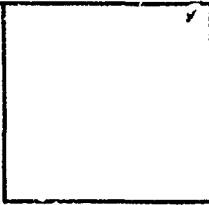




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LOW PRESSURE TIRES IN MUD

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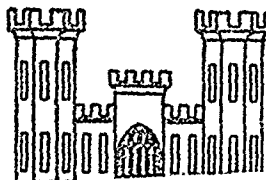
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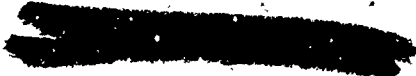
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Report No. 796

LOW PRESSURE TIRES IN MUD

Project MES 433

1 March 1944

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THE ENGINEER BOARD

Fort Belvoir, Virginia

and/or

The Chief of Engineers

U. S. Army

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SYLLABUS

1. This report is a record of comparative traction and flotation tests of 2½-ton 6 x 6 and 4-ton 6 x 6 trucks equipped with low pressure tires versus high pressure tires, with emphasis on mud performance.
2. Available data on general service durability, which is deemed satisfactory, are included in the report.
3. The report concludes that mud performance of these vehicles is increased by the use of low pressure tires and recommends their adoption as standard equipment.

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LOW PRESSURE TIRES IN MUD

I. SCOPE OF REPORT

1. Scope. This report covers tests of 2½-ton 6 x 6 and 4-ton 6 x 6 vehicles equipped with low pressure tires. The tests were conducted at the request of the Ordnance Department to aid in determining the mud traction and flotation ability of these vehicles when equipped with low pressure tires of the desert type. The report also covers the general service durability of this type tire, as it was evident throughout the tests. The test period covered was from 12 August 1943 to 31 December 1943.

II. AUTHORITY

2. Directives. Specific authority for conducting the tests was as follows:

a. Letter from Chief of Ordnance to Chief of Engineers, dated 21 April 1943, subject: Special Traction and Flotation Tire Tests, which resulted in a directive to the Engineer Board, dated 28 May 1943, subject: Special Traction and Flotation Tire Tests.

b. First indorsement from Chief of Engineers, dated 30 June 1943, approving service project MES 433, Service on Tires for Engineer Equipment.

Copies of these directives are in Appendix D. Copies of other correspondence relating to the conduct of the tests are contained in other appendices.

III. PREVIOUS INVESTIGATION

3. Summary. No previous investigation specifically directed at the mud performance of low pressure tired vehicles has been made by the Engineer Board, but reports have been submitted by the Engineer Board on allied subjects, and reports on mud performance, submitted by other agencies, are known to exist. These reports are as follows:

a. Sand Performance of Low Pressure Tires.

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(1) "Low Pressure Automobile and Truck Tires for Sand Operation" by Mr. R. C. Kerr, which detailed the low pressure tire experience of the Standard Oil Company of Arabia.

(2) "Performance Tests of 14:00 x 20 Tires in Sand", Report No. EB 136 by the Engineer Board, 2 January 1943, which presented the interim findings of sand tests of this size low pressure tire.

(3) Various reports of the Ordnance Desert Proving Ground.

b. Mud Performance of Low Pressure Tires.

(1) B. F. Goodrich Company report, dated 6 June 1943, on mud flotation and traction.

(2) Various reports of the Ordnance Desert Proving Ground.

c. Allied Subjects.

(1) Engineer Board Desert Test Branch Interim Report, dated 20 December 1942, on Tests of Road Expedients, Desert Sand.

(2) Engineer Board Desert Test Branch Interim Report, dated 26 May 1943, on Tests of Road Expedients, Mud Operations.

(3) Engineer Board Report No. 782, dated 17 November 1943, on Tiro and Wheel Standardization, which was based on all work of the Engineer Board, to that date, on vehicular performance under all types of adverse terrain conditions.

#### IV. PRESENT INVESTIGATION

4. Purpose of Tests. Previous investigations conducted by various U. S. Army agencies have shown beyond a doubt that low pressure tires radically improve the performance of a vehicle under sand conditions. The adoption of this tire equipment for the  $2\frac{1}{2}$ -ton 6 x 6 amphibian truck and the standardization of low pressure tire equipment for desert service, resulted from these tests. Throughout previous investigations there were indications, and some facts, which made desirable an investigation into the mud performance of low pressure tired vehicles. The present investigation resulted specifically from the desirability of establishing or disproving the belief that low pressure tires would improve mud performance. At the same time data as to the general service durability of these tires were gathered and are here recorded.

5. Tests Conducted. The only tests specifically conducted as a result of the directives issued pertained exclusively to mud performance. These tests included mud traction, mud flotation, and mud "go-no-go" tests, and were conducted by the Desert Warfare Section of the Engineer Board using desert-tire-equipped 2½-ton 6 x 6 and 4-ton 6 x 6 vehicles carrying loads as specified in the directives. Prior to the actual conduct of these tests, preliminary tests were conducted to determine the most suitable wheel equipment for the 4-ton 6 x 6 when equipped with 14:00 x 20 tires.

a. Incident to the loan of several 2½-ton dump trucks to the Engineer School, an opportunity was afforded for general service durability tests of the 11:00 x 18 10-ply desert type low pressure tire, when applied to the 2½-ton 6 x 6 dump truck in regular service. These trucks were operated by the Engineer School mostly on good hard roads, with 75 percent of the mileage on hard surfaced roads. The service to which they were subjected was not severe, but useful data were gathered on the subject of tire durability and on vehicle steering.

b. Included also in this report as Appendix C is a "Report of Service Life Tests of 14:00 x 20 Truck Tires of Various Ply Construction". The data recorded in that report, which is a report to the Engineer Board by its Desert Warfare Section, are here included since they bear directly on the subject of Low Pressure tires, and because they have not heretofore been made available in report form.

c. All reports made to the Engineer Board by its Desert Warfare Section have been reproduced without modification as Appendices A, B, and C to this report. Detailed information as to the conduct of all tests made is to be found therein.

## V. DISCUSSION

6. Importance of Tests. The performance of a vehicle, particularly under poor road conditions or under off-road conditions, is, among other things, a direct function of its tire equipment. Good tire equipment, properly applied to tire load conditions, is a necessary part of vehicular design, especially in the case of military vehicles which are required to negotiate such adverse terrain, under war conditions, and cannot rely on hard surfaced roads. In military operations, the miles which are difficult to negotiate become the valuable miles when negotiation is made possible. Economy of operation, long life, maximum tire mileage, and minimum cost in dollars and in rubber are desired, but ability to traverse the route is imperative to the accomplishment of the military mission.

