52	Mississippi River	Vicksburg Bridge	--	116	30	0.5	2800	9.0	2641	8.5	128	---	3.0	Moist	95.0	--
53			--	115	20	0.5	2300	7.4	2144	6.9	130	---	3.2	Moist	93.4	--
54			--	114	15	-1.1	1900	6.1	2237	7.2	134	---	2.9	Moist	96.6	--
55			--	113	10	0	1709	5.5	1709	5.5	126	---	3.1	Moist	96.0	--
5-ton XM520 GOER, 4x4 Cargo Carrier, Test Weight 26,670 lb 18.00-26, 10-PR Tires																
56	Mississippi River	Vicksburg Bridge	--	1-7	30	0	1733	6.5	1733	6.5	126	---	8.6	Moist	93.5	--
57			--	2-6	20	0	1490	5.6	1490	5.6	135	---	---	Moist	--	--
58			--	3-6	15	0	1390	5.2	1390	5.2	144	---	5.2	Moist	90.6	--
59			--	4-3	10	0	--	---	--	---	141	---	---	Moist	--	--
5-ton XM520 GOER, 4x4 Cargo Carrier, Test Weight, 26,670 lb 15.00-34, 10-PR Tires																
60	Mississippi River	Vicksburg Bridge	--	1-6	30	0	1490	5.6	1490	5.6	144	---	3.9	Moist	90.1	--
61			--	2-7	20	0	1575	5.9	1575	5.9	129	---	3.5	Moist	91.6	--
62			--	3-8	15	0	1470	5.5	1470	5.5	139	---	3.8	Moist	94.8	--
63			--	4-5	10	0	--	---	--	---	126	---	---	Moist	--	--
Tracked Vehicles																
1/4-ton M29C Weasel, Test Weight 5,560 lb																
64	Mississippi River	Vicksburg Bridge	--	85A		-1.1	400	7.2	460	8.3	140	---	4.6	Moist	88.8	
Standard D4 Engineer Tractor, Test Weight 14,870 lb																
65	Mississippi River	Vicksburg Bridge	--	123		-2.6	1100	7.4	1487	10.0	142	---	3.3	Moist	93.8	
Standard D6 Engineer Tractor, Test Weight 22,667 lb																
66	Cape Cod	Wellfleet	FS	130		0	1750	7.7	1750	7.7	97	---	3.8	Moist	103.2	
67			BC	135		3.0	2000	8.8	1315	5.8	39	---	---	Moist	--	
Standard D7 Engineer Tractor, Test Weight 27,000 lb																
68	Mississippi River	Vicksburg Bridge	--	124		-0.5	1800	6.7	1944	7.2	135	---	2.2	Moist	97.3	
13-ton M5A4 Hi-Speed Tractor, Test Weight 25,230 lb																
69	Mississippi River	Vicksburg Bridge	--	130		-0.2	2400	9.5	2447	9.7	135	---	4.9	Moist	94.4	
18-ton M4 Hi-Speed Tractor, Test Weight 28,700 lb																
70	Mississippi River	Vicksburg Bridge	--	159		0.4	3700	12.9	3587	12.5	118	---	2.6	Moist	92.6	
18-ton M4 Hi-Speed Tractor, Test Weight 30,250 lb																
71	Cape Cod	Wellfleet	FS	126		0	2500	8.3	2500	8.3	112	---	2.8	Moist	89.2	

Table 6

Summary of Data and Test Results on "Honeycomb" sand

Self-propelled Wheeled Vehicles

Padre Island Test Program

Item No.	Location	Test Area*	Test No.	Passes Com-pleted	Immo-bilized	Pass No.	Average Cone Index 0- to 6-in. Depth	Average Cone Index 6- to 12-in. Depth	Average Cone Index 12- to 18-in. Depth	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Content % by Weight 6- to 12-in. Depth	Moisture Content % by Weight 12- to 18-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth	Dry Density lb/cu ft 6- to 12-in. Depth	Dry Density lb/cu ft 12- to 18-in. Depth	Rut Depth in.
1/4-ton M38A1, 4x4 Truck, Test Weight 3,200 lb																
1	Gulf	BSF	68A**	3	Yes	0	26	40	57	--	--	--	--	--	--	
						3	9	34	104							--
2	Lagoon	TF	149	20	No	0	31	78	217+	23.5	23.8	23.0	97.6	94.8	101.0	
						1	17	73	220+							1.75
						10	36	158	---							6.00
3		TF	150	20	No	0	50	49	66	20.0	23.2	22.2	98.1	89.4	93.7	
						1	52	71	76							2.00
4		TF	151	2	Yes	0	33	69	114	20.8	21.2	22.0	91.6	99.2	90.1	
						1	16	25	83							3.00
5		TF	152	2	Yes	0	15	41	68	20.8	21.2	22.0	91.6	99.2	90.1	
						1	--	--	---							--
6		TF	167	2	Yes	0	26	35	55	23.1	22.5	23.2	95.4	97.1	98.3	
						1	14	29	49							4.00
7		TF	169	25	No	0	23	66	138	21.2	21.5	21.8	89.3	100.8	105.3	
						1	24	67	153							3.75
						10	28	105	195							--
8		TF	170	25	No	0	25	74	145	21.2	21.5	21.8	89.3	100.8	105.3	
						1	34	86	152							3.50
						10	32	102	216							7.50
9		TF	179	4	Yes	0	26	38	58	22.2	22.9	22.2	94.4	85.6	85.8	
						1	32	46	110							6.50
3/4-ton M37, 4x4 Truck, Test Weight 7,187 lb																
10	Lagoon	TF	145	1	Yes	0	19	36	57	23.2	22.5	23.0	94.7	91.0	90.4	
						1	14	40	125							8.00
11		TF	146	3	Yes	0	36	72	85	20.8	21.2	22.0	91.6	99.2	90.1	
						1	21	37	106							5.25
12		TF	147	10	Yes	0	78	73	74	20.0	23.2	22.2	98.1	89.4	93.7	
						1	49	56	61							5.00
13		TF	148	20	No	0	35	74	234+	23.6	23.8	23.8	97.6	94.8	101.0	
						1	19	69	212+							2.50
						10	18	113	---							--
14		TF	165	2	Yes	0	20	33	53	23.1	22.5	23.2	95.4	97.1	98.3	
						1	11	27	60							7.50
15		TF	168	27	No	0	31	80	148	21.2	21.5	21.8	89.3	100.8	105.3	
						1	18	45	96							4.00
						10	15	75	135							--
16		TF	171	4	Yes	0	40	46	97	23.0	23.3	22.0	100.7	92.8	95.1	
						1	16	34	46							5.00
17		TF	172	25	No	0	38	53	136	23.0	23.3	22.0	100.7	92.8	95.1	
						1	22	60	121							2.00
						10	21	106	171							7.50
18		TF	173	3	Yes	0	68	65	37	17.2	23.1	22.6	93.3	97.5	89.2	
						1	51	59	57							7.00
19		TF	175	3	Yes	0	39	37	99	21.6	22.5	21.1	98.5	88.9	98.7	
						1	44	120	174							7.00
20		TF	178	5	Yes	0	51	40	46	16.2	21.5	22.2	91.7	82.2	90.6	
						1	41	56	95							9.00
21	Gulf	BSF	213**	25	No	0	43	125	249+	23.8	21.3	--	89.8	95.4	--	
						1	37	103	233+							--
						10	30	144	---							--
22		BSF	214**	36	No	0	26	91	---	23.0	22.6	--	94.6	97.4	--	
						1	16	56	---							--
						10	8	61	---							--
23		BSF	215**	25	No	0	22	31	---	24.6	23.8	--	91.6	82.1	--	
						1	18	101	---							--
						10	10	85	---							--
24		BSF	216**	1	No	0	26	43	---	--	--	--	--	--	--	
						1	15	114	---							--

(Continued)

Note: All tests conducted at 15-psi tire pressure except where noted.
* See "Beach Terms" under "Definitions" in text.
** Test conducted at 30-psi inflation pressure.

Table 6 (Concluded)

Item No.	Location	Test Area	Test No.	Passes Completed	Immobilized	Pass No.	Average Cone Index 0- to 6-in. Depth	Average Cone Index 6- to 12-in. Depth	Average Cone Index 12- to 18-in. Depth	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Content % by Weight 6- to 12-in. Depth	Moisture Content % by Weight 12- to 18-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth	Dry Density lb/cu ft 6- to 12-in. Depth	Dry Density lb/cu ft 12- to 18-in. Depth	Rut Depth in.
							2-1/2-ton M135, 6x6 Truck, Test Weight 14,750 lb									
25	Lagoon	TF	153	2	Yes	0	19	41	66	22.7	23.5	22.9	87.6	94.1	89.5	
						1	19	55	116							8.50
26		TF	154	3	Yes	0	18	44	73	22.7	23.5	22.9	87.6	94.1	89.5	
						1	16	49	97							8.50
27		TF	155	2	Yes	0	35	85	90	21.8	21.9	22.6	91.0	94.2	89.2	
						1	21	43	85							6.50
28		TF	156	6	Yes	0	61	73	108	--	--	--	--	--	--	
						1	54	76	107							7.50
29		TF	157	25	No	0	46	62	105	23.2	23.5	23.2	92.9	90.7	89.4	
						1	36	78	211+							7.50
						10	40	180+	---							13.50
30		TF	158	25	No	0	59	63	74	20.4	21.8	22.6	94.4	97.0	91.6	
						1	40	59	157							9.00
						10	46	199+	---							13.00
31		TF	159	23	No	0	53	90	52	18.8	22.3	22.9	93.3	96.2	88.3	
						1	45	60	79							7.00
						10	57	197+	---							9.50
32		TF	160	3	Yes	0	69	62	67	17.6	24.1	22.7	96.5	90.8	96.3	
						1	35	51	71							7.50
33		TF	161	3	Yes	0	41	40	70	23.2	22.6	22.4	92.8	89.9	92.2	
						1	29	53	102							8.25
34		TF	162	5	Yes	0	24	72	107	23.6	22.9	22.7	90.7	96.2	89.7	
						1	15	39	98							11.50
35		TF	163	30	No	0	36	78	97	21.0	21.6	22.0	98.8	101.1	93.4	
						1	16	37	85							5.00
						10	9	58	213+							
36		TF	164	32	No	0	34	76	89	21.1	18.5	21.6	87.9	100.9	89.3	
						1	19	44	99							7.50
						10	13	90	219+							--
37		TF	166	2	Yes	0	25	36	62	23.1	22.5	23.2	95.4	97.1	98.3	
						1	16	34	67							8.50
38		TF	174	5	Yes	0	57	74	38	17.2	23.1	22.6	93.3	97.5	89.2	
						1	46	67	78							13.50
39		TF	176	25	No	0	47	37	52	--	--	--	--	--	--	
						1	41	66	93							13.50
						10	34	170	--							--
40		TF	177	25	No	0	55	47	54	16.2	21.5	22.2	91.7	82.2	90.6	
						1	37	64	110							7.50
						10	46	199	---							--

Table 7

Summary of Data and Test Results, Drawbar Pull-Slip Tests with Self-propelled Wheeled and Tracked Vehicles

Mississippi River Test Program, Vicksburg Bridge

Item No.	Test No.	Tire Pressure psi	Measured Towing Force lb	Measured Towing Force % of Test Weight	Wheel or Track Slip, %	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
				2-1/2-ton M135, 6x6 Truck, Test Weight 18,320 lb					
1	138-1	30	2,100	11.5	6	123	3.5	Moist	95.9
2	138-2		2,700	14.7	13				
3	138-3		3,200	17.5	12				
4	138-4		1,000	5.5	0				
5	138-5		2,800	15.3	12				
6	139-1		2,900	15.8	11	117	3.8	Moist	96.4
7	140-1		3,000	16.4	8	129	4.6	Moist	89.3
8	140-2		3,000	16.4	10				
9	140-3		1,100	6.0	1				
10	140-4		600	3.3	1				
11	140-5		1,600	8.7	4				
12	140-6		3,000	16.4	8				
13	140-7		3,100	16.9	11				
14	140-8		2,400	13.1	33				
15	140-9		1,800	9.8	58				
16	140-10		1,200	6.5	4				
17	140-11		2,400	13.1	24				
18	140-12		4,000	21.8	100				
19	140-13		2,000	10.9	33				
20	141-1	10	4,000	21.8	6	126	2.9	Moist	96.7
21	141-2		3,000	16.4	5				
22	141-3		1,600	8.7	3				
23	141-4		6,400	35.0	19				
24	141-5		6,200	33.8	10				
25	142-1		5,800	31.6	11	131	2.9	Moist	94.2
26	142-2		6,800	37.1	12				
27	142-3		3,600	19.7	3				
28	142-4		3,600	19.7	3				
29	142-5		4,800	26.2	3				
30	142-6		5,600	30.5	80				
31	142-7		7,600	41.5	100				
32	143-1		1,600	8.7	1	132	2.9	Moist	93.7
33	143-2		2,400	13.1	2				
34	143-3		6,800	37.1	12				
35	143-4		6,200	33.8	25				
36	143-5		6,800	37.1	9				
37	143-6		1,200	6.5	3				
38	144-1		6,600	36.0	9	129	3.0	Moist	95.6
39	144-2		5,600	30.5	45				
40	144-3		5,600	30.5	62				
41	144-4		6,200	33.8	88				
42	144-5		8,000	43.6	100				
43	144-6		5,500	30.0	67				
44	144-7		4,900	26.7	74				
				Standard D7 Engineer Tractor, Test Weight 27,000 lb					
45	125-1		4,000	14.8	0	127	3.1	Moist	95.3
46	125-2		12,500	46.3	4				
47	125-3		3,500	13.0	1				
48	125-4		16,000	59.2	33				
49	125-5		12,000	44.4	10				
50	125-6		15,000	55.5	10				
51	125-7		16,000	59.2	47				
52	125-8		16,100	59.6	78				
53	125-9		14,000	51.8	10				
54	125-10		15,500	57.4	52				
55	125-11		16,000	59.2	71				
56	125-12		15,500	57.4	18				
57	125-13		15,750	58.4	12				
58	126-1		15,750	58.4	8	132	2.4	Moist	94.8
59	126-2		16,250	60.0	25				
60	126-3		5,000	18.5	0				
61	126-4		11,500	42.6	1				
62	126-5		12,500	46.3	2				
63	126-6		16,500	61.1	88				
64	126-7		9,000	33.3	10				
65	126-8		16,000	59.2	25				
66	126-9		5,500	20.4	0				
67	127-1		5,000	18.5	0	131	2.6	Moist	94.1
68	127-2		8,500	31.5	2				
69	127-3		11,250	41.6	1				

(Continued)

Table 7 (Concluded)

Item No.	Test No.	Tire Pressure psi	Measured Towing Force lb	Measured Towing Force % of Test Weight	Wheel or Track Slip, %	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
				13-ton M5A4 Hi-Speed Tractor, Test Weight 25,230 lb					
70	128-1		9,000	35.7	26	124	5.7	Moist	95.6
71	128-2		16,500	65.4	100				
72	128-3		5,250	20.8	1				
73	128-4		9,500	37.6	24				
74	128-5		12,000	47.5	37				
75	128-6		12,250	48.5	52				
76	128-7		5,000	19.8	1				
77	129-1		9,000	35.7	15	127	4.8	Moist	95.7
78	129-2		12,000	47.5	38				
79	129-3		16,000	63.4	98				
80	129-4		9,500	37.6	15				
81	129-5		12,000	47.5	45				
82	129-6		12,000	47.5	42				
83	129-7		15,000	59.4	76				
84	129-8		2,500	9.9	0				
85	129-9		8,800	34.9	19				
86	129-10		17,000	67.4	100				
87	160-1		13,250	52.5	53	121	2.8	Moist	94.7
88	160-2		8,750	34.7	16				
89	160-3		10,000	39.6	25				
90	161-1		12,500	49.5	43	118	---	Moist	--
91	161-2		18,000	71.3	100				
92	162-1		8,500	33.7	10	121	---	Moist	--
93	162-2		5,000	19.8	4				
94	162-3		9,250	36.6	19				
95	162-4		11,500	45.6	43				

Table 8

Summary of Data and Test Results

Special Maximum Towing Force Tests with 2-1/2-ton M135 Truck

Mississippi River Test Program, Marshall Cutoff

Item No.	Test No.	Tire Pressure psi	Maximum Measured Towing Force on Slopes: Slope %	lb	% of Test Weight	Corrected Max Towing Force for Level: lb	% of Test Weight	Soil Data, 0- to 6-in. Depth: Average Cone Index Before Traffic	Moisture Content % by Weight	Moisture Class.	Dry Density lb/cu ft
Tested as a 6x6, Mounted with 11.00-20, 12-PR Tires (Tread Removed) Test Weight 18,100 lb											
1	1	30	0			3200	17.7	133	4.8	Moist	96.2
2	2					3194	17.6	128	3.8	Moist	96.6
3	3					3416	18.9	138	4.1	Moist	98.1
4	4					3200	17.7	120	6.2	Moist	96.5
5	15					2810	15.5	101	2.8	Moist	97.5
6	16					2328	12.9	117	2.8	Moist	95.8
7	55					2600	14.4	90	---	Moist	--
8	56					2500	13.8	113	5.2	Moist	101.6
9	57					2610	14.4	99	---	Moist	--
10	5	20	0			4300	23.8	125	4.0	Moist	94.8
11	6					4655	25.7	129	3.4	Moist	97.5
12	7					4628	25.6	141	4.8	Moist	96.2
13	8					4288	23.7	128	3.0	Moist	96.9
14	17					4556	25.2	109	---	Moist	--
15	18					4431	24.5	112	5.2	Moist	100.0
16	19					4310	23.8	118	---	Moist	--
17	9	15	0			4800	26.5	127	---	Moist	--
18	10					5047	27.9	119	3.5	Moist	95.0
19	11					5504	30.4	126	---	Moist	--
20	20					4996	27.6	103	---	Moist	--
21	21					5157	28.5	111	---	Moist	--
22	22					4786	26.4	105	5.2	Moist	100.0
23	12	10	0			6067	33.5	140	---	Moist	--
24	13					6150	34.0	125	5.4	Moist	97.3
25	14					6200	34.3	147	---	Moist	--
26	23					6025	33.3	107	---	Moist	--
27	24					6272	34.6	114	---	Moist	--
28	25					6050	33.4	101	3.2	Moist	98.1
29	26					6079	33.6	125	---	Moist	--
Tested as a 6x6, Mounted with 11.00-20, 12-PR Tires (Std NDCC Tread) and Snap-Tracs, Test Weight 19,188 lb											
30	131	60	-0.5	1390	7.2	1286	6.7	127	3.4	Moist	95.3
31	132	30	-1.0	1992	10.4	1804	9.4	139	3.8	Moist	98.0
32	133		0.1	2451	12.8	2475	12.9	127	4.8	Moist	92.5
33	38		1.0	2226	11.6	2418	12.6	135	4.7	Moist	89.4
34	39		-1.4	1996	10.4	1727	9.0	125	3.3	Moist	87.4
35	40		-0.6	1787	9.3	1669	8.7	116	2.9	Moist	86.7
36	41		-0.3	1835	9.6	1784	9.3	126	3.6	Moist	86.2
37	42		-0.9	2317	12.1	2149	11.2	131	3.6	Moist	87.0
38	43		-0.3	2115	11.0	2053	10.7	121	3.7	Moist	88.3
39	44		-1.0	2074	10.8	1880	9.8	119	3.2	Moist	82.3
40	45		0.6	2029	10.6	2149	11.2	124	5.2	Moist	89.6
41	134	15	0.2	3265	17.0	3300	17.2	116	4.1	Moist	98.2
42	135		0	3784	19.7	3784	19.8	125	4.1	Moist	94.6
43	46	10	1.1	4191	21.8	4410	22.9	120	3.6	Moist	86.0
44	47		-0.4	4290	22.4	4221	22.0	125	5.1	Moist	89.7
45	48		-0.3	4120	21.5	4078	21.2	136	3.4	Moist	89.4
46	49		1.6	3800	19.8	4100	21.4	127	3.2	Moist	89.4
47	50		0	4400	22.9	4400	22.9	138	3.5	Moist	90.2
48	51		0	4300	22.4	4300	22.4	131	5.1	Moist	88.5

(Continued)

Table 8 (Concluded)

Item No.	Test No.	Tire Pressure psi	Maximum Measured Towing Force on Slopes: Slope %	lb	% of Test Weight	Corrected Max Towing Force for Level: lb	% of Test Weight	Soil Data, 0- to 6-in. Depth: Average Cone Index Before Traffic	Moisture Content % by Weight	Moisture Class.	Dry Density lb/cu ft
			Tested as a 4x4, Mounted with 11.00-20, 12-PR Tires (Std NDCC Tread) Test Weight 17,610 lb								
49	58	30	0			1926	10.9	104	---	Moist	--
50	59					2161	12.3	104	3.2	Moist	96.0
51	60					1710	9.7	109	---	Moist	--
52	61					1808	10.3	101	2.2	Moist	97.7
53	62					1821	10.3	105	---	Moist	--
54	63					1844	10.5	116	2.4	Moist	96.6
55	64					1973	11.2	117	---	Moist	--
56	65					2065	11.7	120	---	Moist	--
57	66					2064	11.7	106	2.4	Moist	95.7
58	67	20	0			3339	19.0	98	---	Moist	--
59	68					3275	18.6	112	2.4	Moist	97.0
60	69					3558	20.2	118	---	Moist	--
61	70					3599	20.4	116	---	Moist	--
62	71					3595	20.4	111	---	Moist	--
63	72					3418	19.4	111	2.4	Moist	95.5
64	73					3938	22.4	108	---	Moist	--
65	74	15	0			4574	26.0	106	2.2	Moist	94.6
66	75					4768	27.1	120	---	Moist	--
67	76					4431	25.2	106	---	Moist	--
68	77					4538	25.8	106	6.0	Moist	99.2
			Tested as a 4x4, Mounted with 11.00-20, 12-PR Tires (Tread Removed) Test Weight 17,610 lb								
69	27	30	0			2308	13.1	99	2.6	Moist	96.9
70	28					2641	15.0	91	---	Moist	--
71	29					2769	15.7	105	2.7	Moist	98.2
72	30					2381	13.5	100	---	Moist	--
73	31					2903	16.5	109	3.0	Moist	96.2
74	32					2409	13.7	100	---	Moist	--
75	33					2804	15.9	94	2.7	Moist	98.1
76	34					3265	18.5	107	---	Moist	--
77	35					2754	15.6	111	2.6	Moist	99.7
78	36					2698	15.3	111	---	Moist	--
79	37					2723	15.5	86	2.4	Moist	102.9
80	38	20	0			4239	24.1	113	2.3	Moist	95.0
81	39					4181	23.7	101	---	Moist	--
82	40					4731	26.9	106	---	Moist	--
83	41					4428	25.1	109	---	Moist	--
84	42					4134	23.5	100	2.7	Moist	97.0
85	43					4295	24.4	99	2.8	Moist	96.3
86	44					4579	26.0	105	---	Moist	--
87	45					4188	23.8	106	1.2	Moist	95.0
88	46					4308	24.5	96	---	Moist	--
89	47					4430	25.1	102	2.9	Moist	98.0
90	48	15	0			5200	29.5	99	---	Moist	--
91	49					5353	30.4	100	2.8	Moist	99.0
92	50					5825	33.1	111	---	Moist	--

Table 9

Summary of Data and Test Results, Truck-Trailer Combination

Maximum-Towing-Force Tests of 5-ton M52, 6x6 Truck Towing 12-ton M127A1 Semitrailer

Cape Cod Test Program, Wellfleet

Item No.	Test Area*	Test No.	Truck Tire Pressure psi	Measured Maximum Towing Force on Slopes: Slope %	Measured Maximum Towing Force on Slopes: lb	Measured Maximum Towing Force on Slopes: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected Maximum Towing Force for Level: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Content % by Weight 0- to 6-in. Depth	Moisture Class. 0- to 6-in. Depth	Dry Density lb/cu ft 0- to 6-in. Depth
1	DA	52	60**	1.5	900	4.4	1316	5.9	214	1.6	Moist	98.0
2	DA	53		1.5	0	0	335	1.5	188	---	Moist	--
3	DA	54	30**	1.0	1800	8.1	2030	9.1	213	1.6	Moist	99.4
4	DA	55		-4.0	3000	13.4	2097	9.4	168	---	Moist	--
5	DA	56		3.0	1900	8.5	2566	11.5	216	2.2	Moist	100.9
6	DA	57		-1.5	2400	10.8	2075	9.3	178	---	Moist	--
7	DA	58		0.5	1900	8.5	2008	9.0	161	1.7	Moist	102.2
8	DA	59		1.0	1500	6.7	1718	7.7	154	---	Moist	--
9	DA	60	20**	4.0	2800	12.6	3703	16.6	233	---	Moist	--
10	DA	61		0	2500	11.2	2500	11.2	156	1.5	Moist	99.8
11	DA	62		3.0	2400	10.8	3079	13.8	138	1.7	Moist	96.6
12	DA	63		-3.0	2800	12.6	2142	9.6	159	---	Moist	--
13	DA	64		0	2400	10.8	2400	10.8	169	1.7	Moist	101.1
14	DA	65		-3.0	3200	14.3	2521	11.3	157	---	Moist	--
15	DA	66		0	3500	15.7	3500	15.7	212	1.5	Moist	99.7
16	DA	67		0	3350	15.0	3350	15.0	214	---	Moist	--
17	DA	68		2.0	2800	12.6	3257	14.6	181	1.5	Moist	100.6
18	DA	69		-4.0	2600	11.7	1718	7.7	147	---	Moist	--
19	DA	106	20†	2.0	3500	15.7	3949	17.7	195	2.9	Moist	100.2
20	DA	107		-1.5	3600	16.1	3257	14.6	142	2.7	Moist	96.3
21	DA	108		2.0	3400	15.2	3837	17.2	150	---	Moist	--
22	DA	109		1.5	4000	17.9	4328	19.4	178	---	Moist	--
23	DA	110		3.5	2900	13.0	3680	16.5	150	3.3	Moist	94.2
24	DA	111		-2.0	2600	11.7	2164	9.7	123	2.6	Moist	98.1
25	DA	112		2.0	4300	19.3	4819	21.6	235	---	Moist	--
26	DA	113		2.0	4000	17.9	4440	19.9	195	---	Moist	--
27	DA	70	15**	-2.0	3200	14.3	2744	12.3	162	---	Moist	--
28	DA	71		-2.0	4000	17.9	3547	15.9	162	1.9	Moist	99.4
29	DA	72		1.0	3800	17.0	4016	18.0	196	---	Moist	--
30	DA	73		2.0	3800	17.0	4239	19.0	219	---	Moist	--
31	DA	74		1.0	3000	13.4	3213	14.4	164	1.8	Moist	99.9
32	DA	75		0	3300	14.8	3300	14.8	249	---	Moist	--
33	DA	76		5.0	2750	12.3	3860	17.3	216	2.1	Moist	99.3
34	DA	77		1.5	3400	15.2	3726	16.7	168	---	Moist	--
35	BS	86	15†	0	1250	5.6	1250	5.6	81	---	Moist	--
36	BS	87		1.0	1200	5.4	1428	6.4	85	---	Moist	--
37	BS	88		-3.0	1000	4.5	335	1.5	61	8.4	Moist	103.9
38	BS	89		0	100	0.4	100	0.4	38	4.3	Moist	98.9
39	BS	90		1.0	1100	4.9	1316	5.9	69	---	Moist	--
40	BS	91		0	1000	4.5	1000	4.5	72	3.5	Moist	95.9
41	BS	92		0	500	2.2	500	2.2	53	---	Moist	--
42	BS	93		0	50	0.2	50	0.2	60	---	Moist	--

Note: Percent maximum towing force computed on basis of truck weight of 22,310 lb. Test weight of trailer, 10,400 lb.

* See "Beach Terms" under "Definitions" in text.

** Trailer at 60 psi.

† Trailer at 15 psi.

Table 10

Summary of Data and Test Results, Tests on Gravel Beaches

Single Self-propelled (Slope Climbing) and Maximum-Towing-Force Tests with Wheeled Vehicles

Cape Cod Test Program, Duxbury

Item No.	Test Area*	Test No.**	Slope %	Tire Pressure psi	Immobilized	Measured Maximum Towing Force on Slopes: Slope %	Measured Maximum Towing Force on Slopes: lb	Measured Maximum Towing Force on Slopes: % of Test Weight	Corrected Maximum Towing Force for Level: lb	Corrected Maximum Towing Force for Level: % of Test Weight	Average Cone Index 0- to 6-in. Depth Before Traffic	Moisture Class. 0- to 6-in. Depth
					Slope-Climbing Tests							
					3/4-ton M37, 4x4 Truck, Test Weight 6,187 lb							
1	BS	155	17	30	Yes						188+	Dry
2	BS	156	13		No						188+	Dry
3	BS	158	19		Yes						188+	Dry
4	BS	159	12		No						188+	Dry
5	BS	175	11		No						171+	Dry
6	BS	182	13		No						---	Dry
7	BS	188	21		Yes						153+	Moist
8	BS	189	11		No						147+	Moist
9	BS	200	17.5		Yes						---	Dry
10	BS	160	10.5	15	No						188+	Dry
11	BS	164	20		Yes						---	Dry
12	BS	165	12		No						---	Dry
13	BS	167	9.5		No						---	Dry
14	BS	174	11.5		No						171+	Dry
15	BS	179	13.5		No						---	Dry
16	BS	198	18		No						---	Dry
17	BS	202	20.5		Yes						---	Dry
					2-1/2-ton M135, 6x6 Truck, Test Weight 12,700 lb							
18	BS	153	17	30	Yes							Dry
19	BS	154	8.5		No							Dry
20	BS	157	24		Yes							Dry
21	BS	176	13.5		No							Dry
22	BS	180	13.5		No							Dry
23	BS	201	17.5		Yes							Dry
24	BS	163	10	15	No							Dry
25	BS	166	7.5		No							Dry
26	BS	173	12		No							Dry
27	BS	181	13		No							Dry
28	BS	199	21.5		Yes							Dry
29	BS	203	24		Yes							Dry
					Towing Tests							
					3/4-ton M37, 4x4 Truck, Test Weight 6,187 lb							
30	BS	162		30		0	700	11.3	700	11.3	---	Dry
31	BS	169				0	600	9.7	600	9.7	---	Dry
32	BS	177				0	500	8.1	500	8.1	171+	Dry
33	BS	183				0	700	11.3	700	11.3	---	Dry
34	BS	187				0.5	450	7.3	483	7.8	69	Dry
35	FS	190				0.5	800	12.9	829	13.4	150+	Moist
36	FS	192				2.0	800	12.9	922	14.9	---	Moist
37	BS	194				4.5	400	6.5	681	11.0	---	Dry
38	BS	195				3.0	450	7.3	637	10.3	---	Dry
39	BS	161		15		0	1200	19.4	1200	19.4	---	Dry
40	BS	168				0	1000	16.2	1000	16.2	---	Dry
41	BS	178				0	1000	16.2	1000	16.2	171+	Dry
42	BS	184				2.0	1000	16.2	1126	18.2	---	Dry
43	BS	185				0	1000	16.2	1000	16.2	69	Dry
44	BS	186				1.0	950	15.4	1015	16.4	69	Dry
45	FS	191				0	1400	22.6	1400	22.6	150+	Moist
46	FS	193				1.0	1400	22.6	1460	23.6	---	Moist
47	BS	196				4.0	1000	16.2	1250	20.2	---	Dry
48	BS	197				1.0	900	14.5	959	15.5	---	Dry
					2-1/2-ton M135, 6x6 Truck, Test Weight 12,700 lb							
49	BS	170		15		0	1800	14.2	1800	14.2	---	Dry

* See "Beach Terms" under "Definitions" in text.

** See fig. 2 of plate 7 for soil classification of each test.

Table 11

Summary of Data and Test Results with Airoll Vehicle, Weight 19,100 lb

Lake Michigan Test Program

Item No.	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Measured Towing Force lb	Measured Towing Force % of Test Weight	Slip %	Average Cone Index 0- to 6-in. Depth Before Traffic
				Slope-Climbing Tests*				
1	26	61.5	15	Yes				25
2	24	55.5		Yes				16
3	23	51.0		No**				39
4	25	50.0		No**				24
5	22	38.5		No†				29
6	20	30.5		No†				33
7	21	28.5		No†				43
8	41	20.5		No†				58
9	19	19.5		No††				65
10	40	18.5		No††				53
11	27	16.5		No††				52
12	38	62.5	10	Yes				44
13	31	59.0		Yes				16
14	37	57.5		No**				47
15	64	56.5		Yes				23
16	71	54.5		Yes				30
17	67	53.0		Yes				21
18	36	49.0		No†				48
19	30	46.5		No†				16
20	39	45.5		No†				45
21	29	44.5		No†				25
22	70	41.5		No†				37
23	28	37.5		No†				23
24	63	35.5		No†				56
25	66	27.5		No†				57
26	62	26.0		No†				60
27	69	24.0		No†				70
28	32	22.0		No†				68
29	34	21.5		No†				25
30	65	21.5		No††				69
31	68	21.5		No††				83
32	33	20.5		No††				95
33	61	18.5		No††				71
34	35	18.5		No††				89
35	75	54.5	5	Yes				27
36	89	49.0		Yes				24
37	86	47.5		Yes				81
38	88	47.5		Yes				24
39	82	45.5		Yes				58
40	74	33.5		No**				53
41	77	31.5		No†				75
42	83	31.5		No†				83
43	87	29.5		No†				82
44	73	27.5		No†				59
45	76	27.5		No††				80
46	84	27.5		No††				73
47	72	25.0		No††				67
48	85	24.0		No††				100
49	90	24.0		No††				47
50	91	13.0		No††				50
				Drawbar Pull-Slip Tests‡				
51	78		5		9500	49.7	50	64
52	78				7500	39.3	28	
53	78				6000	31.4	1	
54	78				5000	26.2	-6	
55	78				4750	24.9	-8	
56	78				4500	23.6	-17	
57	78				4250	22.3	-52	
58	78				4000	20.9	-80	
59	79		5		9500	49.7	100	63
60	79				7500	39.3	9	
61	79				6250	32.7	-6	
62	79				2500	13.1	-90	
63	79				750	3.9	-97	

Note: Sand classified as dry to moist; moisture contents, 1.5 to 3.0% dry weight.
* Dune area.
** Moved forward with difficulty, stationary-wheel track action.
† Moved forward easily, stationary-wheel track action.
†† Moved forward with rolling-wheel track action.
‡ Backshore area.

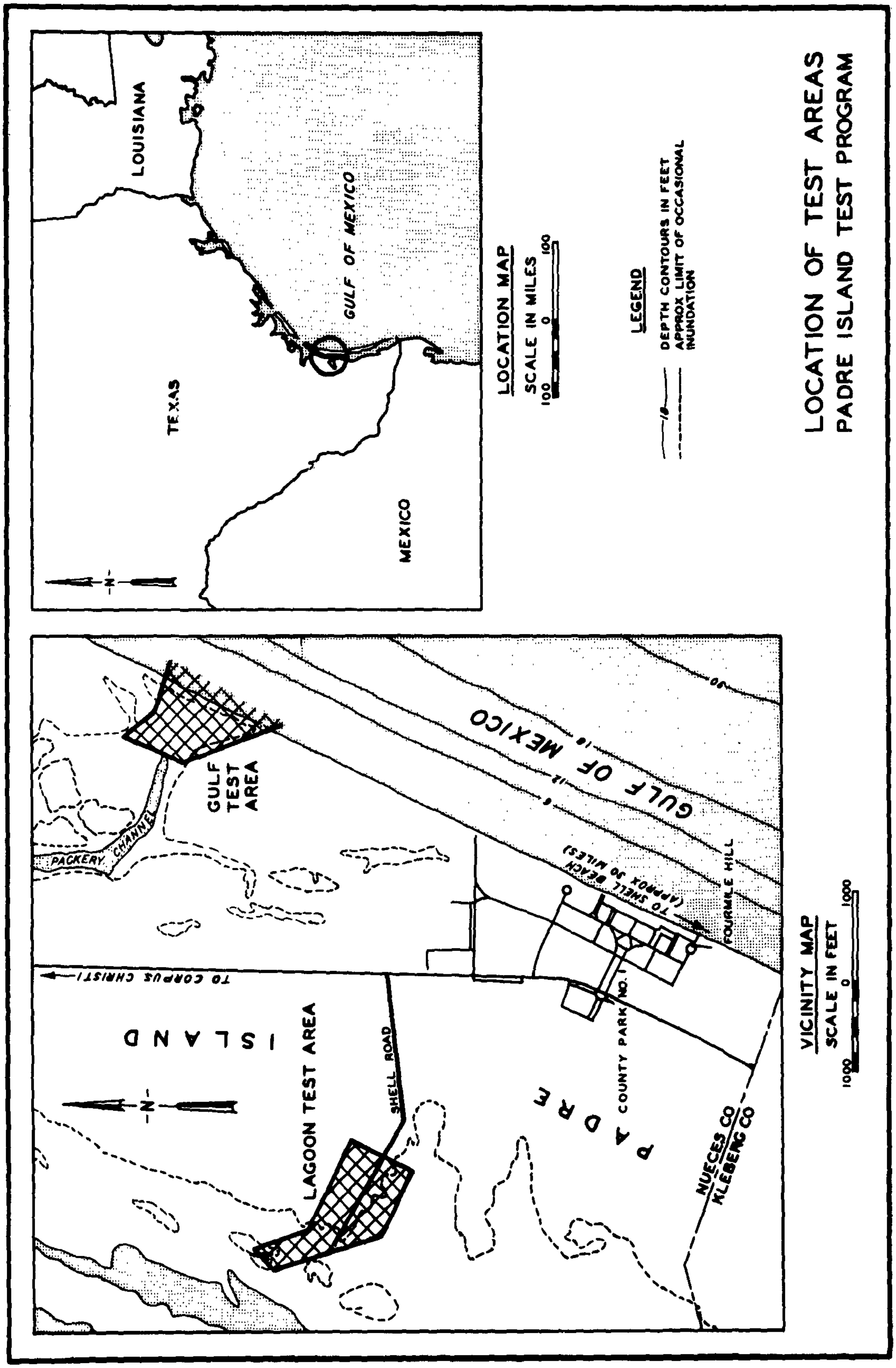
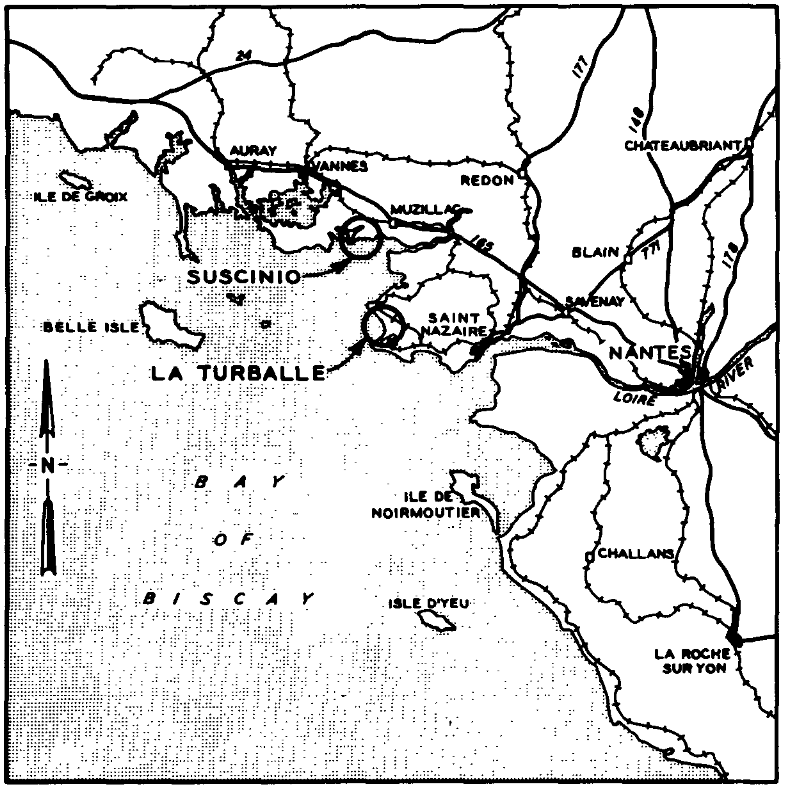

LOCATION OF TEST AREAS
PADRE ISLAND TEST PROGRAM
LOCATION MAP
SCALE IN MILES
100 0 100
LEGEND
DEPTH CONTOURS IN FEET
APPROX. LIMIT OF OCCASIONAL INUNDATION
LOUISIANA
TEXAS
MEXICO
GULF OF MEXICO
N
VICINITY MAP
SCALE IN FEET
1000 0 1000
GULF TEST AREA
PACKERY CHANNEL
LAGOON TEST AREA
SHELL ROAD
TO CORPUS CHRISTI
ISLAND
PADRE
COUNTY PARK NO. 1
TO SHELL BEACH (APPROX 30 MILES)
FOURMILE HILL
NUECES CO
KLEBERG CO