7. The Low Pressure Tire. Fundamentally, and without becoming involved in the details of tire construction, a low pressure tire is a

tire which is so constructed as to be able to carry a given load, in a normal manner, with a low inflation pressure. As an example, the 9:00 x 20 10-ply tire as used on standard U. S. Army 4-ton 6 x 6 truck requires 70 pounds inflation to support a 3650-pound loading without speed restriction, whereas the 14:00 x 20 12-ply tire requires but 22 pounds inflation to support the same load, under the same conditions. Low pressure tires are often termed flotation tires, since ground bearing pressures are but little in excess of inflation pressures.

8. Mud Conditions. There is nothing constant about mud. It may mean anyone of an infinite number of variations of soil and water from a slippery slimy layer over a firm base, to a bottomless quagmire resembling quicksand in its action. Some types of mud are definitely impassable to any type of vehicle, but tire equipment has a definite relationship to a vehicle's ability to traverse the more common types of mud. A generally accepted classification of mud, in use by the Ordnance Department, is as follows:

a. Type I Mud. Bottomless and of such a consistency that it will not support a vehicle with standard tire equipment at 20 pounds inflation pressure. This implies that if a firm sub-surface exists, it is at a depth greater than the ground clearance of the vehicle.

b. Type II Mud. A mud top surface with hard pan at a depth not to exceed vehicle ground clearance; or mud of such consistency that sufficient bearing surface results from compaction at 20 pounds inflation pressure at a depth not to exceed vehicular ground clearance.

(1) Type IIa Mud. Type II mud with a cleaning quality; i.e., non-adhesive.

(2) Type IIb Mud. Type II mud, but highly adhesive; i.e., with no cleaning quality.

9. Factors Influencing Mud Performance. Numerous factors influence the performance of a vehicle in mud, in addition to the type of mud and such items as state of vehicular maintenance, driver skill, distribution of load, etc. The more important items are as follows:

a. Flotation. A vehicle cannot traverse ground which will not support its weight. Both the 2½-ton and 4-ton vehicles used as test vehicles carry heavier loads on the forward tires than they do on the rear tires. Dualing the front wheels improves mud performance because greater flotation is provided. Reduced tire inflation pressures result in increased contact area and hence increased flotation.

b. Lower Inflation. Reduced tire inflation pressures aid in mud performance in another way also, since greater



FIG. 1. 2½-TON 6x6 TRUCK STUCK IN LOCALIZED TYPE I MUD.



FIG. 2. 1-TON 6x6 TRUCK STUCK IN TYPE IIa MUD.



FIG. 3. 4-TON 6x6 TRUCK IN TYPE IIB MUD.

flexing of the tire results in causing a certain amount of the mud to be shaken off, allowing tread pattern more influence.

c. Traction. A vehicle cannot traverse ground upon which it cannot get sufficient traction. The 4-ton 6 x 6 truck with 9:00 x 20 tires, duals rear, and with chains all around is generally a better mud vehicle than the same truck with 14:00 x 20 tires without chains, due to greater traction. When the 9:00 x 20 tires are at highway inflations and the 14:00 x 20 tires are at reduced inflation, the 14:00 x 20 tires develop flotation sufficient to offset the gain in traction. Traction and flotation must be considered together, and are the two fundamental factors to mud mobility, so far as tire equipment is concerned.

d. Vehicular Ground Clearance. All other things being equal, increased ground clearance results in greater mud mobility due to an increased ability of a vehicle to negotiate bad spots.

e. All Wheel Drives. All wheel drive vehicles are mandatory to good mud performance. Lack of all wheel drive results in greatly decreased traction.

10. Reasons for Preliminary Tests. Since it was known (see Appendices D and G) that the Ordnance Department had furnished wheels of 4-3/4 inch dish to other Service Boards for test use with the 14:00 x 20 tires on the 4-ton 6 x 6 truck, and since the Engineer Board had already done some testing using this wheel and found it unsuited, preliminary tests were conducted to determine the proper dish to use for the tests conducted. These tests confirmed previous findings that the 4-3/4 inch dish wheel was unsuited and that a 5-3/8 inch dish wheel was best. The 5-3/8 inch dish wheel was used throughout the tests. Pertinent data as to this point are as follows:

a. The 4-3/4 Inch Dish Wheels. This wheel moves the front wheel load line outboard 1-3/8 inches increasing the track from 73-3/4 inches to 76-1/2 inches. This displacement resulted in shimmy trouble and hard steering. If it were impossible to reduce this displacement, it would be acceptable because the benefits to be gained by the installation of the large tires far outweigh the shimmy trouble and the minor steering gear troubles that will develop. On the rear bogies 4-3/4 inch dish wheels cause an outboard displacement of the load lines of 4-3/8 inches, increasing the wheel track from 72 inches to 80-3/4 inches. Front and rear wheels therefore do not track. This load line displacement could be accepted if it were impossible to correct the situation.

b. The 5-3/8 Inch Dish Wheel. This wheel moves the front wheel load line outboard but 3/4-inch increasing the

track from 73-3/4 inches to 75-1/4 inches. Every fraction of an inch reduction in load line displacement is a distinct gain in shimmy trouble elimination and in steering ease. On the rear bogies, the hubs must be padded with a 7-inch hub adapter, or a new hub with a 7-inch hub face extension must be built to permit the wheels to be installed dish in, in the normal manner, and to track the front wheels at 75-1/4 inches. The resulting load line displacement is 1-5/8 inches. Hub adapters are not desirable, as they are a source of trouble. New hubs are inexpensive, easily constructed, and easily installed in the field. Wheels of 5-3/8 inch dish do require a modification to the front wheel brake diaphragm bracket. This is considered minor, as compared to the advantages to be gained from the use of wheels of this dish dimension.

c. Comparison.

	<u>4-3/4 Inch Dish Wheels</u>	<u>5-3/8 Inch Dish Wheels</u>
Front track	76-1/2"	75-1/4"
Rear track	80-3/4"	75-1/4"
Front load line displacement	1-3/8"	3/4"
Rear load line displacement	4-3/8"	1-5/8"

11. Engineer School General Service Tests. The Engineer School operated the several 2 1/2-ton 6 x 6 dump trucks, equipped with 11:00 x 18 10-ply desert type tires (3 1/2-inch dish wheels - singles), a total of "650 miles hauling dry batches for concrete paving. Most of the operation was on good hard roads with approximately 75 percent of the mileage on hard surfaced roads." The service to which the trucks were subjected was "not severe", but "no failures of the tire equipment" occurred "during the entire time the trucks were used by the School", and, "There was no noticeable wearing of the tires", at this mileage. Inflation pressure used was 35 p.s.i., and the loads carried did not exceed 2 1/2 tons. The School further reported that "no steering difficulties were encountered, and it is the opinion of the drivers that the trucks equipped with low pressure tires steer as well as trucks equipped with standard tires". These vehicles were not operated in difficult terrain or in mud, and hence no performance comparisons with standard equipment were possible. While this service was not severe and quite limited, the data as to ease of steering, "no noticeable wearing of tires" and no tire failures, are believed particularly pertinent to the matter of general service durability of the low pressure tire.