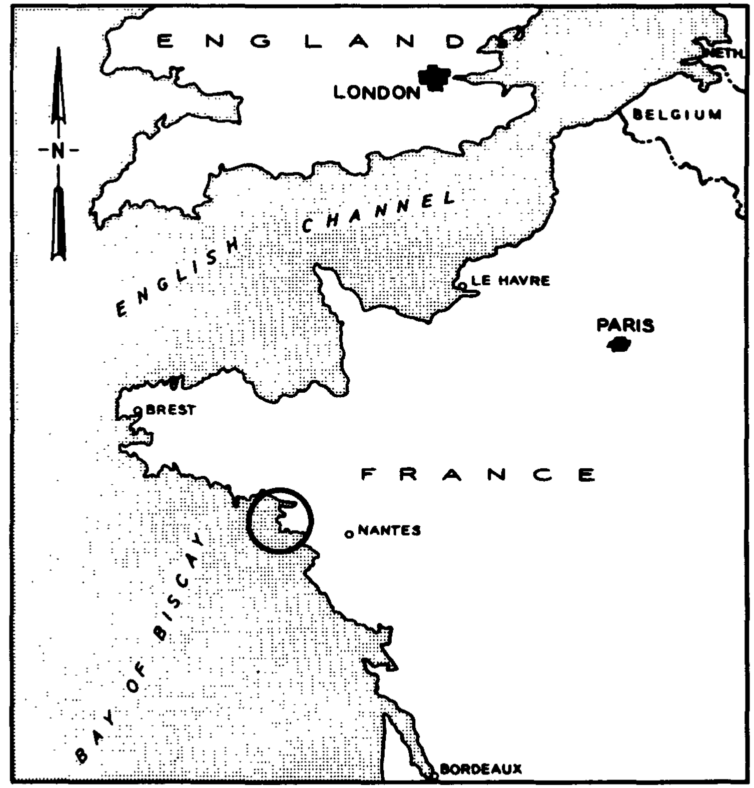
PLATE I



VICINITY MAP

SCALE IN MILES

10 0 10 20 30 40



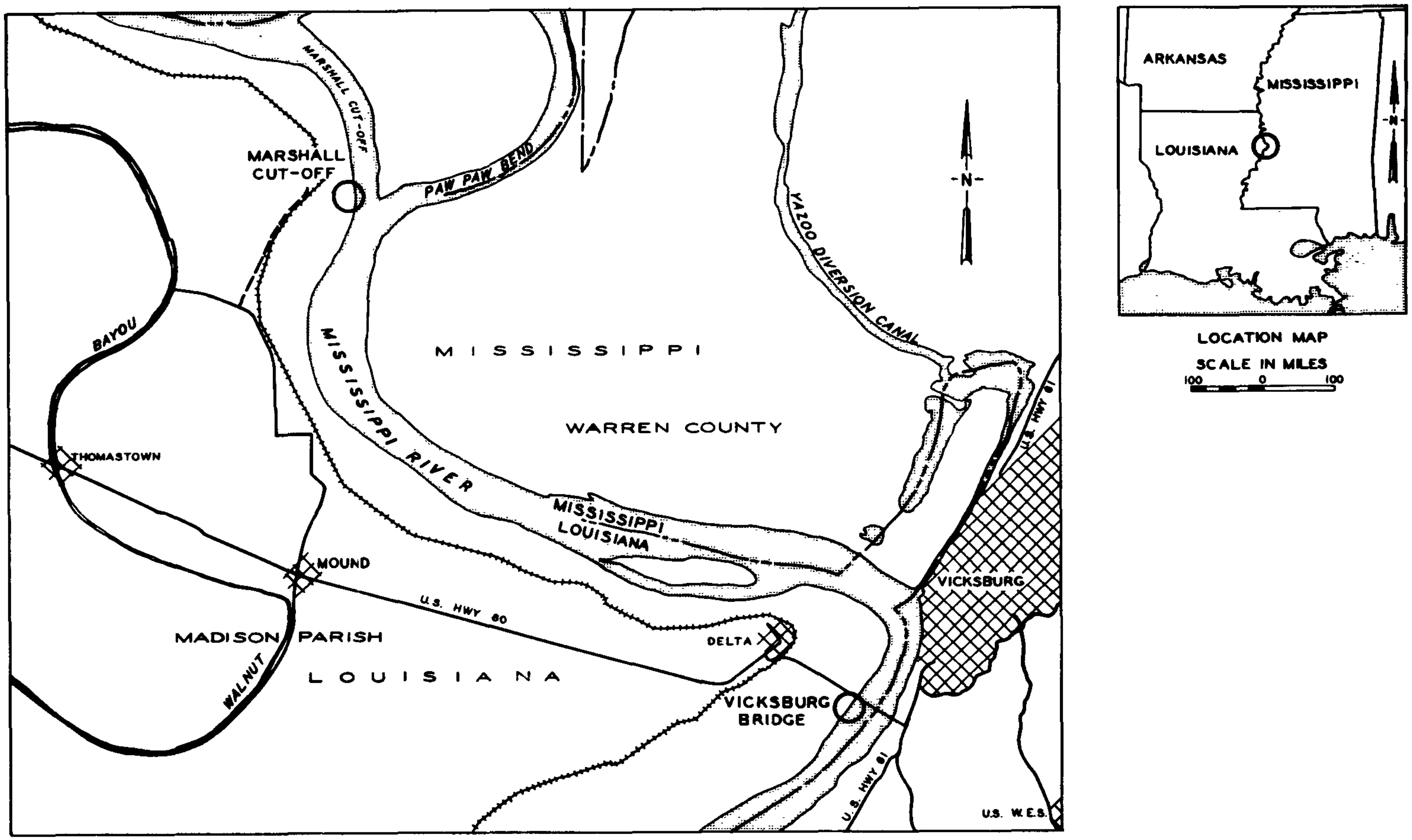
LOCATION MAP

SCALE IN MILES

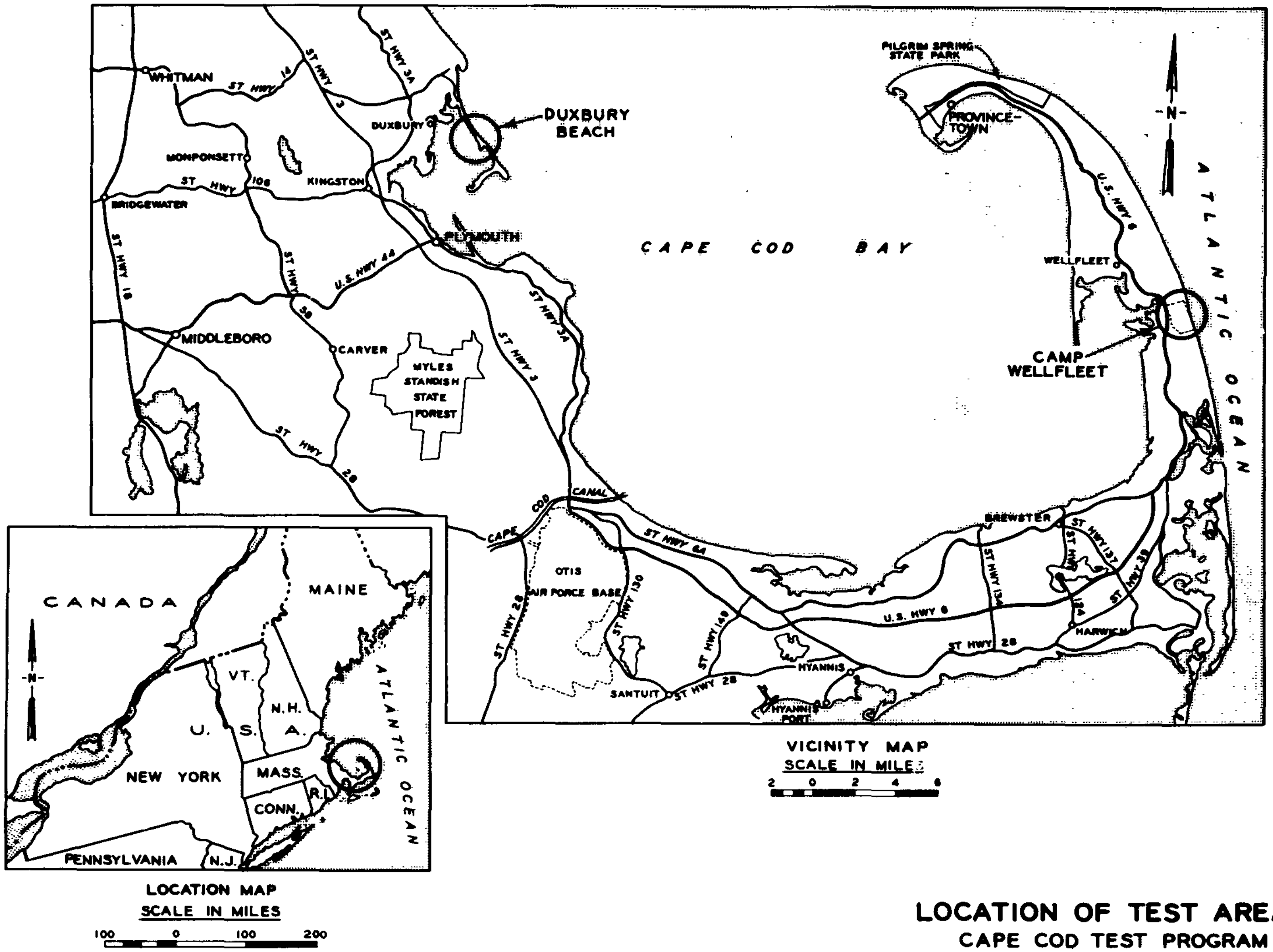
50 0 50 100 150

LOCATION OF TEST AREAS
FRANCE TEST PROGRAM

PLATE 2

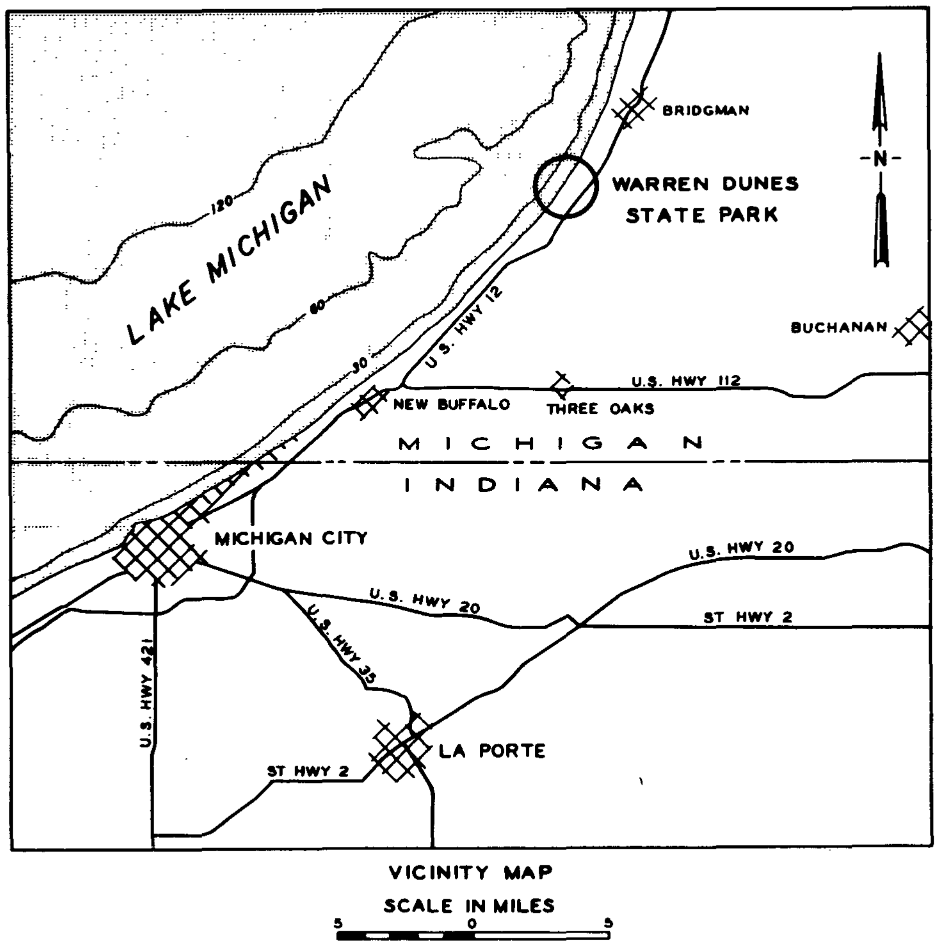


LOCATION OF TEST AREAS
MISSISSIPPI RIVER TEST PROGRAM

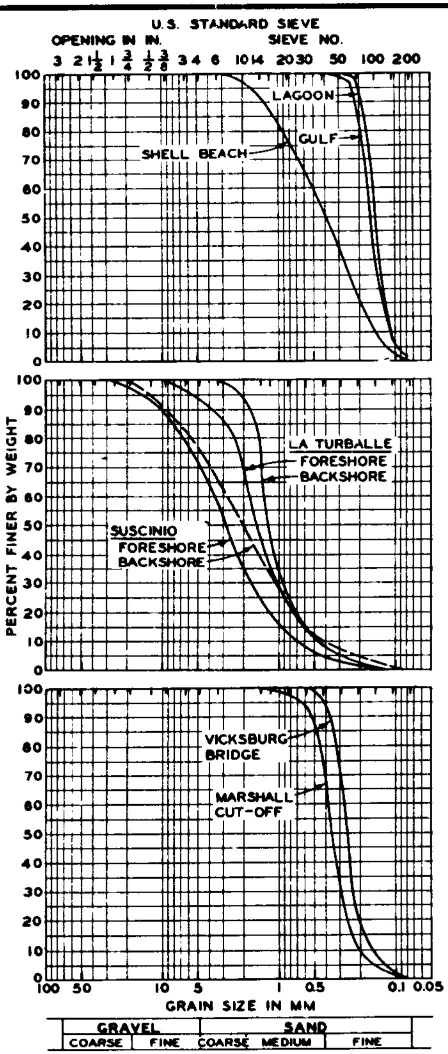


LOCATION OF TEST AREAS
CAPE COD TEST PROGRAM

PLATE 4



LOCATION OF TEST AREA
LAKE MICHIGAN TEST PROGRAM



TEST LOCATION*	DEPTH IN.	MECHANICAL ANALYSIS IN PERCENT ** COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	NAME
GULF FORESHORE	0-6	-	-	-	-	0	98	2	SP	FINE SAND
LAGOON AREA	6-12	-	-	-	-	0	98	2	SP	FINE SAND
SHELL BEACH	0-6	-	-	0	2	46	52	0	SP	MEDIUM TO FINE SAND

FIG. 1. PADRE ISLAND TEST PROGRAM

TEST LOCATION*	DEPTH IN.	MECHANICAL ANALYSIS IN PERCENT ** COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	NAME
LA TURBALLE										
FORESHORE	0-6	-	0	6	24	62	8	0	SP	COARSE TO MEDIUM SAND
BACKSHORE	0-6	-	-	0	6	86	8	0	SP	MEDIUM SAND
SUSCINIO										
FORESHORE	0-6	0	2	27	36	30	5	0	SW	GRAVELLY SAND
BACKSHORE	0-6	0	1	24	24	40	11	0	SW	GRAVELLY SAND

FIG. 2. FRANCE TEST PROGRAM

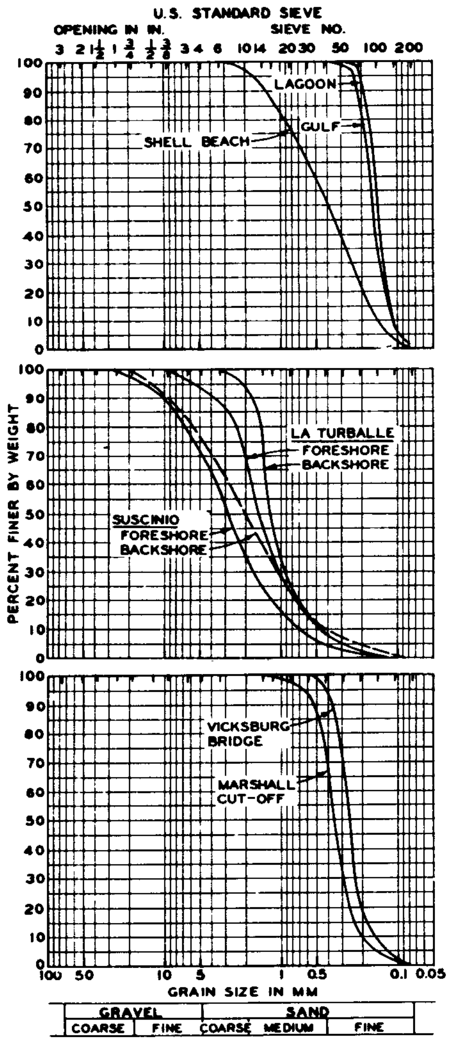
TEST LOCATION*	DEPTH IN.	MECHANICAL ANALYSIS IN PERCENT ** COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	NAME
VICKSBURG BRIDGE	0-6	-	-	-	0	4	96	0	SP	FINE SAND
MARSHALL CUT-OFF	0-6	-	-	-	0	25	75	0	SP	MEDIUM TO FINE SAND

FIG. 3. MISSISSIPPI RIVER TEST PROGRAM

NOTE: * REFER TO DESCRIPTION OF TEST AREAS IN TEXT
** REFER TO DEFINITIONS IN TEXT AND TM 3-357 MARCH 1953.

GRADATION CURVES AND SUPPLEMENTARY DATA

PADRE ISLAND, FRANCE, AND MISSISSIPPI RIVER TEST PROGRAMS



TEST LOCATION*	DEPTH IN.	COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	UNIFIED SOIL CLASSIFICATION NAME
GULF FORESHORE	0-6	-	-	-	-	0	98	2	SP	FINE SAND
LAGOON AREA	6-12	-	-	-	-	0	98	2	SP	FINE SAND
SHELL BEACH	0-6	-	-	0	2	46	52	0	SP	MEDIUM TO FINE SAND

(MECHANICAL ANALYSIS IN PERCENT **)

FIG. I. PADRE ISLAND TEST PROGRAM

TEST LOCATION*	DEPTH IN.	COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	UNIFIED SOIL CLASSIFICATION NAME
LA TURBALLE										
FORESHORE	0-6	-	0	6	24	62	8	0	SP	COARSE TO MEDIUM SAND
BACKSHORE	0-6	-	-	0	6	86	8	0	SP	MEDIUM SAND
SUSCINIO										
FORESHORE	0-6	0	2	27	36	30	5	0	SW	GRAVELLY SAND
BACKSHORE	0-6	0	1	24	24	40	11	0	SW	GRAVELLY SAND

(MECHANICAL ANALYSIS IN PERCENT **)

FIG. 2. FRANCE TEST PROGRAM

TEST LOCATION*	DEPTH IN.	COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	UNIFIED SOIL CLASSIFICATION NAME
VICKSBURG BRIDGE	0-6	-	-	-	0	4	96	0	SP	FINE SAND
MARSHALL CUT-OFF	0-6	-	-	-	0	25	75	0	SP	MEDIUM TO FINE SAND

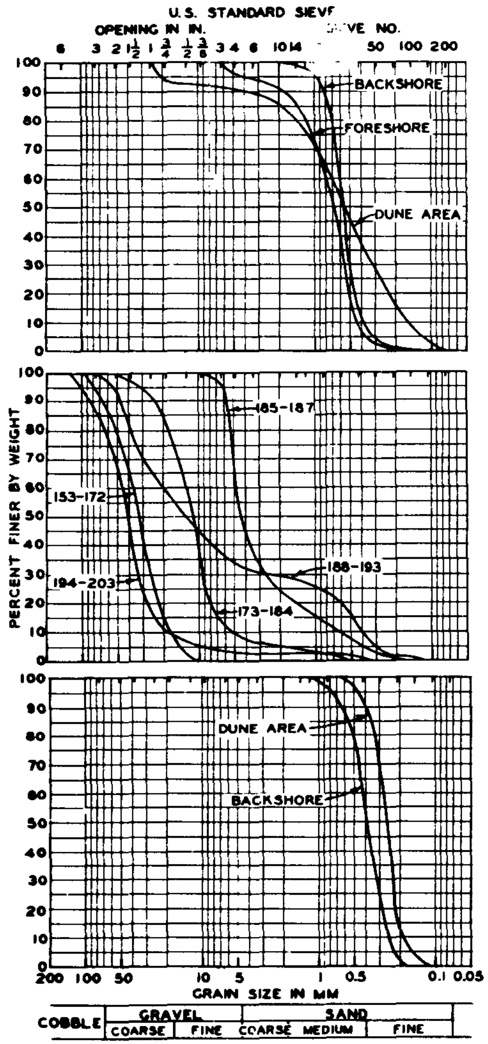
(MECHANICAL ANALYSIS IN PERCENT **)

FIG. 3. MISSISSIPPI RIVER TEST PROGRAM

NOTE: * REFER TO DESCRIPTION OF TEST AREAS IN TEXT
** REFER TO DEFINITIONS IN TEXT AND TM 3-357 MARCH 1953.

GRADATION CURVES AND SUPPLEMENTARY DATA

PADRE ISLAND, FRANCE, AND MISSISSIPPI RIVER TEST PROGRAMS



TEST LOCATION*	DEPTH IN.	MECHANICAL ANALYSIS IN PERCENT ** COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	NAME
FORESHORE	0-6	-	0	4	5	83	8	0	SP	MEDIUM SAND
BACKSHORE	0-6	-	-	-	0	85	15	0	SP	MEDIUM SAND
DUNE AREA	0-6	0	6	3	6	45	40	0	SW	GRAVELLY SAND

FIG. 1. CAMP WELLFLEET, CAPE COD TEST PROGRAM

TESTS +	DEPTH IN.	MECHANICAL ANALYSIS IN PERCENT ** COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	NAME
153 - 172	0-6	0	88	12	0	-	-	-	GP	FINE TO COARSE GRAVEL
173 - 184	0-6	0	17	74	4	5	0	-	GP	COARSE TO FINE GRAVEL
185 - 187	0-6	-	0	40	35	19	6	0	SW	GRAVELLY SAND
188 - 193	0-6	0	42	24	4	19	11	0	GP	SANDY GRAVEL
194 - 203	0-6	14	75	8	1	1	1	0	GP	COARSE GRAVEL WITH COBBLES

FIG. 2. DUXBURY BEACH, CAPE COD TEST PROGRAM

TEST LOCATION*	DEPTH IN.	MECHANICAL ANALYSIS IN PERCENT ** COBBLE	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	FINES	UNIFIED SOIL CLASSIFICATION SYMBOL	NAME
BACKSHORE	0-6	-	-	-	0	40	60	0	SP	MEDIUM TO FINE SAND
DUNE AREA	0-6	-	-	-	0	8	92	0	SP	FINE SAND

FIG. 3. LAKE MICHIGAN TEST PROGRAM

NOTE: * REFER TO DESCRIPTION OF TEST AREAS IN TEXT.
** REFER TO DEFINITIONS IN TEXT AND TM 3-357, MARCH 1953 (REVISED APRIL 1960)
+ REFER TO TABLE 10 FOR LOCATION OF EACH TEST.

GRADATION CURVES AND SUPPLEMENTARY DATA

CAPE COD AND LAKE MICHIGAN TEST PROGRAMS

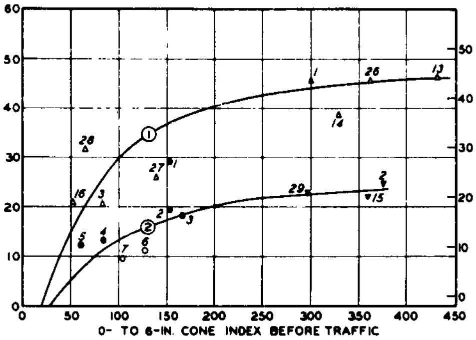


FIG. 1. 30-PSI TIRE PRESSURE

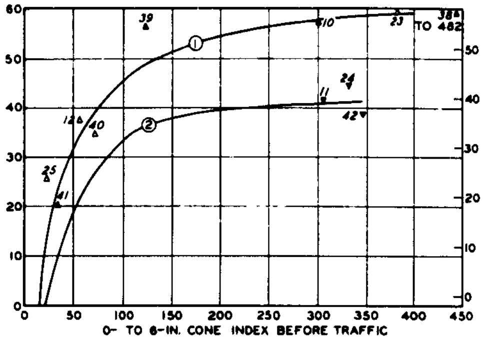


FIG. 4. 10-PSI TIRE PRESSURE

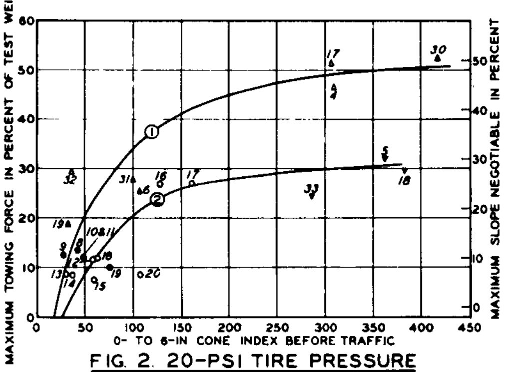


FIG. 2. 20-PSI TIRE PRESSURE

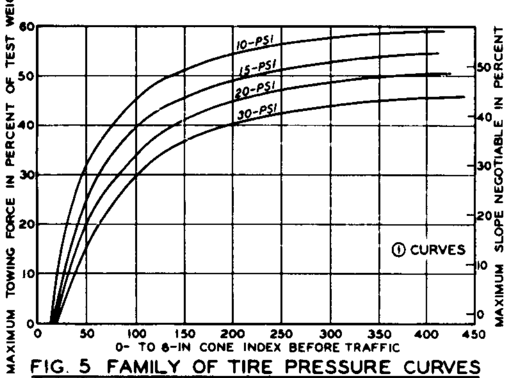


FIG. 5 FAMILY OF TIRE PRESSURE CURVES WET-TO-INUNDATED SAND

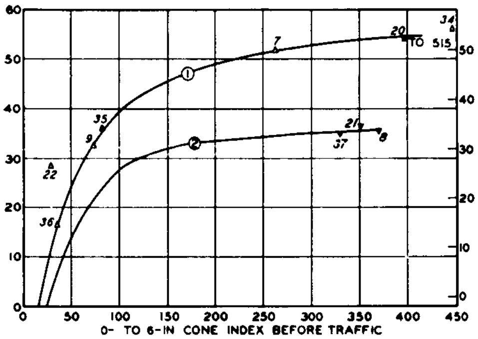


FIG. 3. 15-PSI TIRE PRESSURE

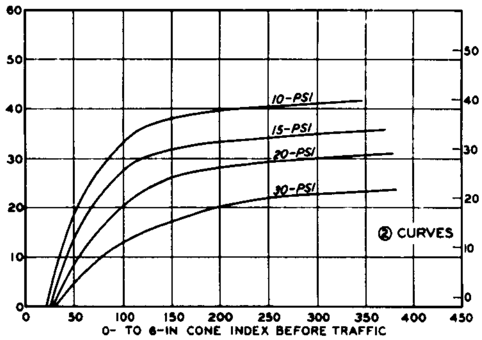


FIG. 6. FAMILY OF TIRE PRESSURE CURVES DRY-TO-MOIST SAND

LEGEND

SINGLE SELF-PROPELLED (SLOPE CLIMBING) TESTS ON DRY-TO-MOIST SAND
- ● IMMOBILIZED ON SLOPE
- O NOT IMMOBILIZED ON SLOPE

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 2

MAXIMUM TOWING FORCE TESTS
- Δ TESTS ON WET-TO-INUNDATED SAND
- ∇ TESTS ON DRY-TO-MOIST SAND

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3

PERFORMANCE CURVES
- —①— WET-TO-INUNDATED SAND
- —②— DRY-TO-MOIST SAND

NOTE: 15TH SUPPLEMENT DATA AND TEST DATA SHOWN WERE COMBINED TO DEVELOP CURVES.

SELF-PROPELLED VEHICLE PERFORMANCE

1/4-TON M38 AND M38A1 4X4 TRUCK 7.00-16 6-PR TIRES (SINGLE)

TEST WEIGHT 2625-3200 LB

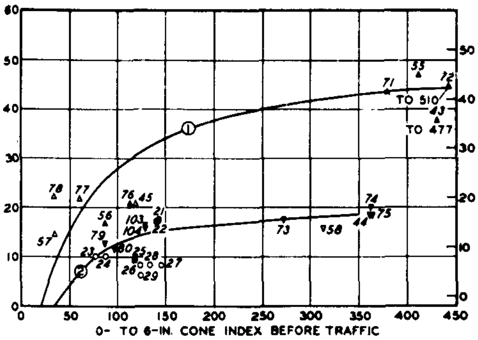


FIG. 1. 30-PSI TIRE PRESSURE

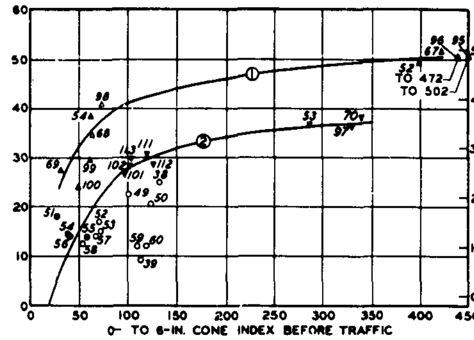


FIG. 4. 10-PSI TIRE PRESSURE

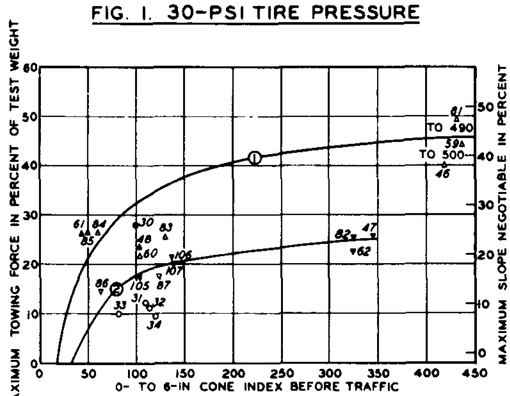


FIG. 2. 20-PSI TIRE PRESSURE

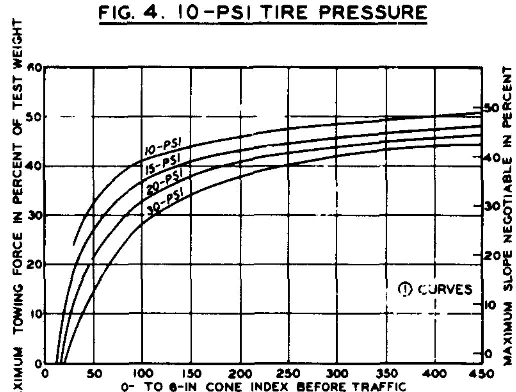


FIG. 5 FAMILY OF TIRE PRESSURE CURVES
WET-TO-INUNDATED SAND

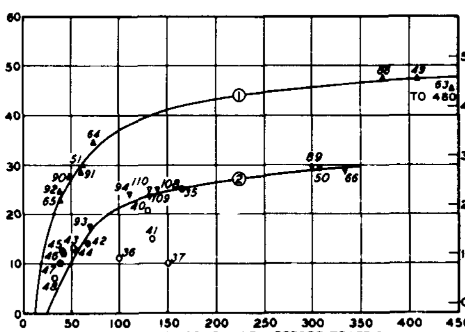


FIG. 3. 15-PSI TIRE PRESSURE

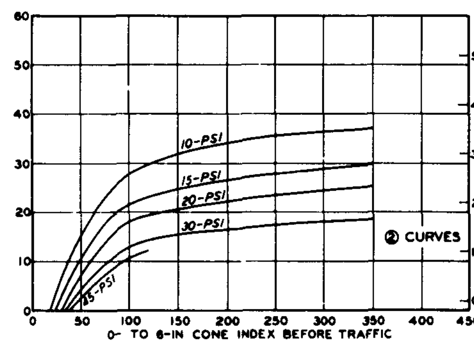


FIG. 6. FAMILY OF TIRE PRESSURE CURVES
DRY-TO-MOIST SAND

LEGEND

SINGLE SELF-PROPELLED (SLOPE CLIMBING)
TESTS ON DRY-TO-MOIST SAND
● IMMOBILIZED ON SLOPE
○ NOT IMMOBILIZED ON SLOPE
NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 2

MAXIMUM TOWING FORCE TESTS
△ TESTS ON WET-TO-INUNDATED SAND
▽ TESTS ON DRY-TO-MOIST SAND
NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3

PERFORMANCE CURVES
—①— WET-TO-INUNDATED SAND
—②— DRY-TO-MOIST SAND

NOTE: 15TH SUPPLEMENT DATA AND TEST DATA SHOWN WERE COMBINED TO DEVELOP CURVES

SELF-PROPELLED VEHICLE PERFORMANCE

$\frac{3}{4}$-TON M37 4X4 TRUCK
9.00-16 8-PR TIRES (SINGLE)

TEST WEIGHT 5687 - 7187 LB

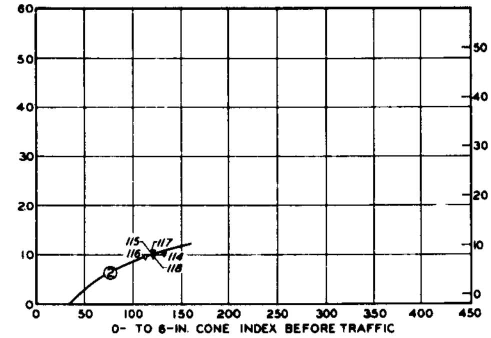


FIG. 1. 30-PSI TIRE PRESSURE

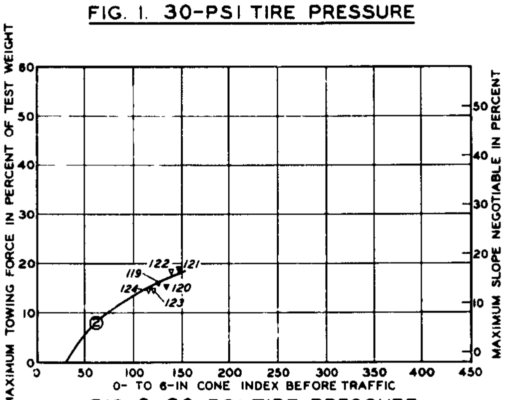


FIG. 2. 20-PSI TIRE PRESSURE

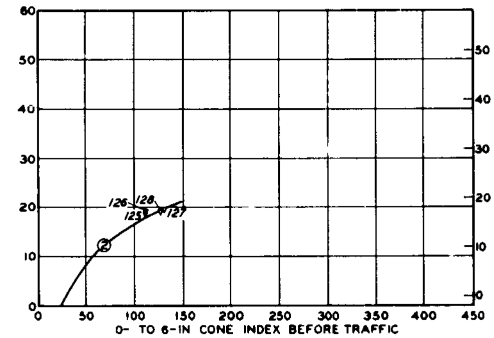


FIG. 3. 15-PSI TIRE PRESSURE

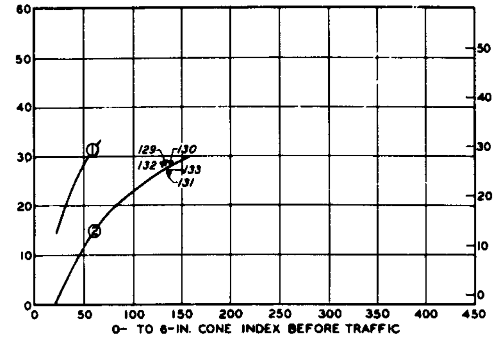


FIG. 4. 10-PSI TIRE PRESSURE

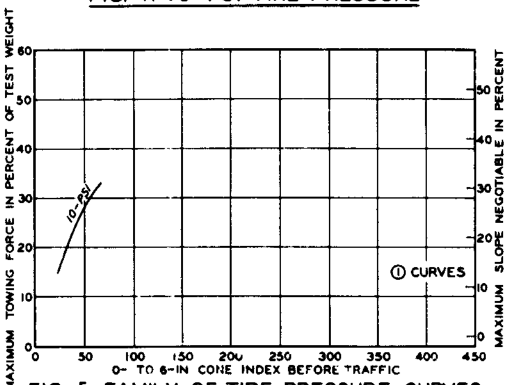


FIG. 5 FAMILY OF TIRE PRESSURE CURVES
WET-TO-INUNDATED SAND

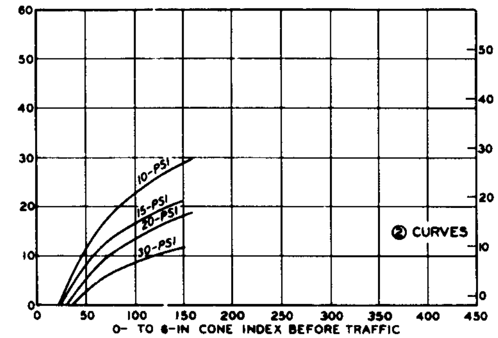


FIG. 6. FAMILY OF TIRE PRESSURE CURVES
DRY-TO-MOIST SAND

LEGEND

MAXIMUM TOWING FORCE TESTS
▼ ON DRY-TO-MOIST SAND
NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3

PERFORMANCE CURVES
—①— WET-TO-INUNDATED SAND
—②— DRY-TO-MOIST SAND

NOTE 15TH SUPPLEMENT DATA AND TEST DATA SHOWN WERE COMBINED TO DEVELOP CURVES.

SELF-PROPELLED VEHICLE PERFORMANCE

2½-TON M211 6X6 TRUCK
9.00-20 8-PR TIRES(DUAL)

TEST WEIGHT 18,470 LB

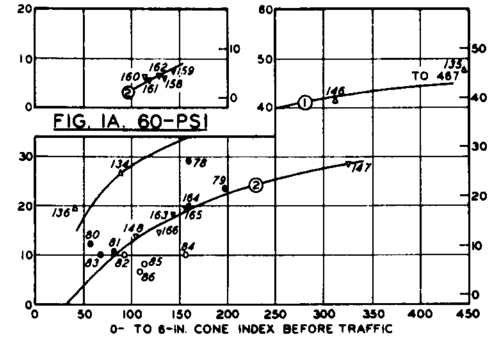


FIG. 1. 30-PSI TIRE PRESSURE

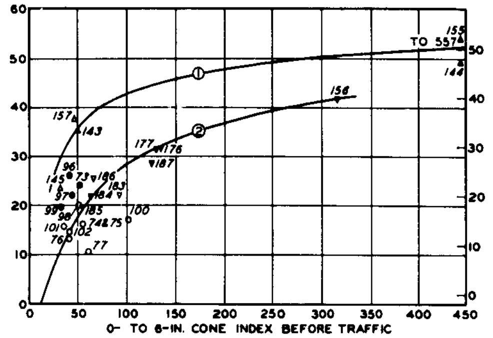


FIG. 4. 10-PSI TIRE PRESSURE

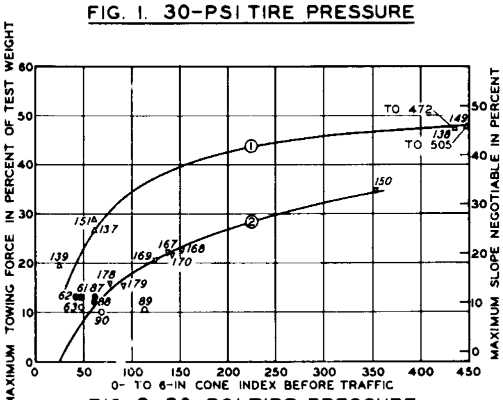


FIG. 2. 20-PSI TIRE PRESSURE

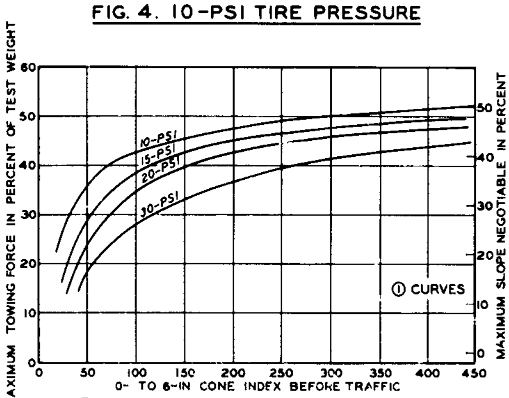


FIG. 5 FAMILY OF TIRE PRESSURE CURVES
WET-TO-INUNDATED SAND

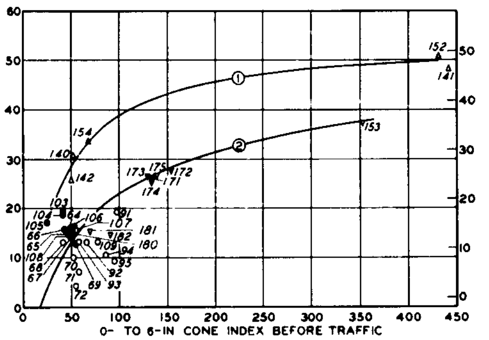


FIG. 3. 15-PSI TIRE PRESSURE

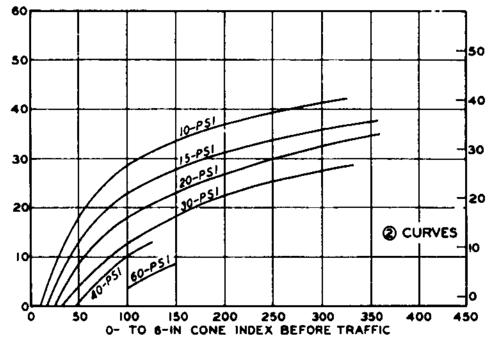


FIG. 6. FAMILY OF TIRE PRESSURE CURVES
DRY-TO-MOIST SAND

LEGEND

SINGLE SELF-PROPELLED (SLOPE CLIMBING)
TESTS ON DRY-TO-MOIST SAND
- ● IMMOBILIZED ON SLOPE
- O NOT IMMOBILIZED ON SLOPE

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 2

MAXIMUM TOWING FORCE TESTS
- Δ TESTS ON WET-TO-INUNDATED SAND
- ∇ TESTS ON DRY-TO-MOIST SAND

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3

PERFORMANCE CURVES
- —①— WET-TO-INUNDATED SAND
- —②— DRY-TO-MOIST SAND

NOTE: 15TH SUPPLEMENT DATA AND TEST DATA SHOWN WERE COMBINED TO DEVELOP CURVES.