Further data as to general service durability, gathered incident to the conduct of the mud tests by the Desert Warfare Section, are included in the Appendices to this report, as submitted by that section.

12. Detailed Discussion. No attempt is made in the body of this report to duplicate the detailed discussion to be found in Appendices A, B, and C. All parts of these appendices are to be considered as much a part of this report as if they were duplicated in this paragraph.

## VI. CONCLUSIONS

13. General Conclusions. Based on the knowledge gained by conduct of the tests, the following general conclusions are made:

a. That the mud performance ability of both the  $2\frac{1}{2}$ -ton 6 x 6 and 4-ton 6 x 6 trucks is better when equipped with low pressure tires than when equipped with present standard tires.

b. That the mud performance ability of both the  $2\frac{1}{2}$ -ton 6 x 6 and 4-ton 6 x 6 trucks, when equipped with present standard tires, is increased by dualing the front wheels.

c. That the mud performance ability of both the  $2\frac{1}{2}$ -ton 6 x 6 and 4-ton 6 x 6 trucks is increased with reduction of tire pressures, with either present standard or low pressure tires.

d. That the mud performance ability of both the  $2\frac{1}{2}$ -ton 6 x 6 and 4-ton 6 x 6 trucks is increased by the use of tire chains, with either the present standard or low pressure tires.

e. That the greater ground clearance of both the  $2\frac{1}{2}$ -ton 6 x 6 and 4-ton 6 x 6 trucks, when equipped with low pressure tires, allows these vehicles better mobility for any operation other than highway.

f. That both the  $2\frac{1}{2}$ -ton 6 x 6 and 4-ton 6 x 6 trucks are easier to steer cross country when equipped with low pressure tires.

g. That the general service durability of the desert type low pressure tire is satisfactory.

h. That the effectiveness of Engineer troops in the field can be increased by the use of low pressure tires as standard equipment.

14. Detailed Conclusions,  $2\frac{1}{2}$ -ton, 6 x 6, Truck.

a. That the standard  $2\frac{1}{2}$ -ton 6 x 6 truck is easier to steer on the highway when equipped with present standard tires.

b. That the use of the Firestone taper wedge bead ring allows both the 7:50 x 20 and 11:00 x 18 tire to be run at Ordnance sand minimum inflations for emergency operation, without premature tire or tube failure.

c. That the standard  $2\frac{1}{2}$ -ton 6 x 6 truck should be modified to give additional fender clearance to adequately accommodate the 11:00 x 18 tire.

d. That the standard  $2\frac{1}{2}$ -ton 6 x 6 truck with rated payload, equipped with standard tires can barely negotiate a flat stretch of flat dry dune sand, whereas when equipped with 11:00 x 18 low pressure tires, it can negotiate a 23 percent grade in dry dune sand.

15. Detailed Conclusions, 4-ton 6 x 6, Truck.

a. That the mud performance ability of the 4-ton 6 x 6 truck is better when equipped with present standard tires, singles in front, and chains all around than when equipped with 14:00 x 20 tires, without chains, at most inflations. When the 14:00 x 20 tires are at Ordnance sand minimum inflations and the 9:00 x 20 tires are at highway inflations, the 14:00 x 20 tires give slightly better performance.

b. That the ease of steering the standard 4-ton truck, without modification, is about the same on the highway, when equipped with either 9:00 x 20 or 14:00 x 20 tires, provided wheels of 5-3/8 inch dish are used with the 14:00 x 20 tires.

c. That the 14:00 x 20 low pressure tire has a greater cleaning action than the 9:00 x 20 standard tire.

d. That mud piling up in front of the duals of the 9:00 x 20 tires, more than any other factor causes trucks so equipped to have less mobility than trucks equipped with 14:00 x 20 low pressure tires.

e. That in severe mud, a truck equipped with 14:00 x 20 tires has a higher tractive effort than the same vehicle equipped with 9:00 x 20 tires.

f. That the rolling resistance of a truck equipped with 14:00 x 20 tires is always less in mud than it is for the same vehicle equipped with 9:00 x 20 tires.

g. That the present standard 4-ton 6 x 6 trucks are equipped with sufficient strong drive shafts, differentials, and axles, to provide for the increased rolling radius of the vehicle when equipped with low pressure tires, as not to require modification for tire conversion. Its reduced gradability is considered satisfactory considering such factors as state of maintenance, and considering the fact that speed and gradability pertain only to operation on hard surfaced roads.

## VII. RECOMMENDATIONS

16. Specific Recommendations. Based on all tests conducted to date by the Engineer Board, the following recommendations are made: *with respect to Engineer tested vehicles:*

a. To improve the performance of both the 2½-ton and 4-ton 6 x 6 vehicles, in sand, in mud, or in cross country operation, that low pressure tires be adopted as standard equipment for tactical vehicles, *replacing present standard tire equipment.* *(in lieu of)*

b. That in providing conversion kits for present vehicles, the 4-ton 6 x 6 truck be provided with 5-3/8 inch dish wheels, and that tire size and application be in accordance with that recommended in Engineer Board Report No. 782 (Tire and Wheel Standardization, dated 17 November 1943.

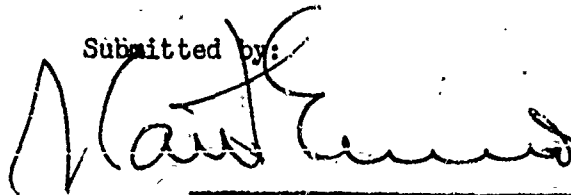
c. That the general service durability of the desert type low pressure tire be considered satisfactory.

d. That chains be used on high and low pressure tired vehicles to increase mud performance.

e. That reduced inflation pressures be used to increase mud performance.

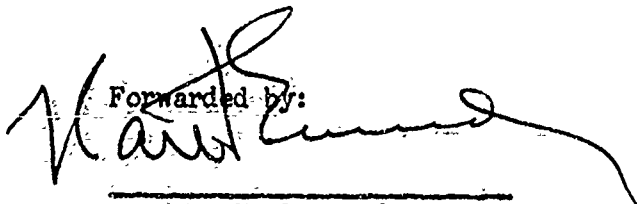
f. That, *(in emergency conditions require)* standard vehicles, equipped with present standard tire equipment, be dual wheeled in front to increase emergency mud performance.