SELF-PROPELLED VEHICLE PERFORMANCE

2½-TON M135 AND M34 6X6 TRUCKS 11.00-20 12-PR TIRES (SINGLE)

TEST WEIGHT 11,775-18,750 LB

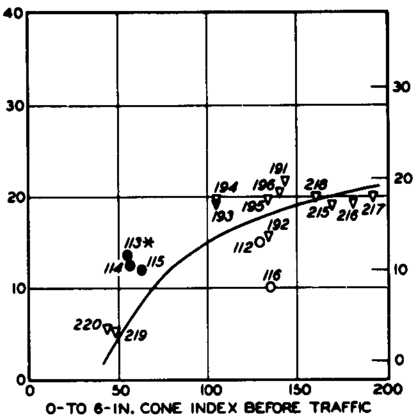


FIG. 1. 30-PSI TIRE PRESSURE

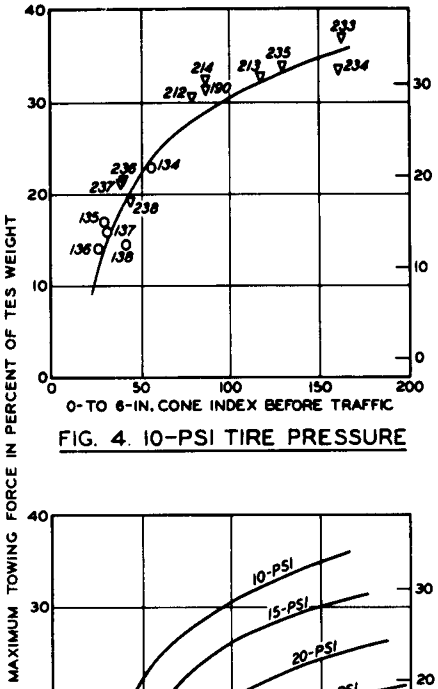


FIG. 4. 10-PSI TIRE PRESSURE

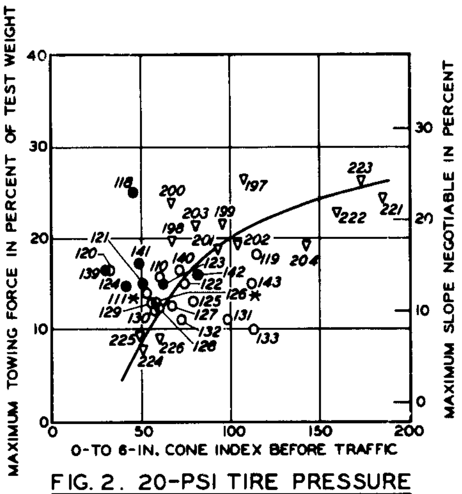


FIG. 2. 20-PSI TIRE PRESSURE

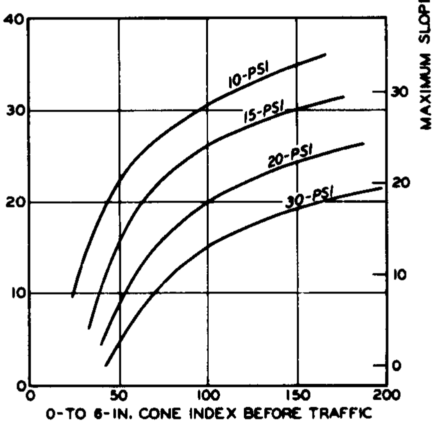


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

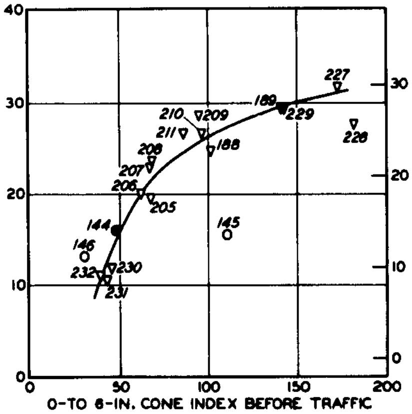


FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

O	SINGLE SELF-PROPELLED (SLOPE CLIMBING) TESTS CLOSED CIRCLES ARE IMMOBILIZATIONS. OPEN CIRCLES ARE NONIMMOBILIZATIONS. NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 2.
∇	MAXIMUM TOWING FORCE TESTS NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3.
——	PERFORMANCE CURVE
*	WET SAND TESTS

SELF-PROPELLED VEHICLE PERFORMANCE

2½-TON DUKW 353 6X6 TRUCK
11.00-18 10-PR TIRES (SINGLE)
TEST WEIGHT 14,670-19,670 LB
DRY-TO-MOIST SAND

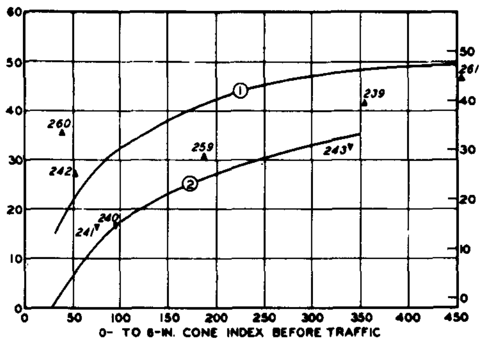


FIG. 1. 30-PSI TIRE PRESSURE

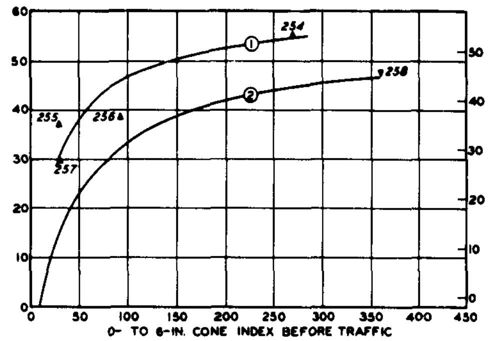


FIG. 4. 10-PSI TIRE PRESSURE

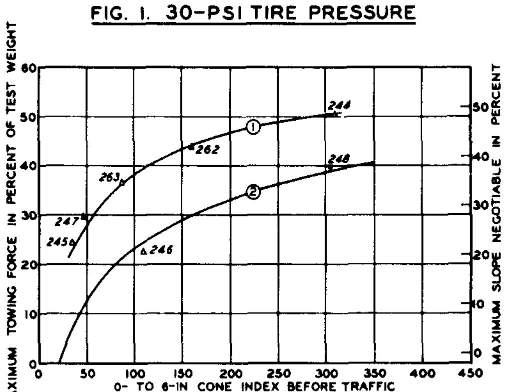


FIG. 2. 20-PSI TIRE PRESSURE

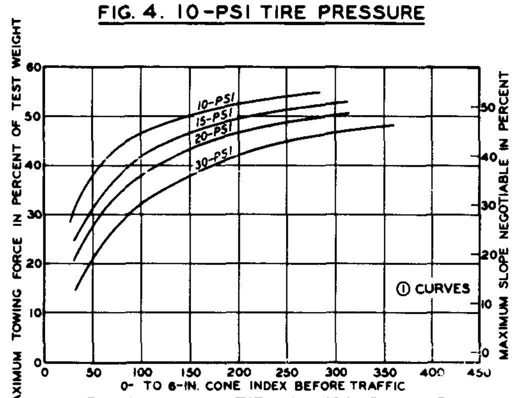


FIG. 5 FAMILY OF TIRE PRESSURE CURVES WET-TO-INUNDATED SAND

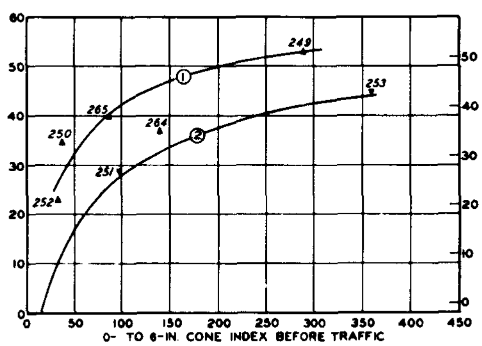


FIG. 3. 15-PSI TIRE PRESSURE

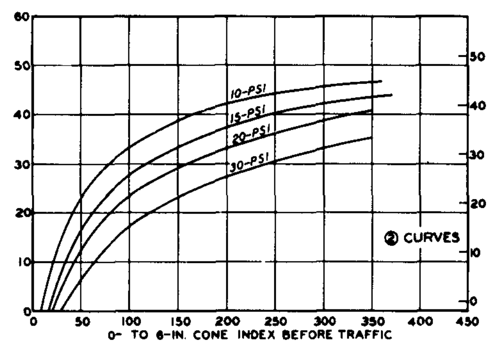


FIG. 6. FAMILY OF TIRE PRESSURE CURVES DRY-TO-MOIST SAND

LEGEND

MAXIMUM TOWING FORCE TESTS
- ▲ TESTS ON WET-TO-INUNDATED SAND
- ▼ TESTS ON DRY-TO-MOIST SAND

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3

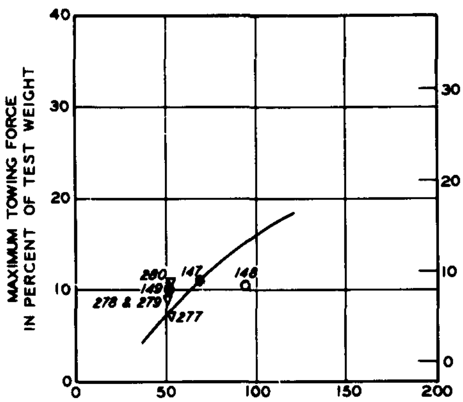
PERFORMANCE CURVES
- —①— WET-TO-INUNDATED SAND
- —②— DRY-TO-MOIST SAND

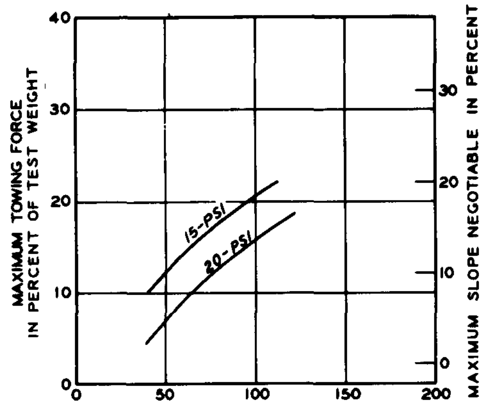
NOTE: 15TH SUPPLEMENT DATA AND TEST DATA SHOWN WERE COMBINED TO DEVELOP CURVES

SELF-PROPELLED VEHICLE PERFORMANCE

5-TON M41 6X6 TRUCK
14.00-20 12-PR TIRES (SINGLE)

TEST WEIGHT 23,070-28,170 LB





0- TO 6-IN. CONE INDEX BEFORE TRAFFIC

FIG. 1. 20-PSI TIRE PRESSURE

FIG. 3. FAMILY OF TIRE PRESSURE CURVES

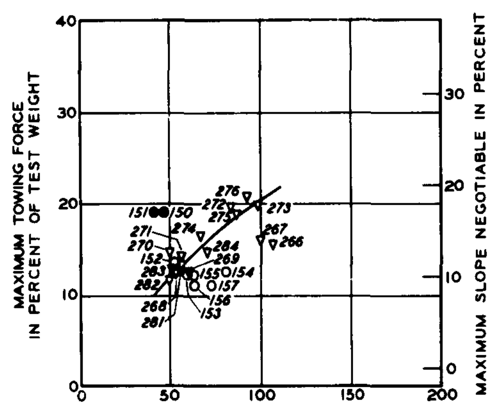


FIG. 2. 15-PSI TIRE PRESSURE

LEGEND

M51 TESTS	
O	SINGLE SELF-PROPELLED (SLOPE CLIMBING) TESTS
	CLOSED CIRCLES ARE IMMOBILIZATIONS. OPEN CIRCLES ARE NONIMMOBILIZATIONS.
	NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 2.
M52 TESTS	
∇	MAXIMUM TOWING FORCE TESTS
	NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3.
———	PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

5-TON M51 AND M52 6X6 TRUCKS
11.00-20 12-PR TIRES (DUAL)

TEST WEIGHT 18,310-32,663 LB
DRY-TO-MOIST SAND

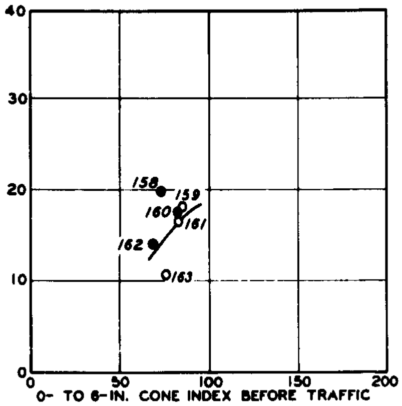


FIG. 1. 30-PSI TIRE PRESSURE

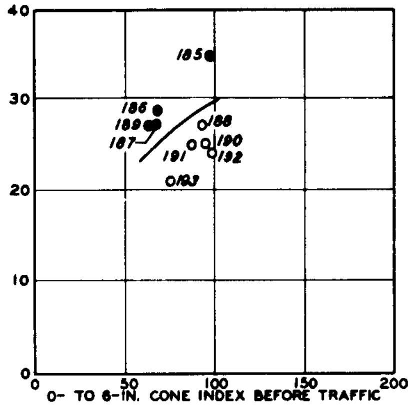


FIG. 4. 10-PSI TIRE PRESSURE

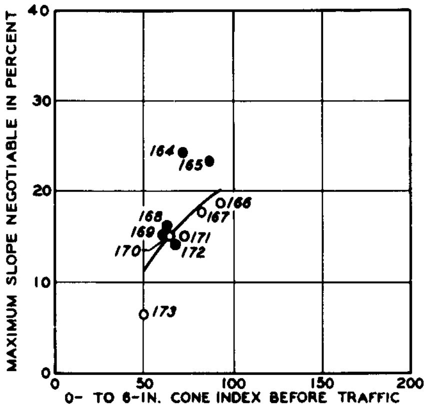


FIG. 2. 20-PSI TIRE PRESSURE

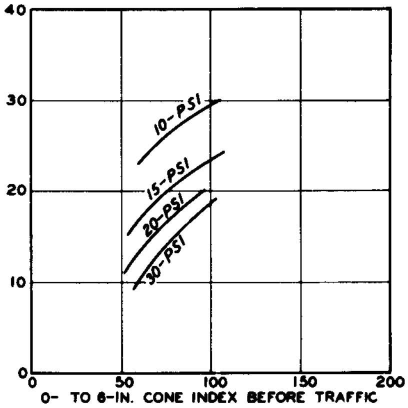


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

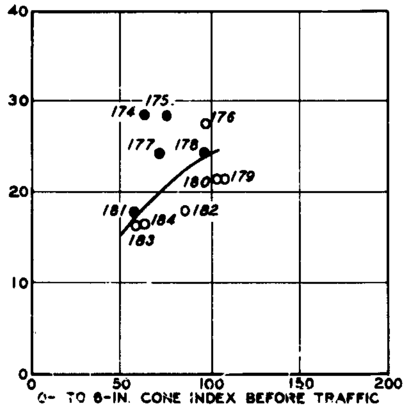


FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

SINGLE SELF-PROPELLED (SLOPE CLIMBING) TESTS

- ● IMMOBILIZED ON SLOPE
- ○ NOT IMMOBILIZED ON SLOPE

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 2

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

5-TON M704 JUMBO 4X4 TRUCK
18.00-26 10-PR TIRES (SINGLE)

TEST WEIGHT 20,100 LB
DRY-TO-MOIST SAND

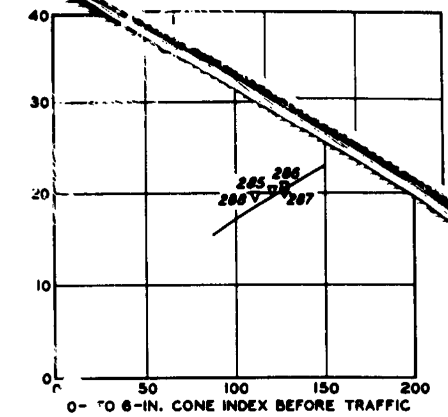


FIG. 1. 30-PSI TIRE PRESSURE

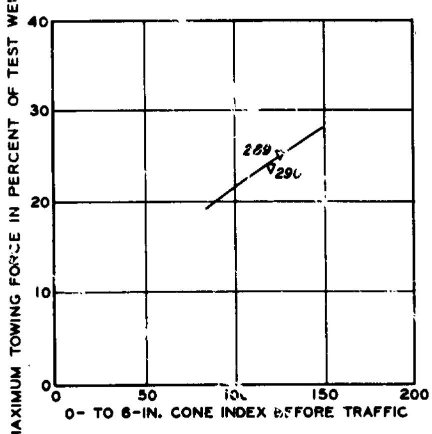


FIG. 2. 20-PSI TIRE PRESSURE

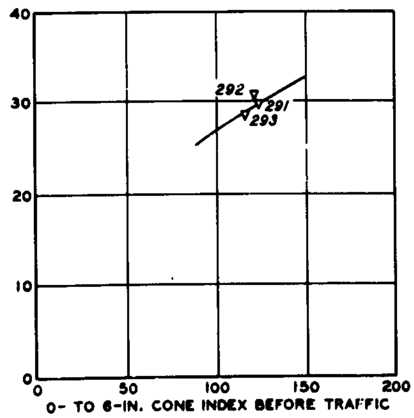


FIG. 3. 15-PSI TIRE PRESSURE

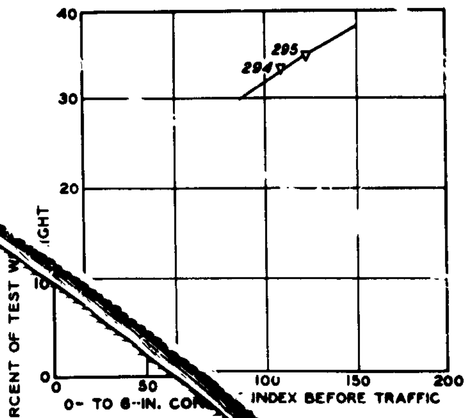


FIG. 4. 10-PSI TIRE PRESSURE

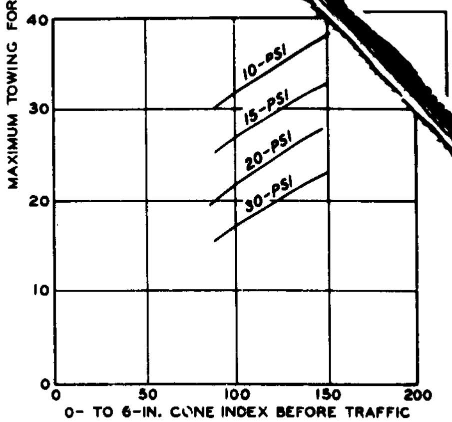


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

LEGEND

▽ MAXIMUM TOWING FORCE TESTS NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

BUCKET LOADER 4 X 4 TRACTOR
14.00-24 8-PR TIRES (SINGLE)
TEST WEIGHT 13,595 LB
DRY-TO-MOIST SAND

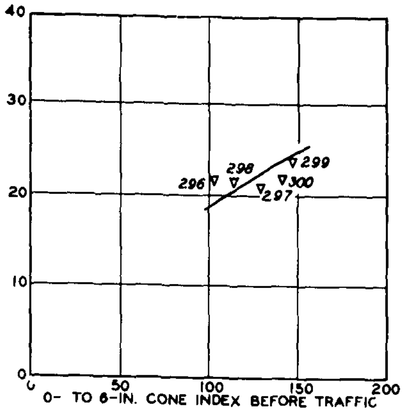


FIG. 1. 30-PSI TIRE PRESSURE

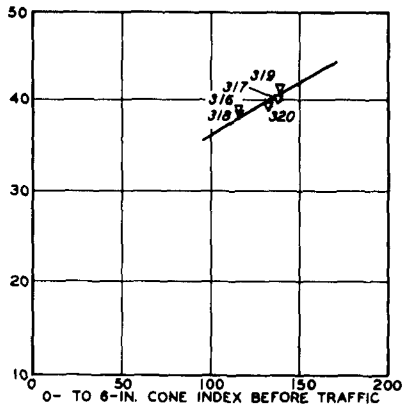


FIG. 4. 10-PSI TIRE PRESSURE

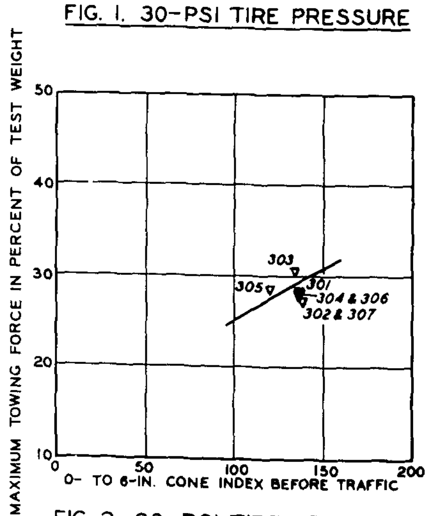


FIG. 2. 20-PSI TIRE PRESSURE

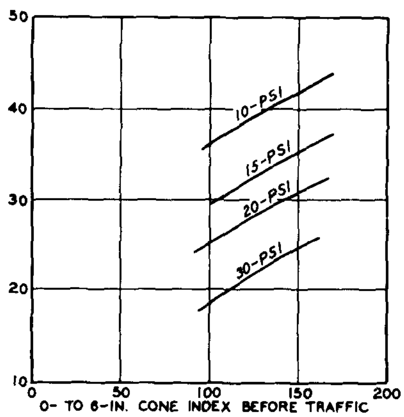


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

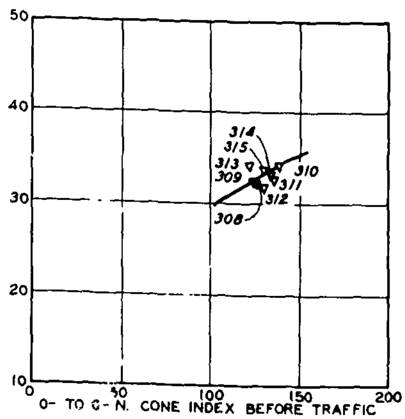


FIG. 3 15-PSI TIRE PRESSURE

LEGEND

▽ MAXIMUM TOWING FORCE TESTS

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

TOURNADOZER 4X4 TRACTOR
21.00-25 16-PR TIRES (SINGLE)

TEST WEIGHT 31,070 LB
DRY-TO-MOIST SAND

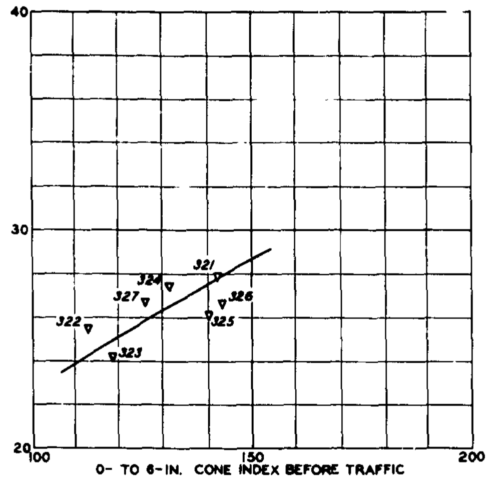


FIG. 1. 30-PSI TIRE PRESSURE

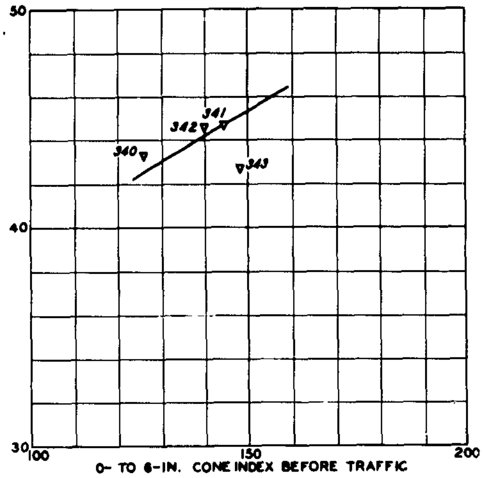


FIG. 4. 10-PSI TIRE PRESSURE

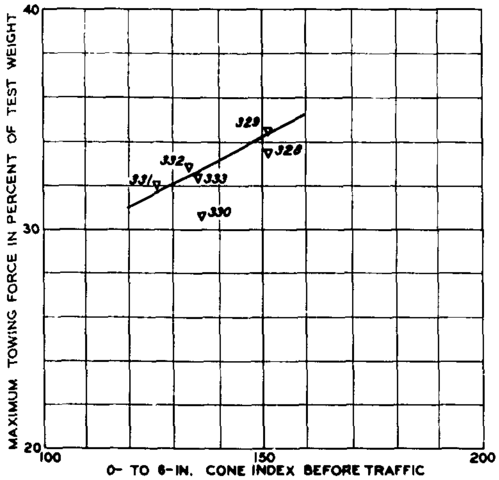


FIG. 2. 20-PSI TIRE PRESSURE

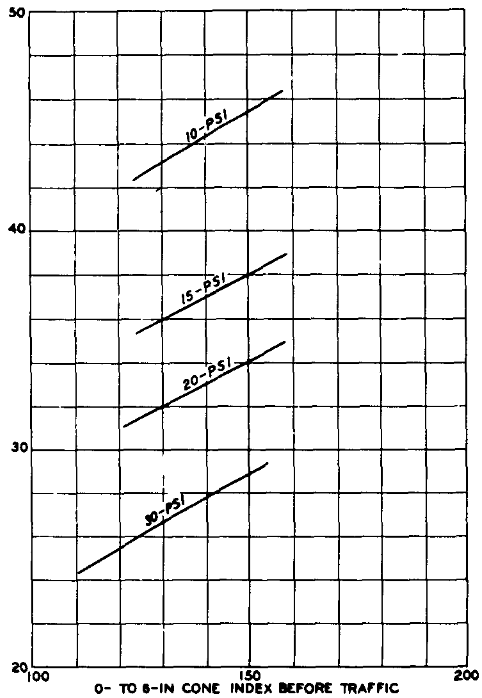


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

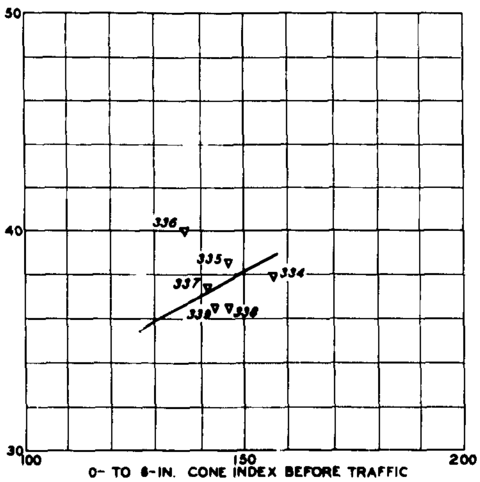


FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

▽ MAXIMUM TOWING FORCE TESTS

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3.

—— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

5-TON XM520 GOER 4X4 CARGO CARRIER
18.00-26 10-PR TIRES (SINGLE)
TEST WEIGHT 26,670 LB
DRY-TO-MOIST SAND

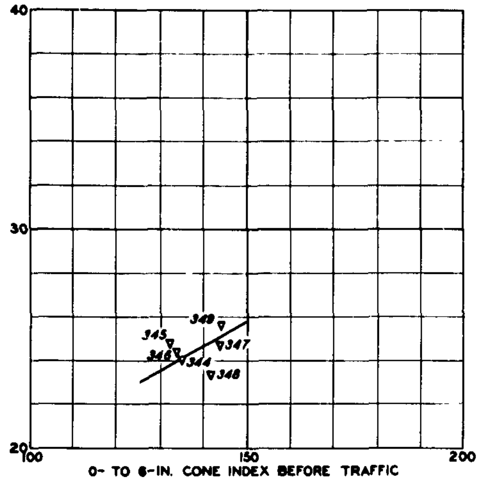


FIG. 1. 30-PSI TIRE PRESSURE

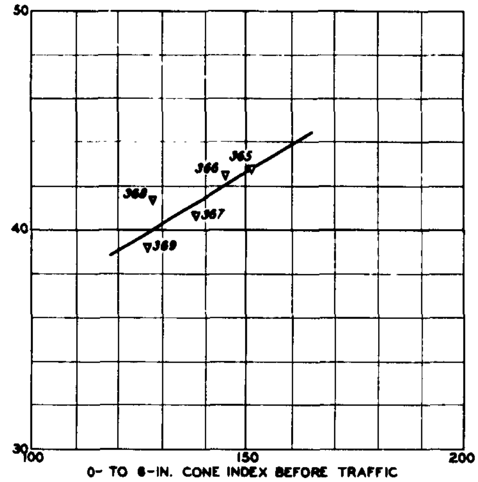


FIG. 4. 10-PSI TIRE PRESSURE

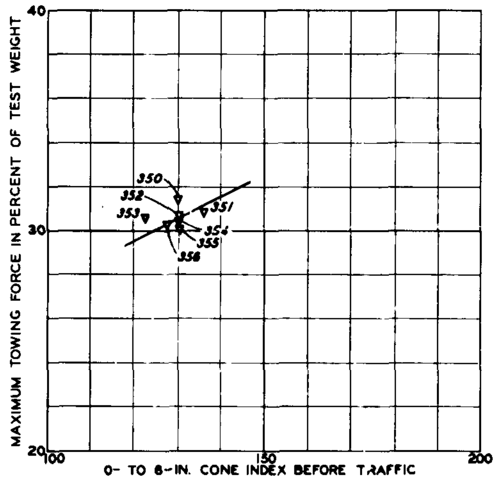


FIG. 2. 20-PSI TIRE PRESSURE

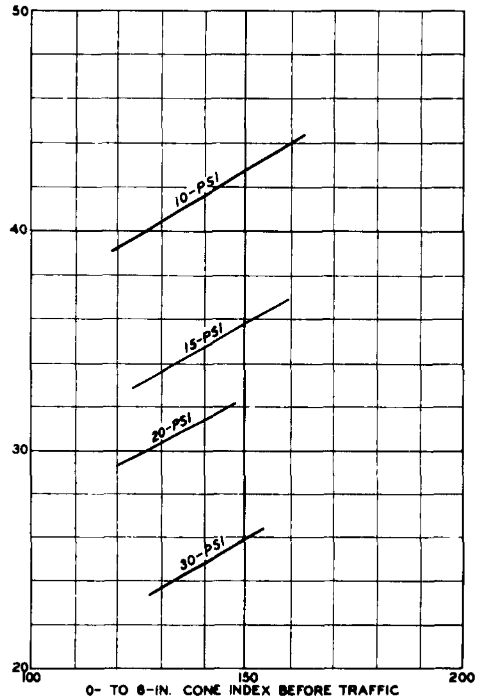


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

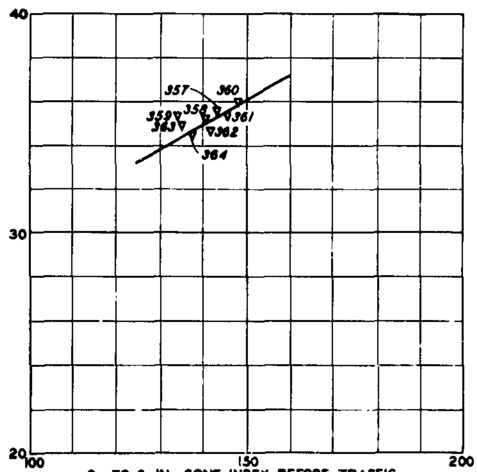


FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

▽ MAXIMUM TOWING FORCE TESTS

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 3.

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

5-TON XM520 GOER 4X4 CARGO CARRIER
15.00-34 10-PR TIRES (SINGLE)
TEST WEIGHT 26,670 LB
DRY-TO-MOIST SAND

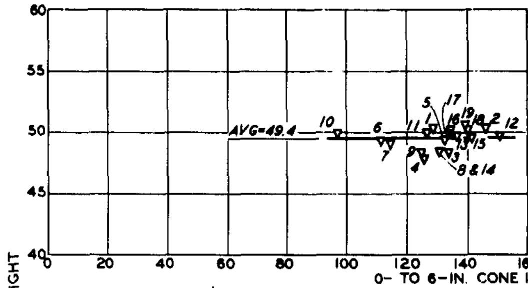


FIG. 1. ¼-TON M29C WEASEL

TEST WEIGHT 5560 LB

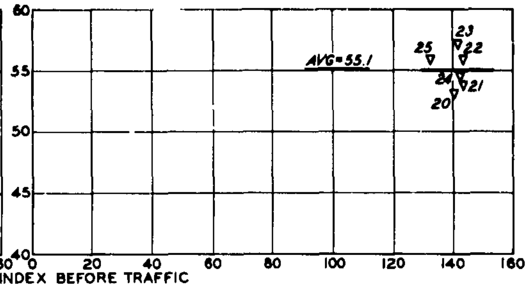


FIG. 2. STANDARD D4 ENGINEER TRACTOR

TEST WEIGHT 14,870 LB

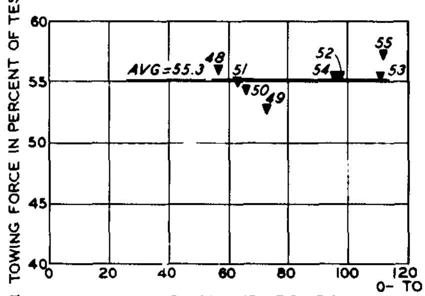


FIG. 3. STANDARD D6 ENGINEER TRACTOR

TEST WEIGHT 22,667 LB

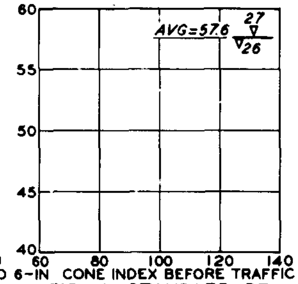


FIG. 4. STANDARD D7 ENGINEER TRACTOR

TEST WEIGHT 27,000 LB

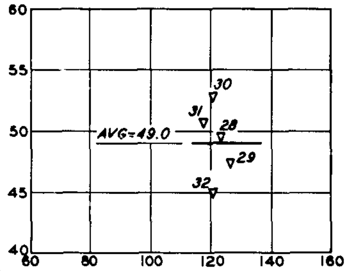


FIG. 5. 13-TON M5A4 HIGH-SPEED TRACTOR

TEST WEIGHT 25,230 LB

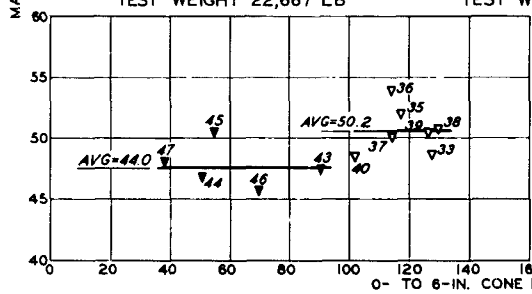


FIG. 6. 18-TON M4 HIGH-SPEED TRACTOR

TEST WEIGHT 28,700-30,250 LB

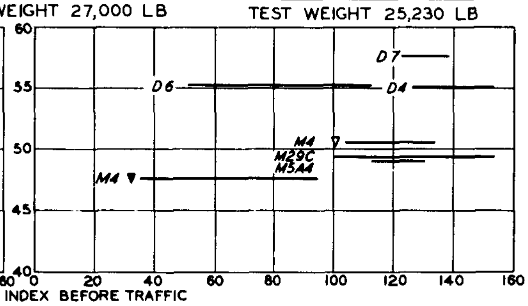


FIG. 7. FAMILY OF PERFORMANCE CURVES FOR FIVE TRACKED VEHICLES

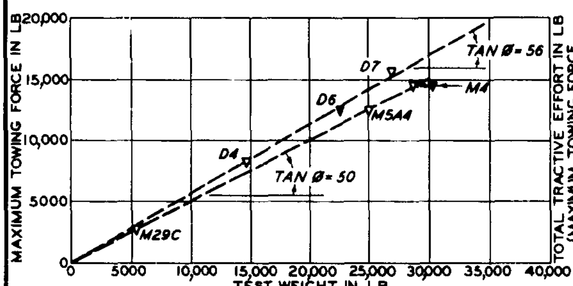


FIG. 8. COMPARISON OF TEST WEIGHT WITH MAXIMUM TOWING FORCE

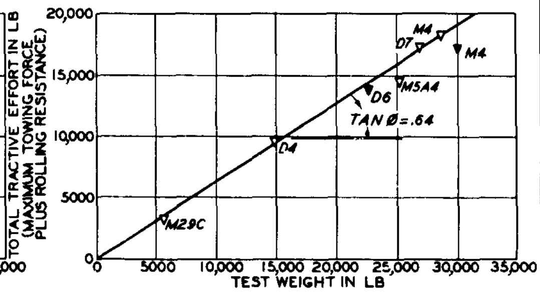


FIG. 9. COMPARISON OF TEST WEIGHT WITH TOTAL TRACTIVE EFFORT

LEGEND

- ▽ MISSISSIPPI RIVER TEST PROGRAM
- ▼ CAPE COD TEST PROGRAM

NUMBERS NEAR PLOTTED POINTS IN FIGS. 1-6 ARE ITEM NUMBERS FROM TABLE 4

SELF-PROPELLED VEHICLE PERFORMANCE

TOWING TESTS WITH TRACKED VEHICLES

DRY-TO-MOIST SAND

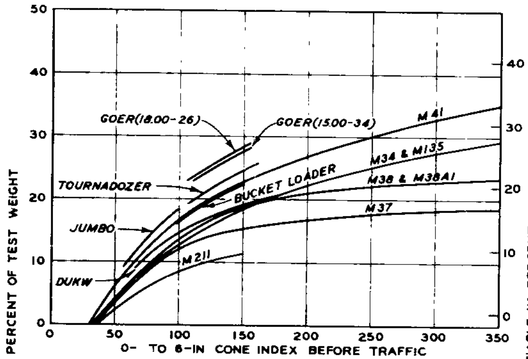


FIG. 1. WHEELED VEHICLES AT 30-PSI

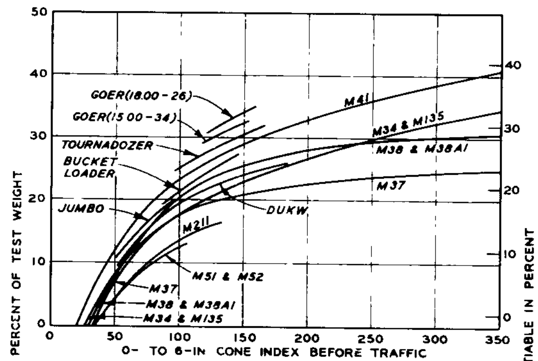


FIG. 2. WHEELED VEHICLES AT 20-PSI

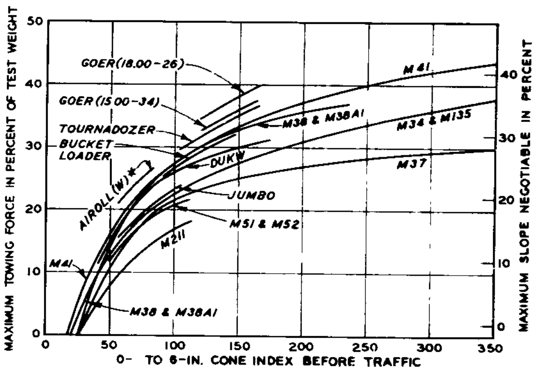


FIG. 3. WHEELED VEHICLES AT 15-PSI

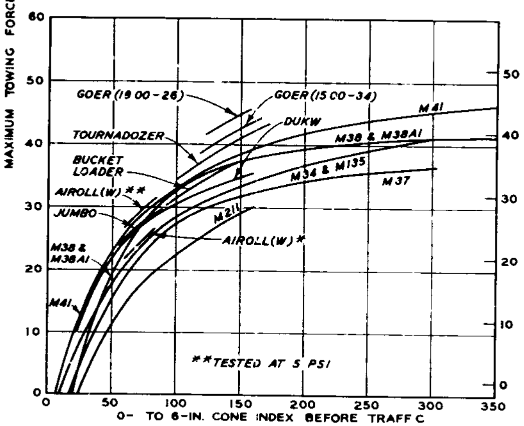


FIG. 4. WHEELED VEHICLES AT 10-PSI

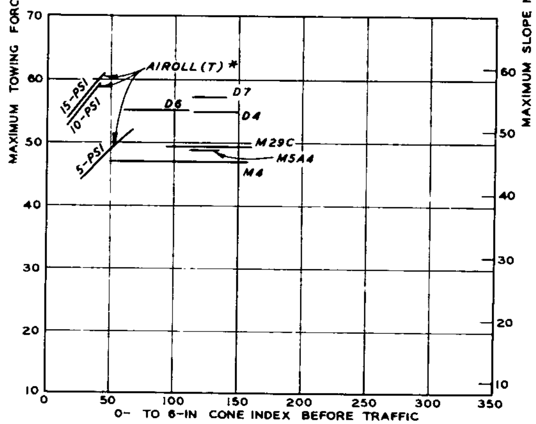
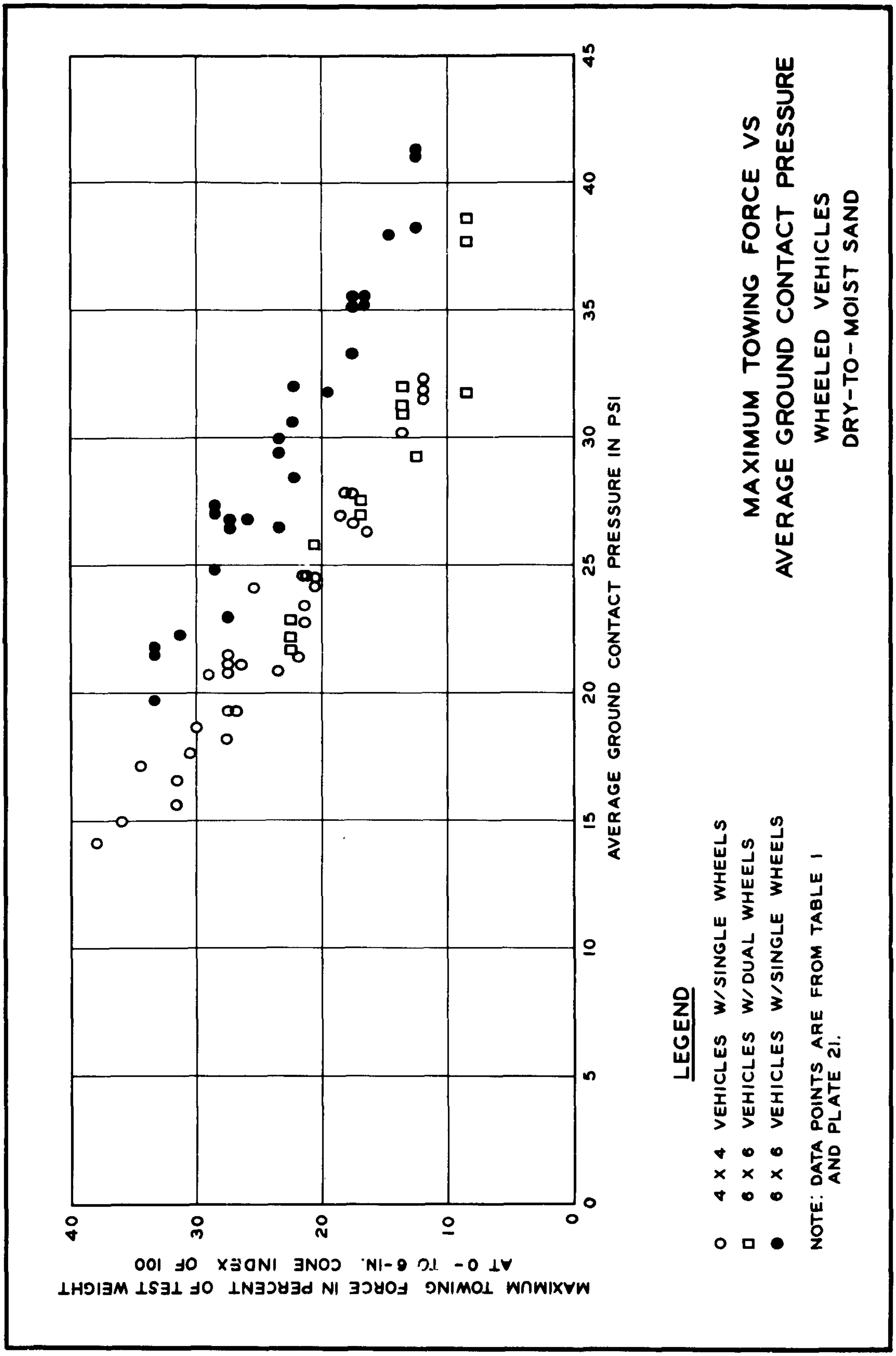


FIG 5. TRACKED VEHICLES

* AIROLL(T) DENOTES STATIONARY WHEEL TRACK ACTION
AIROLL(W) DENOTES ROLLING WHEEL TRACK ACTION

SUMMARY OF VEHICLE PERFORMANCE

DRY-TO-MOIST SAND


MAXIMUM TOWING FORCE VS
AVERAGE GROUND CONTACT PRESSURE
WHEELED VEHICLES
DRY-TO-MOIST SAND
MAXIMUM TOWING FORCE IN PERCENT OF TEST WEIGHT
AT 0- TO 6-IN. CONE INDEX OF 100
AVERAGE GROUND CONTACT PRESSURE IN PSI
0
10
20
30
40
0
5
10
15
20
25
30
35
40
45
LEGEND
4 X 4 VEHICLES W/SINGLE WHEELS
6 X 6 VEHICLES W/DUAL WHEELS
6 X 6 VEHICLES W/SINGLE WHEELS
NOTE: DATA POINTS ARE FROM TABLE 1
AND PLATE 21.