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APPENDIX A

REPORT OF  
TESTS OF 11,00 x 18 10-PLY AND 7:50 x 20  
8-PLY TIRES ON 2 $\frac{1}{2}$ -TON 6 x 6 TRUCK

Desert Warfare Section  
Thermal California

Informal Report No. 181

Part I

TESTS OF 11:00 x 18 10-PLY AND  
7:50 x 20 8-PLY TIRES IN MUD

Project No. MES 433

Service on Tires

For Engineer Equipment

15 December 1943

Submitted to

The Technical Staff  
The Engineer Board  
Fort Belvoir, Virginia

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Engineer (Civil)

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## SYLLABUS

This first Interim Report covers testing by the Desert Warfare Section of standard 7:50 x 20 tires and 11:00 x 18 low pressure tires on loaded  $2\frac{1}{2}$ -ton, 6 x 6, trucks in varying mud conditions. The testing was carried on at the north end of the Salton Sea, at Camp Seeley, and in the vicinity of Thermal, California. The report analyzes the data secured from a series of tests made to determine the relative performance of these tires in mud. The period of testing was from 12 August to 23 October, 1943.

The conclusions based on the results of tests covered in this report and on tests previously conducted in sand by this Section are as follows:

a. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck is better when equipped with 11:00 x 18 low pressure tires than when equipped with 7:50 x 20 3-ply standard military tires, singles on the front wheels.

b. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck with 7:50 x 20 tires is improved by dualing the front wheels.

c. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck equipped with either 7:50 x 20 or 11:00 x 18 tires is increased with reduction of tire pressures.

d. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck equipped with either 7:50 x 20 or 11:00 x 18 low pressure tires is improved by the use of tire chains.

e. The standard  $2\frac{1}{2}$ -ton truck, without modifications, is easier to steer cross country when equipped with 11:00 x 18 tires.

f. The standard  $2\frac{1}{2}$ -ton truck, without modifications, is easier to steer on the highway, when equipped with 7:50 x 20 tires.

g. The use of the Firestone taper wedge bead ring allows both the 7:50 x 20 and 11:00 x 18 tires to be run at Ordnance Sand Minimum Inflation for emergency operation, without premature tire or tube failure.

h. The standard  $2\frac{1}{2}$ -ton truck should be modified to give additional fender clearance to adequately accommodate the 11:00 x 18 tire.

i. Tests by the Desert Warfare Section under the conditions available indicate that the only satisfactory method for

determining the relative performance in mud of the standard  $2\frac{1}{2}$ -ton truck, with various tire combinations, is the "go-no-go method".

j. The standard  $2\frac{1}{2}$ -ton truck, with rated payload, when equipped with 11:00 x 18 tires can negotiate a 23 percent grade in dry dune sand; whereas the same truck when equipped with 7:50 x 20 tires can barely negotiate a flat stretch of flat dune sand.

k. The standard  $2\frac{1}{2}$ -ton truck has greater clearance when equipped with 11:00 x 18 tires than with 7:50 x 20 tires; therefore allowing better mobility for any operation other than highway.

The report recommends that:

a. To improve the performance of  $2\frac{1}{2}$ -ton 6 x 6 trucks in mud of the type in which the tests were made, 11:00 x 18 10-ply non-directional tires be used in preference to 7:50 x 20 8-ply non-directional tires.

b. If trucks are supplied with standard 7:50 x 20 tires the front wheels be dualled for increased "mud-mobility".

c. Chains be used on both 7:50 x 20 and 11:00 x 18 tires to give added "mud-mobility".

d. Reduced tire inflation pressures be used for increased "mud-mobility".

Desert Warfare Section  
Interim Report No. 181  
Part I

15 December 1943

TITLE: Tests of 11:00 x 18, 10-ply and 7:50 x 20, 8-ply tires  
in mud.

PROJECT NO: MES 433, Service on Tires for Engineer Equipment.

I. SUBJECT

1. This report covers special traction and flotation tests in mud of 11:00 x 18, 10-ply low pressure tires and 7:50 x 20, 8-ply standard military tires. Tests were conducted by the Desert Warfare Section during the period 12 August 1943 to 28 October 1943, in mud areas at the Salton Sea, Camp Seeley, and Thermal, California.

II. AUTHORITY

2. Engineer Board Form 104.3, Serial No. 36, dated 11 August 1943.

3. A letter dated 28 May 1943 from the Office, Chief of Engineers directing the Engineer Board to test the military low pressure type tires for traction, flotation, and general service durability with special emphasis on performance in mud. Reference O.C.E. file 400.112 (Tires) SPEED.

III. INVESTIGATION

4. Previous Investigation. No previous investigation, of the performance in mud, of the subject size tires has been conducted by the Desert Warfare Section. Two reports on tires of this size and their performance in mud are known to the writers. They are listed for reference below:

a. B. F. Goodrich Company report on "Ordnance Mud Flotation and Traction Tests", dated 6 June 1943. The tests were conducted and the report written at the request of the Ordnance Department, Tank Automotive Center, Rubber Development Branch, Detroit, Michigan. The testing was carried on in the vicinity of Akron, Ohio. The pertinent conclusions are as follows: (References to "types of mud" are explained in Appendix D.)

(1) "The results of these tests indicated that under the conditions tested, the single military desert tire

equipment gives more mobility than the standard military mud and snow dual tire equipment on the  $2\frac{1}{2}$ -ton 6 x 6 cargo trucks.

(2) "Tests run using reduced inflation pressures showed a definite advantage over highway inflation for both the standard dual tire equipment and the single desert tires. However, for comparable inflation pressures, the single desert tire will perform better than the standard dual tire equipment.

(3) "The tests show that it is not feasible to use pressures below the recommended cross country inflation. Such practice does increase the tire flotation but is deemed inadvisable since it will result in premature tire and tube failures and require the use of a beadlocking device.

(4) "Lack of Mobility was encountered on the  $2\frac{1}{2}$ -ton trucks equipped with standard military non-directional mud and snow tires. It will be noted in the table under "Test Equipment" that the front axle on the  $2\frac{1}{2}$ -ton truck carries only 6 percent less load than each of the rear axles, yet it is equipped with single tires instead of duals. In an effort to correct this condition, duals were applied to the front of the  $2\frac{1}{2}$ -ton trucks. In Type I bottomless mud where flotation is the prime factor, this made the truck on standard military mud and snow tires equal to or slightly better in flotation than the trucks equipped with single military desert tires. However, in Type IIB mud, duals trap and push the mud ahead of the tires. In mud of this type, duals on the front increase the rolling resistance and give the truck less mobility. Use of dual tires on the front is recommended as an emergency measure under conditions in which additional flotation is needed.

(5) "The 11:00 x 18 military desert tires have nearly twice the load carrying capacity of the 7:50 x 20 military mud and snow tires. This added tire capacity on the front of vehicles equipped with military desert tires adds much to their flotation and mobility.