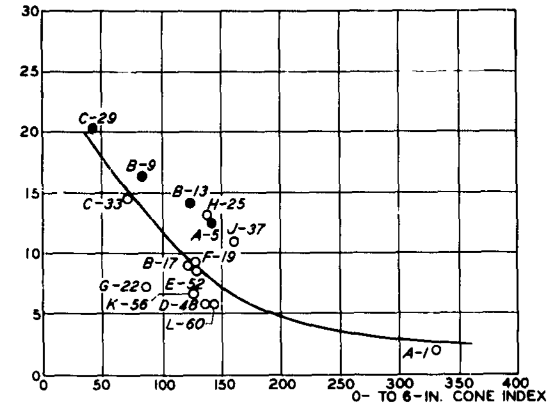


FIG. 1. 30-PSI TIRE PRESSURE

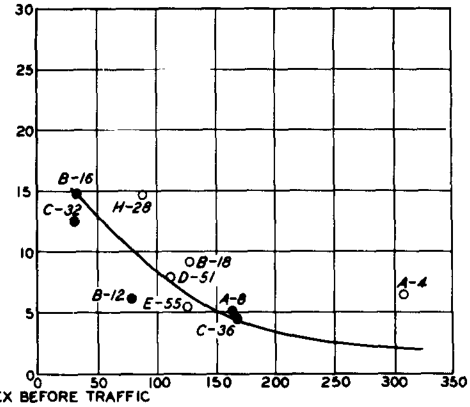


FIG. 4. 10-PSI TIRE PRESSURE

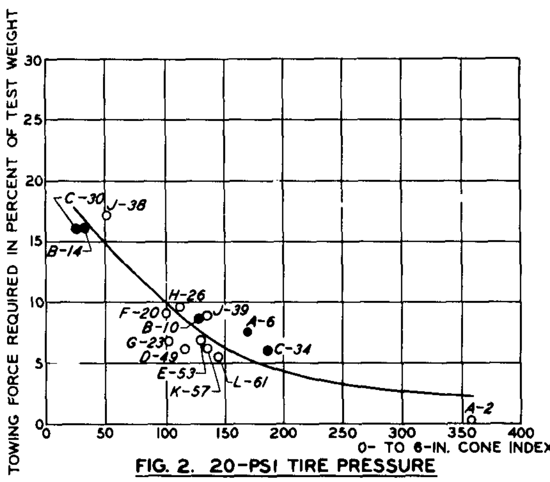


FIG. 2. 20-PSI TIRE PRESSURE

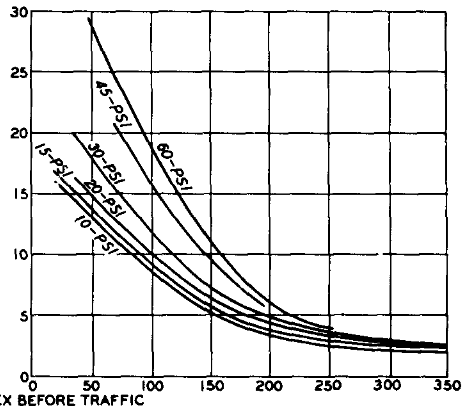


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

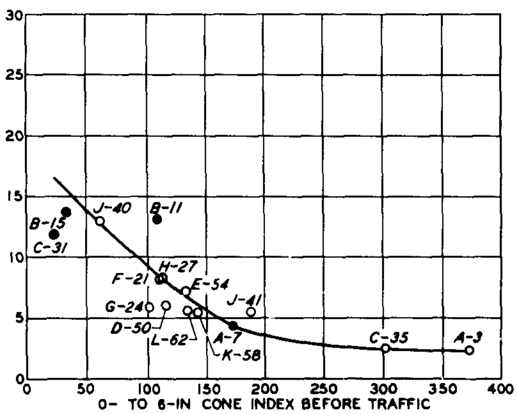


FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

A $\frac{3}{4}$-TON M37 4X4 TRUCK
B $2\frac{1}{2}$-TON M135 6X6 TRUCK
C 5-TON M41 6X6 TRUCK
D BUCKET LOADER 4X4 TRACTOR
E TOURNADOZER 4X4 TRACTOR
F $2\frac{1}{2}$-TON M135 TESTED AS A 4X4 (11.00-20 12-PR TIRES WITH STD NDCC TREAD)
G $2\frac{1}{2}$-TON M135 TESTED AS A 4X4 (11.00-20 12-PR TIRES-TREAD REMOVED)
H $2\frac{1}{2}$-TON DUKW353 6X6 TRUCK
J 5-TON M52 6X6 TRUCK
K 5-TON GOER 4X4 (18.00-26 10-PR TIRES)
L 5-TON GOER 4X4 (15.00-34 10-PR TIRES)

CLOSED SYMBOLS DENOTE TESTS ON WET-TO-INUNDATED SAND
OPEN SYMBOLS DENOTE TESTS ON DRY-TO-MOIST SAND
NUMBERS NEAR PLOTTED POINTS REFER TO ITEM NUMBERS IN TABLE 5

VEHICLE PERFORMANCE

TOWING FORCE REQUIRED FOR SELF-PROPELLED WHEELED VEHICLES TOWED AS TRAILERS

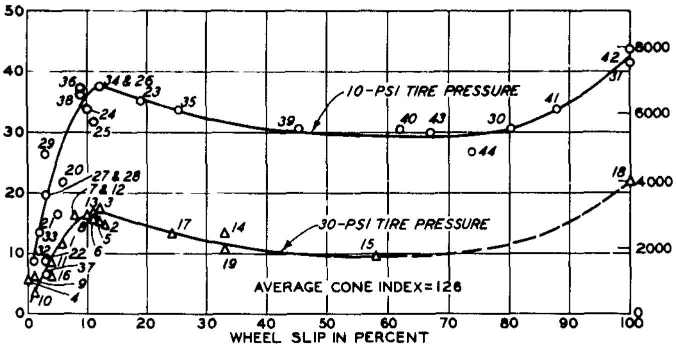


FIG. 1. 2½-TON M135 6X6 TRUCK 11.00-20 12-PR TIRES

TEST WEIGHT 18,320 LB

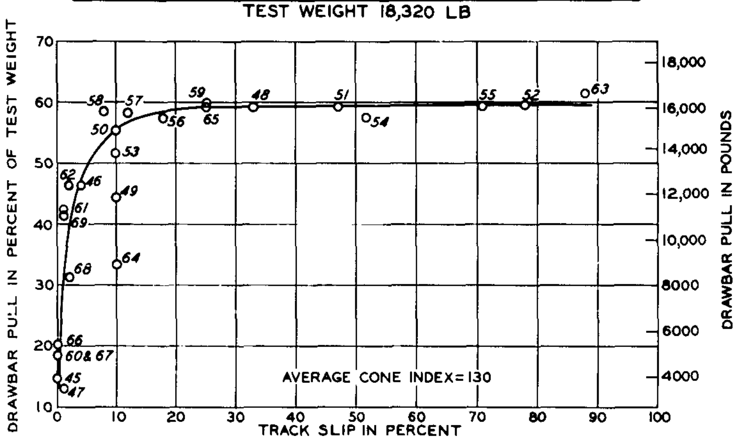


FIG. 2. STANDARD D7 ENGINEER TRACTOR

TEST WEIGHT 27,000 LB

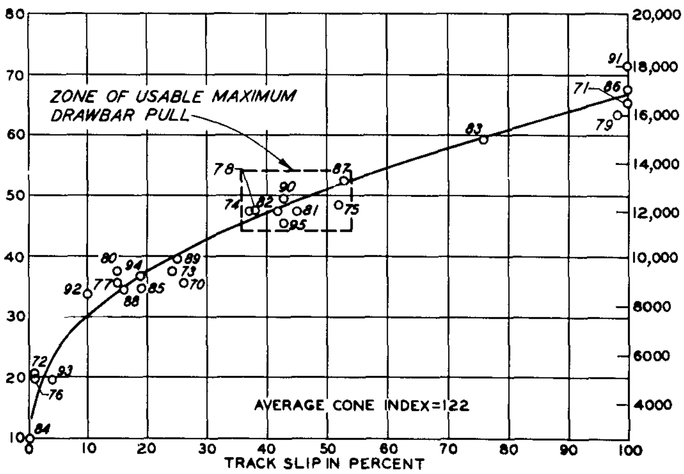


FIG. 3. 13-TON M5A4 HIGH-SPEED TRACTOR

TEST WEIGHT 25,230 LB

NOTE: NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 7.

SELF-PROPELLED VEHICLE PERFORMANCE

DRAWBAR PULL VS SLIP

DRY-TO-MOIST SAND

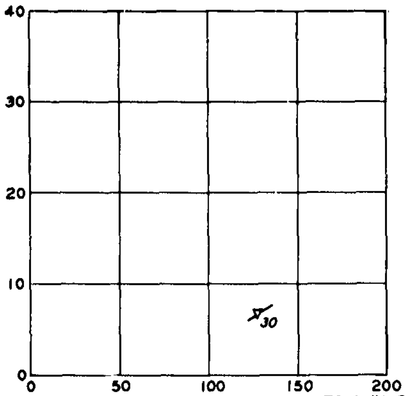


FIG. 1. 60-PSI TIRE PRESSURE

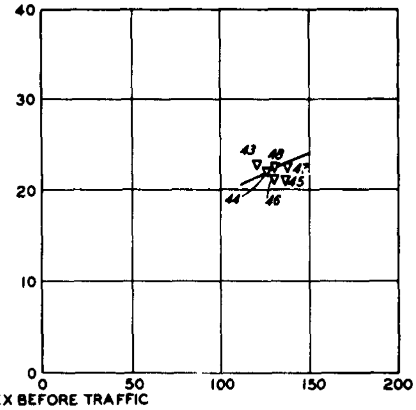


FIG. 4. 10-PSI TIRE PRESSURE

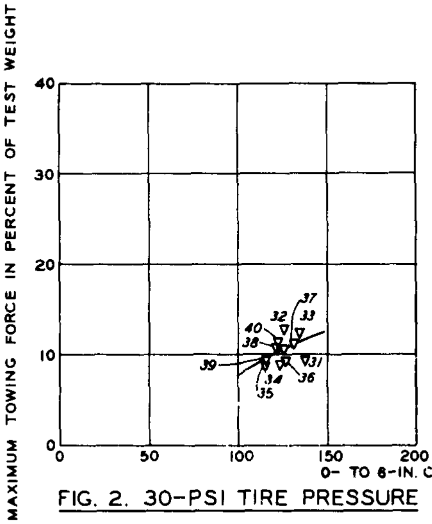


FIG. 2. 30-PSI TIRE PRESSURE

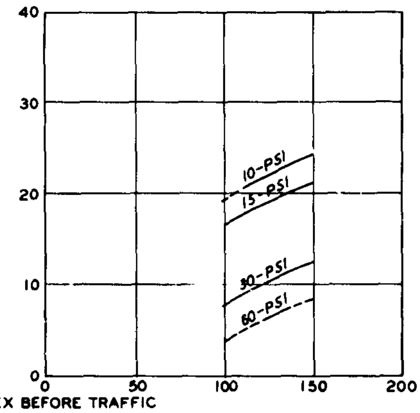


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

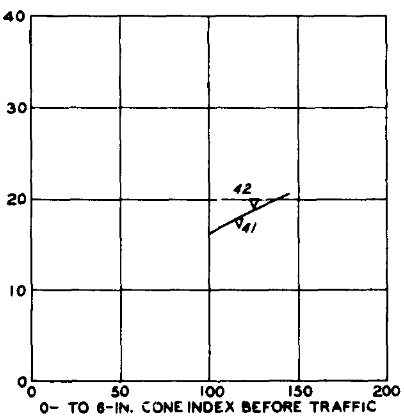


FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

▽ MAXIMUM TOWING FORCE TESTS
NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 8

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

$2\frac{1}{2}$-TON M135 TRUCK TESTED AS 6X6
11.00-20 12-PR TIRES
(STD NDCC TREAD) AND SNAP TRACS
TEST WEIGHT 19,188 LB
DRY-TO-MOIST SAND

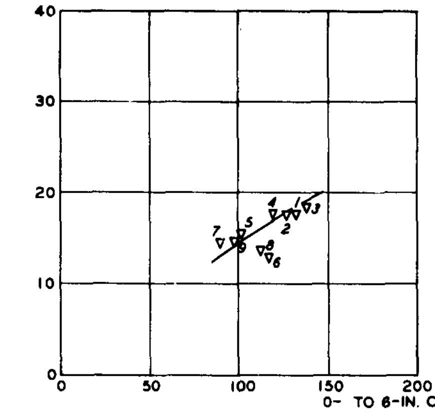


FIG. 1. 30-PSI TIRE PRESSURE

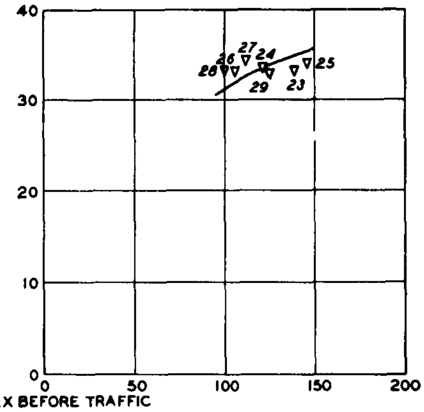


FIG. 4. 10-PSI TIRE PRESSURE

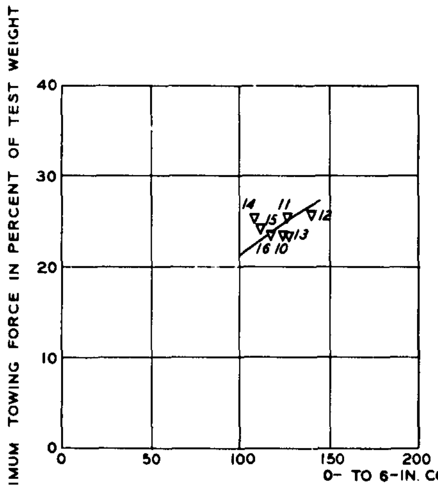


FIG. 2. 20-PSI TIRE PRESSURE

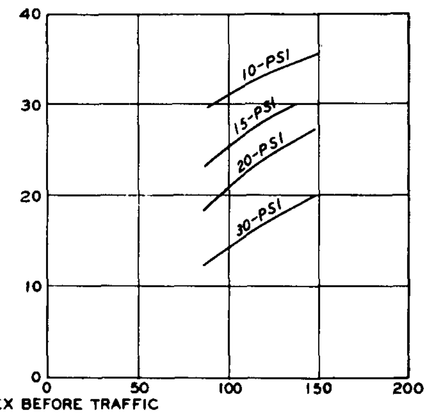


FIG. 5. FAMILY OF TIRE PRESSURE CURVES

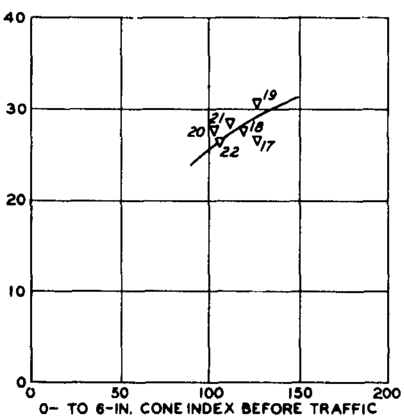


FIG. 3. 15-PSI TIRE PRESSURE

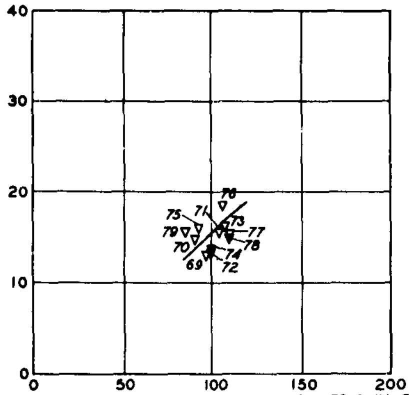
LEGEND

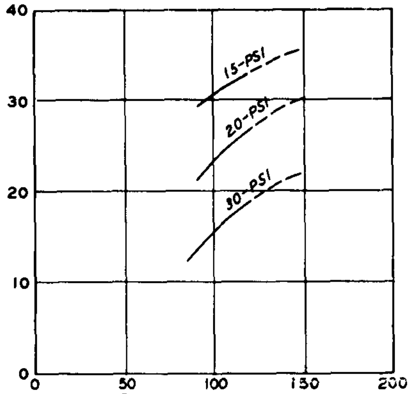
∇ MAXIMUM TOWING FORCE TESTS
NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 8

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

$2\frac{1}{2}$-TON M135 TRUCK TESTED AS 6X6
11.00-20 12-PR TIRES (TREAD REMOVED)
TEST WEIGHT 18,100 LB
DRY-TO-MOIST SAND



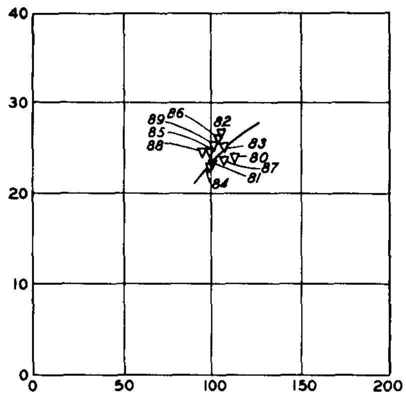


0- TO 6-IN CONE INDEX BEFORE TRAFFIC

FIG. 1. 30-PSI TIRE PRESSURE

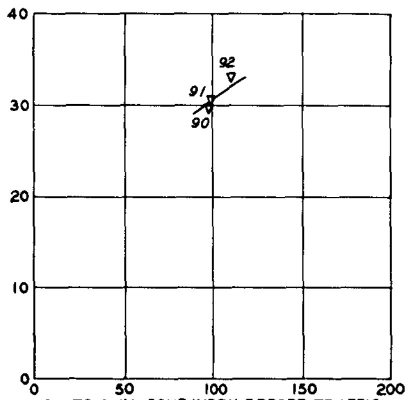
FIG. 4. FAMILY OF TIRE PRESSURE CURVES

MAXIMUM TOWING FORCE IN PERCENT OF TEST WEIGHT



0- TO 6-IN. CONE INDEX BEFORE TRAFFIC

FIG. 2. 20-PSI TIRE PRESSURE



0- TO 6-IN. CONE INDEX BEFORE TRAFFIC

FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

▽ MAXIMUM TOWING FORCE TESTS NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 8

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

$2\frac{1}{2}$-TON M135 TRUCK TESTED AS 4X4

11.00-20 12-PR TIRES (TREAD REMOVED)

TEST WEIGHT 17,610 LB

DRY-TO-MOIST SAND

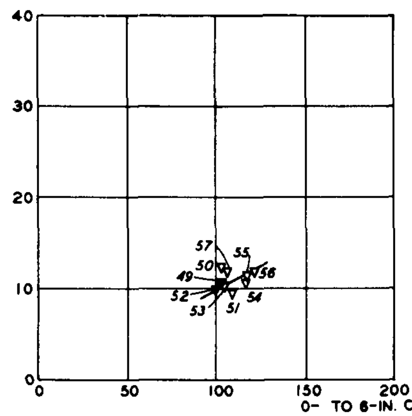


FIG. 1. 30-PSI TIRE PRESSURE

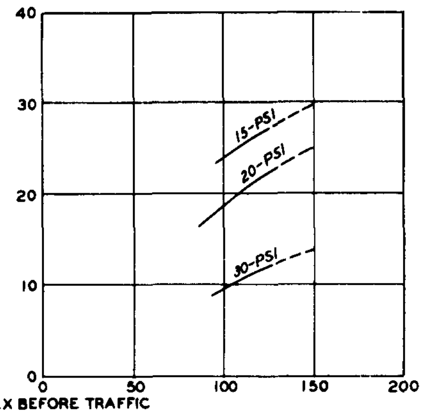


FIG. 4. FAMILY OF TIRE PRESSURE CURVES

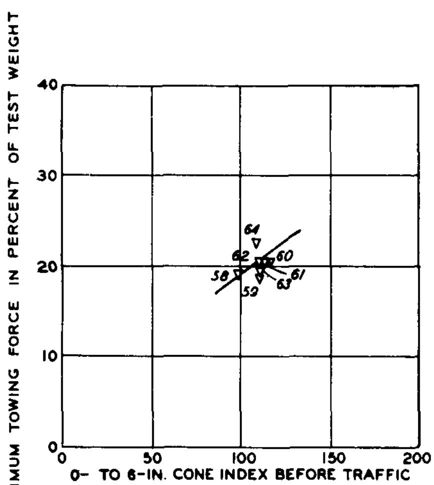


FIG. 2. 20-PSI TIRE PRESSURE

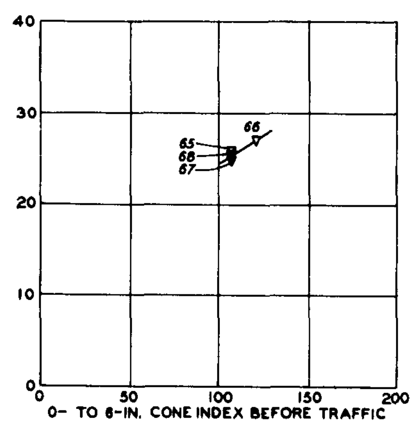


FIG. 3. 15-PSI TIRE PRESSURE

LEGEND

▽ MAXIMUM TOWING FORCE TESTS
NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 8