(6) "In addition to the mud flotation and traction tests, hill climbing trials were made. The trucks equipped with military desert tires using highway inflation climbed a twenty-one degree slope without hesitation. Trucks equipped with standard military mud and snow tires were unable to climb the hill. Use of the emergency inflation with or without chains did not improve the hill climbing ability of these tires. Single military desert tires are recommended for improved hill climbing ability."

b. Ordnance Desert Proving Grounds report on "Mud Tests", dated April 1943, signed by Lt. Col. J. E. Engler. The tests described in this report were carried on at Camp Seeley, Camp Pendleton and in the vicinity of Johnsondale, California. They were similar to those conducted by the B. F. Goodrich Company and substantially the same results and conclusions were reached. The Ordnance report was consulted by the writers during the period ~~the~~ subject tests were being made but a copy of the report was not available at the time this report was written.

5. Acknowledgements.

a. Technical Assistance. Acknowledgment is hereby made to:

(1) Mr. R. C. Korr, Senior Engineer (Automotive), who outlined the types of testing to be conducted, aided in locating the test area and gave helpful advice during the conduct of the test.

(2) Miss Loring Nicholson, Asst. Engineer of this Section for her work in calculating and compiling the data.

(3) Lt. Col. J. E. Engler, Ordnance Desert Proving Ground, for his courtesy in giving valuable information concerning previous tests and in allowing use of the mud test pit at Camp Seeley.

b. Cooperation of Troops. The following troop units furnished enlisted men at various periods to assist in making the tests:

(1) 854th Aviation Engineer Battalion, two men for ten days.

(2) 610th Engineer Light Equipment Company, three men for ten days.

(3) 85th Infantry Division, eight men for five weeks.

(4) 90th Infantry Division, eight men for four weeks.

6. Purpose of Tests. The purpose of these tests was to compare the performance in mud of the standard military 7:50 x 20 8-ply tire with that of the low pressure 11:00 x 18 10-ply tire; also to determine the comparative mud flotation and tractive ability of standard  $2\frac{1}{2}$ -ton 6 x 6 trucks, carrying a full payload, equipped with standard 7:50 x 20 tires or 11:00 x 18 low pressure tires. A similar test program on the comparative performance of standard military 9:00 x 20 10-ply and low pressure 14:00 x 20 12-ply tires is in progress. These tests will be covered in a subsequent report.

7. Location and Description of Test Areas. Tests were made at the following places:

a. North end of Salton Sea.

(1) Repeated Trip Tests. These tests were made in areas where there was either very little or no brush. A salt crust that averaged about 1/8 of an inch in thickness covered the entire area and tended to seal the moisture in the mud. The tests were run in some cases to the waters edge. The elevation at this location is approximately 250 feet below sea level. The depth of the water table was not determined but it was fairly close to the surface, because in many instances water was present in the bottom of the deeper tire tracks. The mud at this point is natural and is about as uniform as it was possible to find in this vicinity. The Ordnance Desert Proving Grounds has classified mud into two types in its report on mud flotation tests. These classifications are quoted in Appendix D. In general, the mud in this area can be classified under the definition of Type IIB. There are spots however, that should be classified as Type I.

(2) Dynamometer Tests. These tests were made in areas in which the native salt brush was cleared away and the mud there could be classified as Type IIA.

b. Camp Seeloy. The "Go-No-Go" tests were made at Camp Seeloy. Areas were laid off, then bordered and flooded. The entire area within the borders was covered with two or three inches of water when tests were run. This is the same location at which the tests were made by the Ordnance Desert Proving Grounds. This mud can be classified as Type IIB. It is a thin slippery slimy layer over a firm base which does not build up excessively on the tires but does form a slick lubricated surface that promotes tire slippages.

c. "Mud Hills" east of Thermal. The comparative hill climbing tests were made about four miles east of Thermal on ramps constructed of sand and clay material. Two ramps were built with a slope of approximately twenty percent and were wetted to simulate mud under actual conditions. This area does not fit any of the classifications as set up by the Ordnance report.

8. Test Equipment Data.

a. Vehicle Equipment. Four test vehicles were fitted with tire, rim and wheel equipment as listed below:

TABLE I

VEHICLE EQUIPMENT				
Vehicle				
Make	GMC	Studebaker	GMC	GMC
Size	2½-ton, 6 x 6	2½-ton, 6 x 6	2½-ton, 6 x 6	2½-ton, 6 x 6
Type	Dump	Compressor	Van	Tanker
Tire Eqpt.	11.00 x 18, 10-ply with flaps		7.50 x 20, 8-ply with flaps	
Tread Type	Non-Directional Military		Non-Directional Military	
Tire Type	Low Pressure Off-Road		Standard Mud and Snow	
Rim	7.33V with Firestone		5.00S with Firestone	
Equipment	Taper Wedge Bead Rings		Taper Wedge Bead Rings	
Wheel	Budd No. 46420, Dish 1-7/16"		Budd No. 44490, Dish 5-1/8"	
Equipment	8-3/4" Bolt Circle, 6 Studs		8-3/4" Bolt Circle, 6 Studs	
	No spacers or hub adapters		No spacers or hub adapters	

b. Vehicle Loadings. In accordance with the directive SPOMD-R, dated 18 May 1943, from Ordnance Department, Tank Automotive Center, Engineering Officer, Detroit, Michigan, signed by Lt. Col. Joseph H. Colby and indorsed to The Engineer Board by Office, Chief of Engineers, file CE 400.112 Tires SPEED, by Lt. Col. F. C. Kendall, the test trucks were loaded as shown in the following tabulation:

TABLE II

Tire Mountings	VEHICLE LOADS		
	Singles All Around	Singles Front Duals Rear	Duals All Around
Tire Size	11.00 x 18, 10-ply	7.50 x 20, 8-ply	7.50 x 20, 8-ply
Axle Load			
Front	5300 lbs.	5300 lbs.	5300 lbs.
Center	5640 lbs.	5640 lbs.	5640 lbs.
Rear	5640 lbs.	5640 lbs.	5640 lbs.
Tire Load			
Front	2650 lbs.	2650 lbs.	1325 lbs.
Center	2820 lbs.	1410 lbs.	1410 lbs.
Rear	2820 lbs.	1410 lbs.	1410 lbs.
Total Vehicle Load	16580 lbs.	16580 lbs.	16580 lbs.

c. Inflation Pressures. The inflation pressures used in these tests were based on average values of the published load-inflation tables of the Tire and Rim Association, Inc., the Ordnance Advisory Pneumatic Tire Committee, the Defense Standards Committee and the various tire manufacturers together with the data obtained by the Ordnance Desert Proving Grounds and the Desert Warfare Section for the loads specified. The pressures

used in the Goodrich tests are those recommended by the B. F. Goodrich Company and were taken into consideration in determining the inflation pressures used in these tests. The load-inflation tables are based on the percent of tire deflection.