——— PERFORMANCE CURVE

SELF-PROPELLED VEHICLE PERFORMANCE

$2\frac{1}{2}$-TON M135 TRUCK TESTED AS 4X4
11.00-20 12-PR TIRES (STD NDCC TREAD)
TEST WEIGHT 17,610 LB
DRY-TO-MOIST SAND

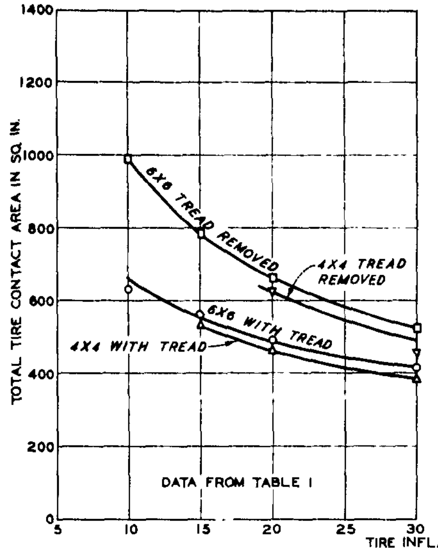


FIG. 1. TIRE INFLATION PRESSURE VS TOTAL TIRE CONTACT AREA

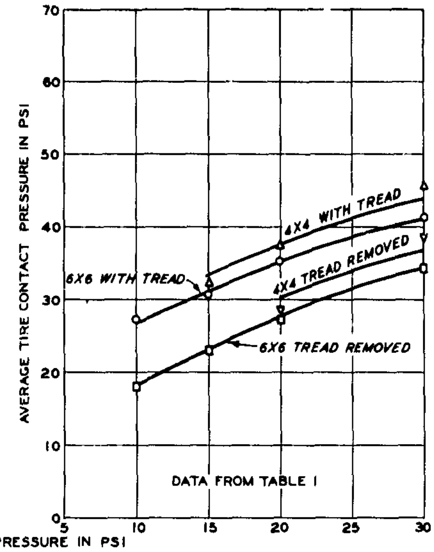


FIG. 2. TIRE INFLATION PRESSURE VS AVERAGE TIRE CONTACT PRESSURE

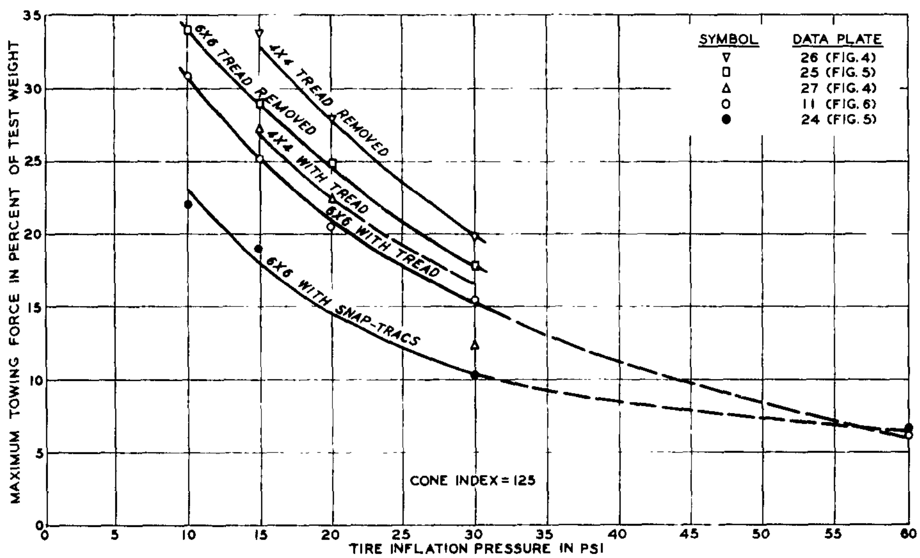


FIG. 3. TIRE INFLATION PRESSURE VS MAXIMUM TOWING FORCE

LEGEND

		VEHICLE WT IN LB
○	6X6 STANDARD NDCC TREAD	17,330
□	6X6 TREAD REMOVED	18,100
△	4X4 STANDARD NDCC TREAD	17,610
▽	4X4 TREAD REMOVED	17,610
●	6X6 SNAP-TRACS OVER STANDARD NDCC TREAD	19,188

COMPARISONS OF VEHICLE CHARACTERISTICS AND MAXIMUM TOWING FORCE

$2\frac{1}{2}$- TON M135 TRUCK EQUIPPED WITH 11.00-20 12-PR TIRES (SINGLE)

DRY-TO-MOIST SAND

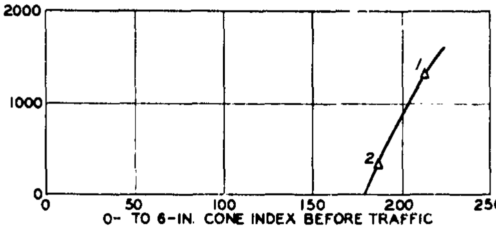


FIG. 1. 60-PSI TIRE PRESSURE FOR TRUCK AND TRAILER

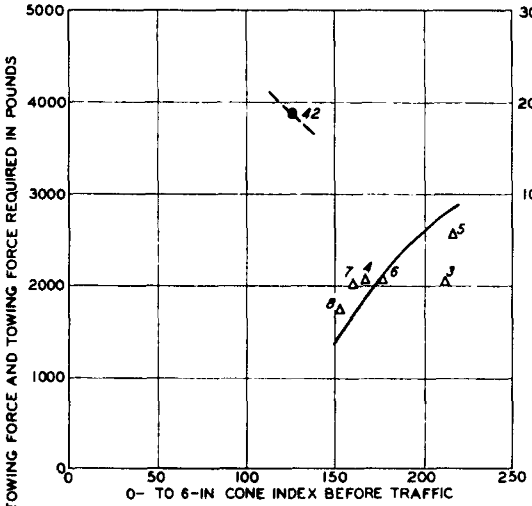


FIG. 2. 30-PSI TIRE PRESSURE FOR TRUCK AND 60-PSI TIRE PRESSURES FOR TRAILER

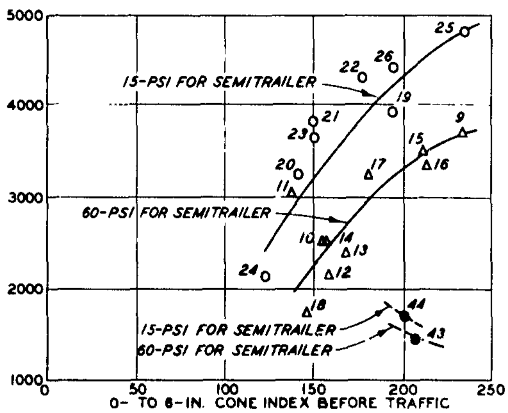


FIG. 3. 20-PSI TIRE PRESSURE FOR TRUCK AND 60-AND 15-PSI TIRE PRESSURES FOR TRAILER

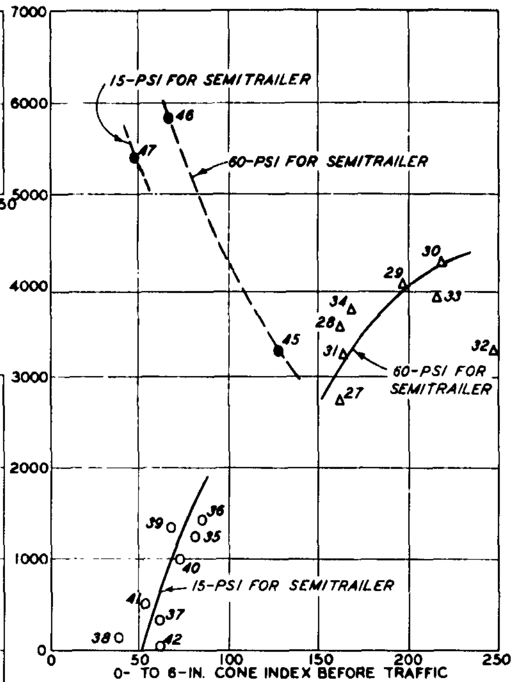


FIG. 4. 15-PSI TIRE PRESSURE FOR TRUCK AND 60- AND 15-PSI TIRE PRESSURES FOR TRAILER

LEGEND

- O MAXIMUM TOWING FORCE TESTS (15-PSI FOR SEMITRAILER)
- Δ MAXIMUM TOWING FORCE TESTS (60-PSI FOR SEMITRAILER)

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 9.

- ● TOWED-VEHICLE TESTS

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 5.

- ——— MAXIMUM TOWING FORCE CURVE
- — — — TOWING FORCE REQUIRED CURVE

VEHICLE PERFORMANCE TRUCK-TRAILER COMBINATION

5-TON M52 6X6 TRUCK
WEIGHT 22,310 LB

TOWING 12-TON M127A1 SEMITRAILER
WEIGHT 10,400 LB

DRY-TO-MOIST SAND

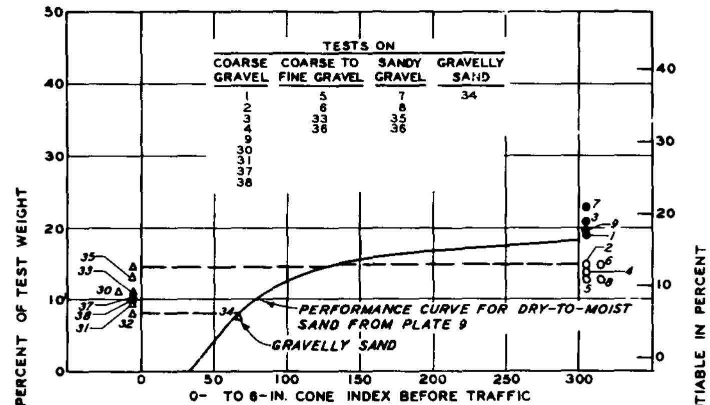


FIG. 1. 30-PSI TIRE PRESSURE

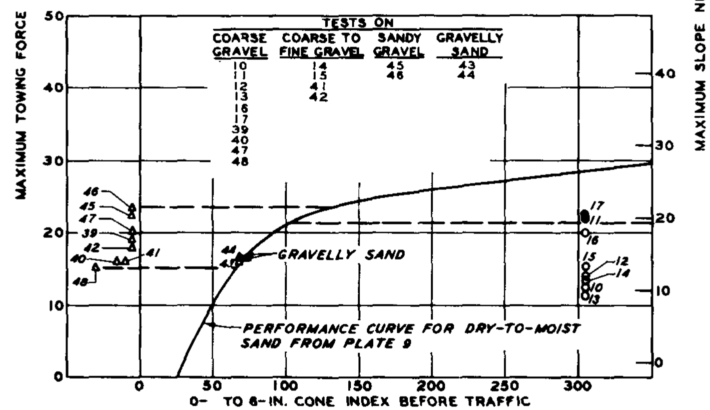


FIG. 2. 15-PSI TIRE PRESSURE

$\frac{3}{4}$-TON M37 4X4 TRUCK

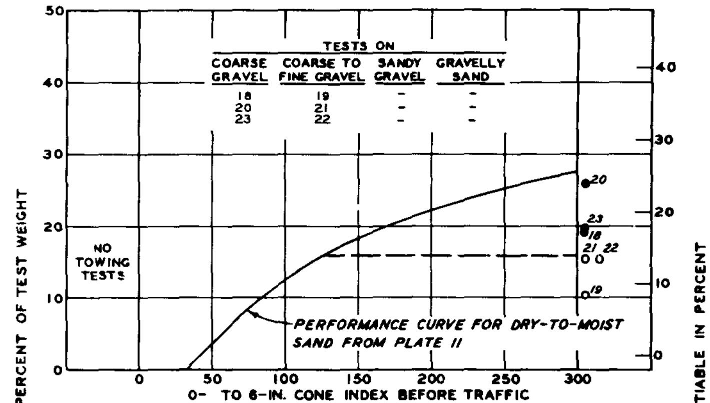


FIG. 3. 30-PSI TIRE PRESSURE

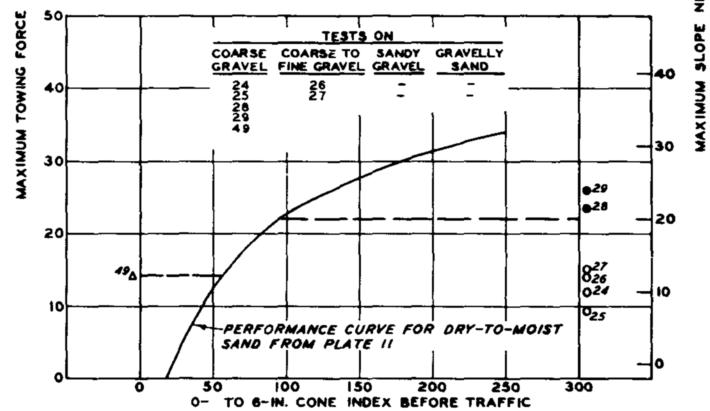


FIG. 4. 15-PSI TIRE PRESSURE

$2\frac{1}{2}$-TON M135 6X6 TRUCK

LEGEND

- △ MAXIMUM TOWING FORCE TEST
- ● SLOPE CLIMBING TEST-IMMOBILIZED ON SLOPE TESTED
- ○ SLOPE CLIMBING TEST-NOT IMMOBILIZED ON SLOPE TESTED

NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 10
FOR ADDITIONAL DATA AND EXPLANATION SEE PLATES 9 AND 11 AND PARAGRAPHS 142 -147

SELF-PROPELLED VEHICLE PERFORMANCE

TESTS ON GRAVEL BEACH WITH

$\frac{3}{4}$-TON M37 4X4 TRUCK AND $2\frac{1}{2}$-TON M135 6X6 TRUCK

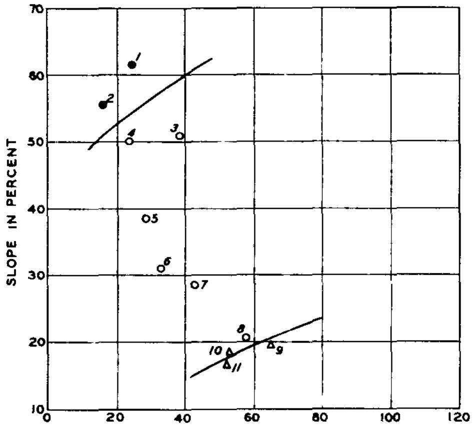


FIG. 1. 15-PSI TIRE PRESSURE

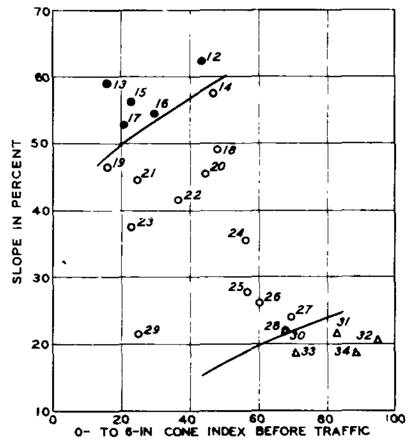


FIG. 2. 10-PSI TIRE PRESSURE

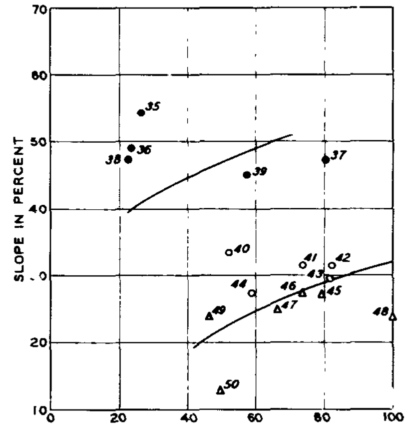


FIG. 3. 5-PSI TIRE PRESSURE

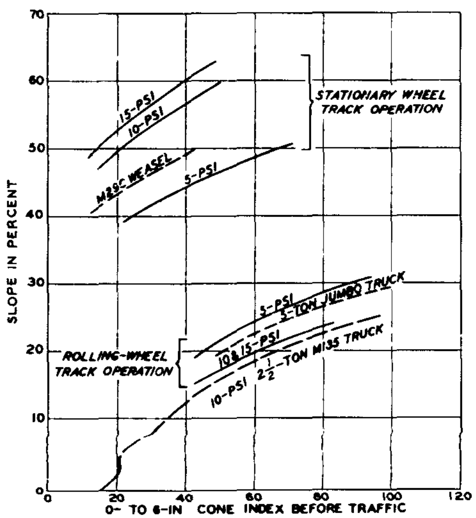


FIG. 4. COMPARISON OF AIROLL PERFORMANCE WITH PERFORMANCE OF OTHER VEHICLES

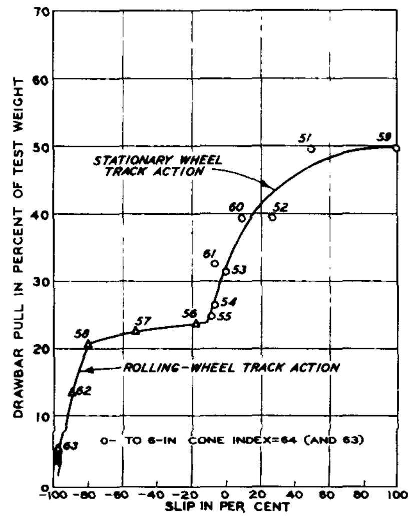


FIG. 5. DRAWBAR PULL-SLIP PERFORMANCE

LEGEND

- ——— PERFORMANCE OF AIROLL AT TIRE PRESSURES AS NOTED
- — — — PERFORMANCE OF OTHER VEHICLES AS NOTED
- ● DENOTES IMMOBILIZATION
- ○ DENOTES NONIMMOBILIZATION, STATIONARY WHEEL TRACK ACTION
- △ DENOTES NONIMMOBILIZATION, ROLLING WHEEL TRACK ACTION

NOTE: NUMBERS NEAR PLOTTED POINTS ARE ITEM NUMBERS FROM TABLE 11
CURVE FOR M135 FROM PLATE 11.
CURVE FOR JUMBO FROM PLATE 15
CURVE FOR WEASEL FROM DATA IN TABLE 2

VEHICLE PERFORMANCE
AIROLL

TEST WEIGHT 19,100 LB
DRY-TO MOIST SAND

KNIGHT/mld

16 NOV 1962

WESSR

SUBJECT: Submission of Technical Report for Approval

TO: Commanding General
U. S. Army Materiel Command
ATTN: AMCRD-RS-ES
Washington 25, D. C.

1. We are inclosing for your comments and/or approval for publication a copy of the draft of Technical Memorandum No. 3-240, Seventeenth Supplement, "Trafficability of Soils, Tests on Coars-Grained Soils with Self-Propelled and Towed Vehicles, 1958-1961," dated April 1962.

2. We plan to distribute this report according to List A. Your approval of the proposed distribution is requested.

1 Incl
as

/s/ ALEX G. SUTTON, JR.
Colonel, Corps of Engineers
Director

AMCRD-RS-ES-E(16 Nov 62) 1st Ind
SUBJECT: Submission of Technical Report for Approval

HQ, DA, Commanding General, Army Materiel Command, Washington 25, D. C.
20 December 1962

TO: Director, ATTN: WESSR, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

1. Returned herewith is the draft copy of Technical Memorandum No. 3-240, Seventeenth Supplement, "Trafficability of Soils, Tests on Coarse-Grained Soils with Self-Propelled and Towed Vehicles," dated April 1962. Publication of this report is approved subject to the comments contained this indorsement and the changes as indicated in red pencil in the draft report.

*****

5. Distribution of the published report is approved as requested in paragraph 2 of the basic letter.

FOR THE COMMANDER:

1 Incl
nc

/s/ ROBERT R. PHILIPPE
Chief, Environmental Sciences Branch
Research Division
Research and Development Directorate

KNIGHT/ap

WESSR (16 Nov 62) 2d Ind 29 JAN 1963

SUBJECT: Submission of Technical Report for Approval

TO: Commanding General, U. S. Army Materiel Command, ATTN: AMCRD-RS-ES-E, Washington 25, D. C.

We sincerely appreciate the thorough review to which you have submitted the subject report. Your general and specific comments and recommendations are well-founded and pertinent, and we are revising the report to incorporate them insofar as feasible.

1 Incl
wd

/s/ ALEX G. SUTTON, JR.
Colonel, Corps of Engineers
Director

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CG, Rock Island Depot Activity, Rock Island, Ill., ATTN: ORDOW-TX	1
CG, Army Materiel Command, ATTN: R&D Directorate, Environmental Sciences Br., Room 2507, Bldg. T-7, Mr. R. F. Jackson, Washington 25, D. C.	1

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British Liaison Officer (Thru OCE ENGTE-PS)	4
Canadian Liaison Officer (Thru OCE ENGTE-PS)	3
USAE Combat Developments Agency	1

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General Staff, U. S. Army

Deputy Chief of Staff for Logistics	1
Deputy Chief of Staff for Military Operations	1

Navy Department

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Office of Naval Research Navy Dept., Washington, D. C., ATTN: Code 463	1
OIC, Naval Photographic Interpretation Center, Naval Receiving Sta., Washington, D. C. ATTN: Librarian	1
Chief, Bur of Yards & Docks, Navy Dept, Washington, D. C. ATTN: Code 70	4
Coastal Studies Institute, LSU, Baton Rouge 3, La.	1
1st Medium Anti-Aircraft Missile Battalion, Marine Corps Training Center, Twenty-nine Palms, Calif.	1

Director, Naval Warfare Research Center, Stanford Research Institute, Menlo Park, Calif. - cc ltr of transmittal to: Resident Representative, Stanford Univ., Stanford, Calif.; Naval Warfare Research Center Representative, Stanford Research Institute, Suite 300, 808 17th St., N. W., Washington 6, D. C.; and Office of Naval Research (Code 493), Navy Dept., Washington, D. C. — 1

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