TABLE III

TIRE INFLATION PRESSURES

Tire Mountings	Singles All Around	Singles Dual Rear	Duals All Around
Tire Size	<u>11.00 x 18, 10-ply</u>	<u>7.50 x 20, 8-ply</u>	<u>7.50 x 20, 8-ply</u>
Highway Operation			
Front	32 lbs.	72 lbs.	25 lbs.
Center	36 lbs.	25 lbs.	25 lbs.
Rear	36 lbs.	25 lbs.	25 lbs.
25 mph Operation			
Front	20 lbs.	45 lbs.	15 lbs.
Center	22 lbs.	16 lbs.	16 lbs.
Rear	22 lbs.	16 lbs.	16 lbs.
Limited Operation			
Front	14 lbs.	33 lbs.	11 lbs.
Center	16 lbs.	12 lbs.	12 lbs.
Rear	16 lbs.	12 lbs.	12 lbs.
Ordnance Sand Minimum			
Front	8 lbs.	19 lbs.	6 lbs.
Center	9 lbs.	7 lbs.	7 lbs.
Rear	9 lbs.	7 lbs.	7 lbs.

d. Loaded Radius at Various Inflation. The following table indicates the distance from the center of the hub to the ground is approximately the same on each wheel at any of the inflations used in these tests. This condition would not be true in the case of the pressures used by the B. F. Goodrich Company in their test.

TABLE IV

LOADED RADIUS AT VARIOUS INFLATIONS

Distance from Center of Hub to Ground in Inches

11.00 x 18, 10-ply Tires - Singlos All Around

Inflation Whools	<u>Highway</u>	<u>25 m.p.h.</u>	<u>Limited Oper.</u>	<u>Ord. Sand Min.</u>
Front				
Left	18-7/8	18-5/8	18-1/4	17-5/8
Right	18-7/8	18-1/2	18-1/8	17-3/8
Center				
Left	18-15/16	18-5/8	18-3/8	17-5/8
Right	19	18-5/8	18-3/8	17-5/8
Rear				
Left	18-7/8	18-1/2	18-1/4	17-3/8
Right	18-15/16	18-1/2	18-1/4	17-1/2

7.50 x 20, 8-ply Tires - Singlos Front, Duals Rear

Whools				
Front				
Left	17-1/4	16-3/4	16-1/8	16-3/8
Right	16-15/16	16-9/16	16-7/16	16-1/8
Center				
Left	17	16-9/16	16-9/16	16-7/16
Right	17	16-3/4	16-1/8	16-5/16
Rear				
Left	17	16-7/8	16-1/2	16-7/16
Right	17	16-9/16	16-9/16	16-7/16

c. Wheel Track Data. The following tabulation, based on the Loads given in Table II and the Highway Inflation Pressures given in Table III, summarizes the wheel track measurements for the four trucks used in the tests.

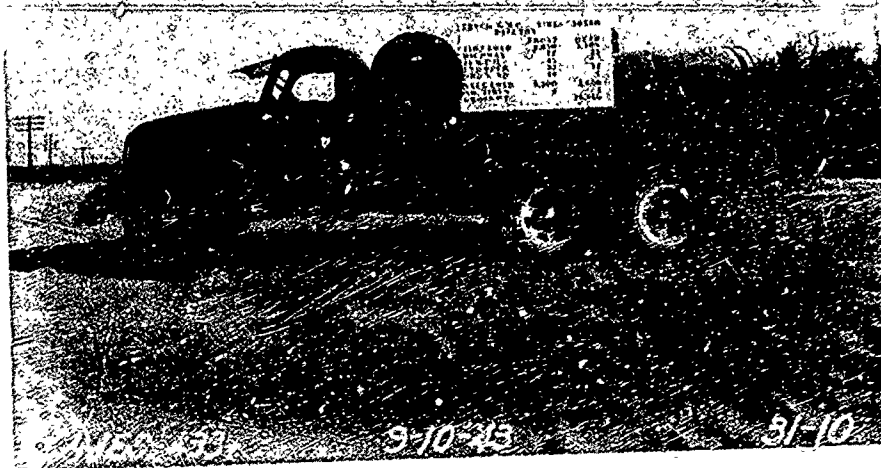
TABLE V  
WHEEL TRACK DATA  
(Measurements in Inches)

Vehicle	GMC		Studebaker		GMC		GMC	
Make	2½-ton, 6 x 6		2½-ton, 6 x 6		2½-ton, 6 x 6		2½-ton, 6 x 6	
Size	Dump		Compressor		Van		Tanker	
Type								
Tire Size	11.00 x 18, 10-ply		11.00 x 18, 10-ply		7.50 x 20, 8-ply		7.50 x 20, 8-ply	
Cen. to Cen. of Tracks	Front	Rear	Front	Rear	Front	Rear	Front	Rear
	Std Mount	70-1/2"	70-1/2"	71-1/4"	68-1/4"	63"	65-3/4"	63-1/4"
Duals-Frt					73-3/4"		74"	
Overall Track Widths								
Std Mount	81-3/4"	81-3/4"	82-1/2"	79-1/2"	71-1/4"	76"	71-1/2"	75-3/4"
Duals-Frt					82"		82-1/4"	
Single Track Widths	11-1/4"	11-1/4"	11-1/4"	11-1/4"	8-1/4"	19"	8-1/4"	19"

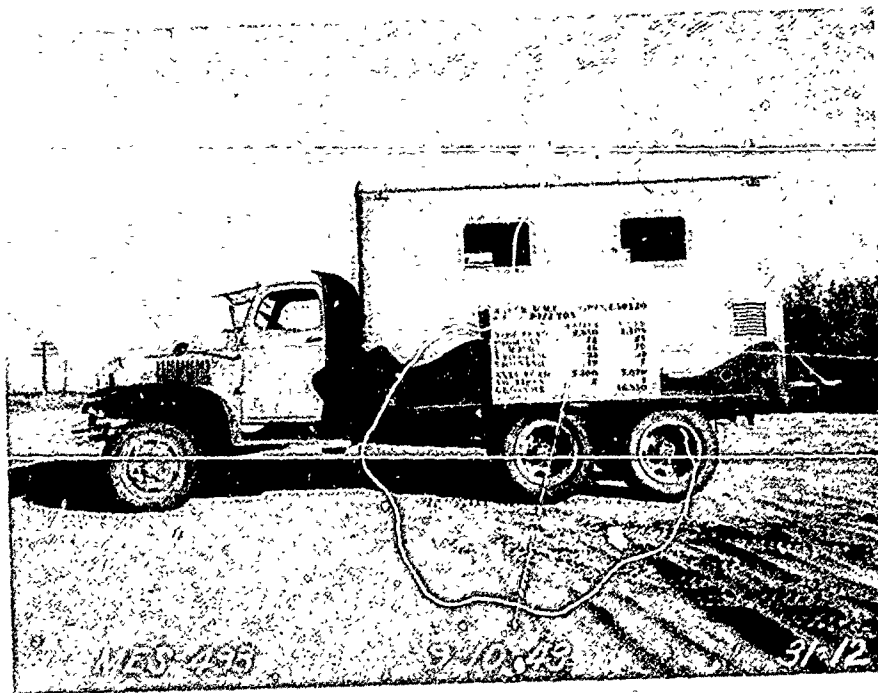
f. Minimum Clearances. Minimum clearances for the front and rear end of each test truck were measured at each of the four inflation pressures used. In each case the minimum clearance was found to be the vertical distance between the lowest point on the differential gear case and the ground. The test trucks were loaded as shown in Table II. Following is a tabulation of the minimum clearances:

TABLE VI  
MINIMUM CLEARANCES IN INCHES

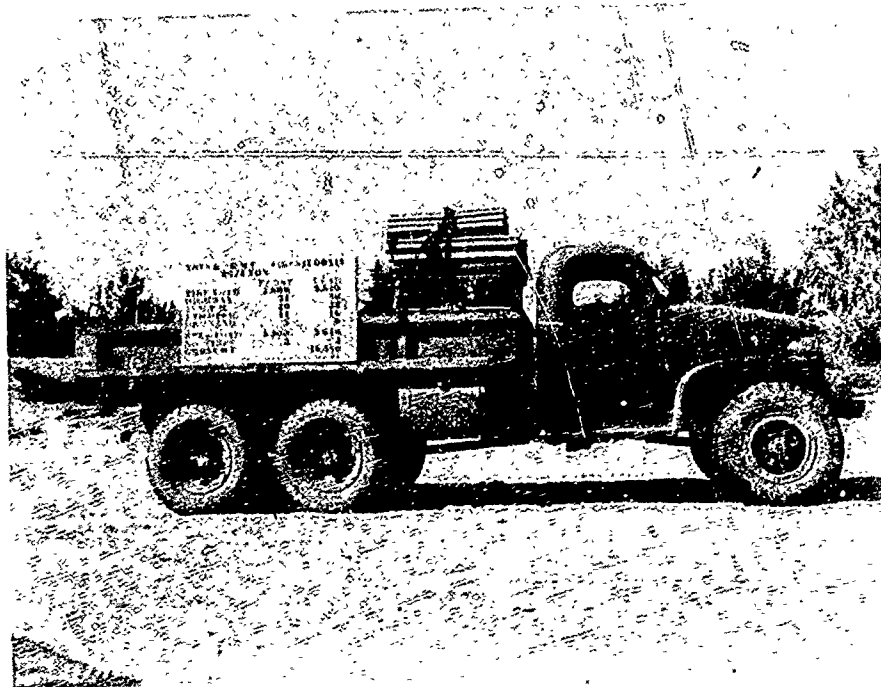
Vehicle	GMC		Studebaker		GMC		GMC	
Make	2½-ton, 6 x 6		2½-ton, 6 x 6		2½-ton, 6 x 6		2½-ton, 6 x 6	
Size	Dump		Compressor		Van		Tanker	
Type								
Tire Size	11.00 x 18, 10-ply		11.00 x 18, 10-ply		7.50 x 20, 8-ply		7.50 x 20, 8-ply	
	Front	Rear	Front	Rear	Front	Rear	Front	Rear
Highway Infl.	11"	11-1/4"	11-1/4"	10-1/4"	9-3/4"	9-1/2"	9-3/4"	9-1/2"
25 mph Infl.	10-5/8"	10-5/8"	10-3/4"	10-3/4"	9-1/2"	9-1/4"	9-1/2"	9-1/4"
Limited Oper.	10-1/4"	10-1/4"	10-3/8"	10-3/8"	9-3/8"	9-1/8"	9-3/8"	9-1/8"
Ord. Sand Min.	9-3/4"	9-5/8"	10"	10"	8-3/4"	8-3/4"	8-3/4"	8-3/4"



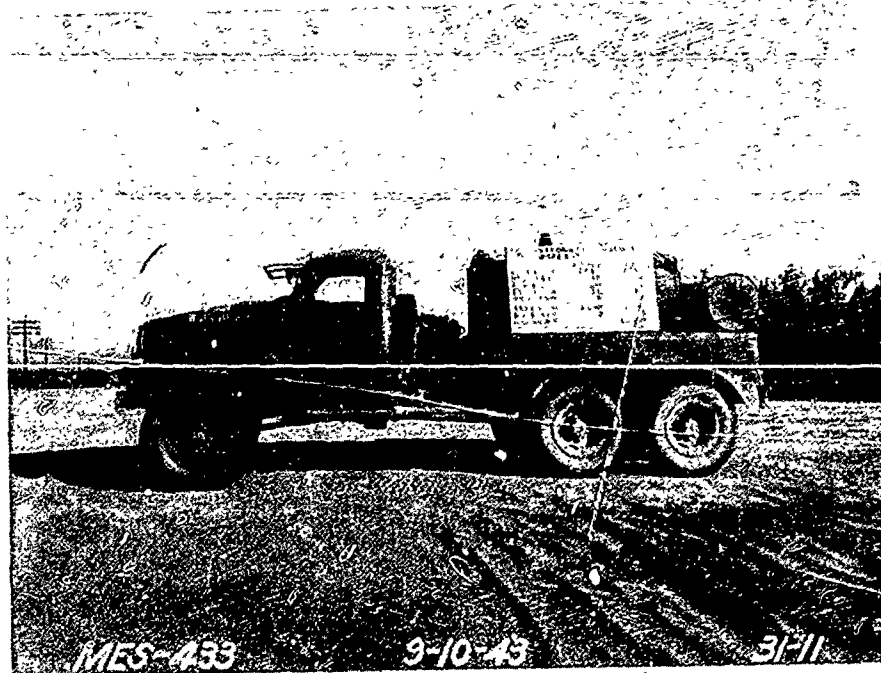
TIRE TESTS IN MUD. G. M. C. 2½-ton Water Tank Truck as used in mud tests. This truck is equipped with 7.50 x 20 tires with singles on front.



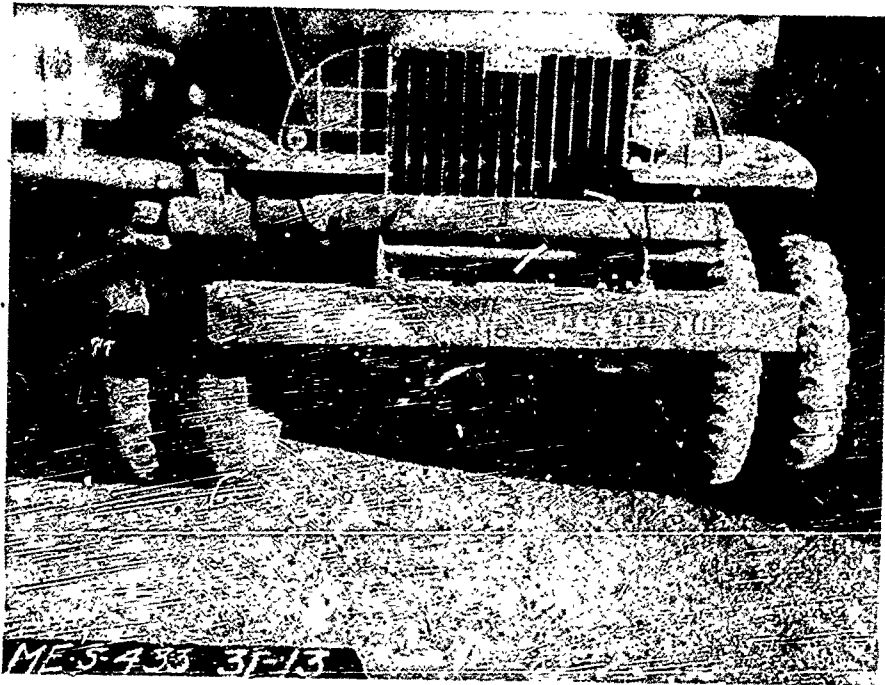
TIRE TESTS IN MUD. G. M. C. 2½-ton Van Body Truck as used in mud tests. This truck is equipped with 7.50 x 20 tires with singles on front.



TIRE TESTS IN MUD. G. M. C. 2 $\frac{1}{2}$ -ton Dump Truck as used in mud tests. This truck is equipped with single low pressure 11.00 x 18 tires.



TIRE TESTS IN MUD. Studebaker 2 $\frac{1}{2}$ -ton Air Compressor Truck as used in mud tests. This truck is equipped with single low pressure 11.00 x 18 tires.



TIRE TESTS IN MUD. G. M. C. 2 $\frac{1}{2}$ -ton Van Body Truck equipped with 7.50 x 20 tires duals in front, as used in mud tests.

9. Types of Tests. Six types of tire tests were conducted, using the four 2½-ton, 6 x 6 test trucks. The types of tests and tire combinations used were as outlined below:

a. Repeated Trip Tests were made with the following tire equipment combinations.

(1) Standard rear duals and front singles against low pressure singles all around.

(2) Standard duals all around against low pressure singles all around.

(3) Standard rear duals and front singles with chains all around against low pressure singles with chains all around.

b. Go or No Go Tests were run with the same tire equipment combinations as outlined under paragraph 9a above.

c. Dynamometer Tests were conducted with the same tire equipment as outlined under paragraph 9a above. These tests were divided into phases to determine:

(1) Tractive Efforts

(2) Rolling Resistances

d. Comparative Hill Climbing Tests were made with the following tire equipment:

(1) Standard rear duals and front singles against low pressure singles all around.

(2) Standard rear duals and front singles with chains all around against low pressure singles with chains all around.

e. Service Durability Tests were run using the same tire equipment combinations as outlined under paragraph 9a.

f. Comparative Mobility Tests were made with the following tire equipment and inflation pressures.

(1) Standard rear duals and front singles against standard rear duals and front duals at Highway Inflation.

(2) Highway Inflation against Ordnance Sand Minimum Inflation using standard rear duals and front singles.

(3) Highway Inflations against Ordnance Sand Minimum Inflations using standard rear duals and front duals.

(4) Highway Inflations against Ordnance Sand Minimum Inflations using low pressure singles all around.

10. Test Procedure. The test procedure for each type of test is summarized in the following outline:

a. Repeated Trip Tests were run in circular and straight tracks.

(1) Circular Tracks. A circle of approximately 100 feet in diameter was described in the mud. The first truck was run with its inside wheels following the described circle as closely as practicable. The inside wheels of the second truck, which was equipped with the competing type of tires, were driven in a concentric track about three feet from the track made by the outside wheels of the first truck. Similarly the third and fourth trucks were driven in concentric circles about three feet from the tracks made by the preceding truck. The relative position of the trucks were varied in each test. The number of trips and the point at which each truck became immobilized were recorded. The trucks were operated in second gear, low range and all-wheel drive. The test was repeated at each of the four inflation pressures listed in Table III but with only standard rear duals and front singles against low pressure singles all around.

(2) Straight Tracks. In making the repeated trip tests in straight track runs the four test vehicles were lined up abreast of each other, alternately spaced as to type of tire equipment, and about 3 feet apart. Starting on comparatively stable ground, the runs were made toward the Salton Sea with the mud condition becoming progressively worse. The trucks advanced in straight parallel lines until each became immobile. Each truck was then backed in its tracks to the starting point, after which it was driven back and forth in the same tracks until it became stuck. If, after making the initial forward trip, the truck became stuck, it was winched back until it was able to back under its own power and the test was continued as in the preceding case. Care was taken, in making the subsequent trips, to advance only to a point a reasonable distance in back of the place where the truck originally became stuck. The distance traveled on the initial trip, the length of the subsequent trips and the point at which the truck was finally immobilized, were recorded. As in the previous described test in circular tracks, the trucks were operated in second gear, low range and all wheel drive. Nine tests were made with the trucks running

in one direction, but using various inflation pressures. That is, the trucks were run as far as possible in a straight line at Highway pressures. When the truck stopped, it was backed out; then the pressures were lowered to 25 mph values and the truck driven forward in the same set of tracks until it stopped. This procedure was repeated utilizing both the Limited Operation and Ordnance Sand Minimum inflation values. The test was repeated with the three different tire equipment combinations and at the four sets of inflation pressures as described previously.

b. Go or No Go Tests. In making these tests the trucks were driven in pairs through the artificially prepared areas, starting at one border and continuing either across the area or until the truck became stuck. In each test the trucks with competing tire equipment were alternated and run so as to straddle one of the wheel tracks of the preceding vehicle. In this manner each truck made new tracks and at the same time traversed mud of comparable consistency. The trucks were operated in low gear, low range and all wheel drive. The distance traveled by each truck, before becoming immobilized, was recorded. Tests were run using the tire equipment combinations outlined in paragraph 9a and at each of the four sets of inflation pressures indicated in Table III.

c. Dynamometer Tests.

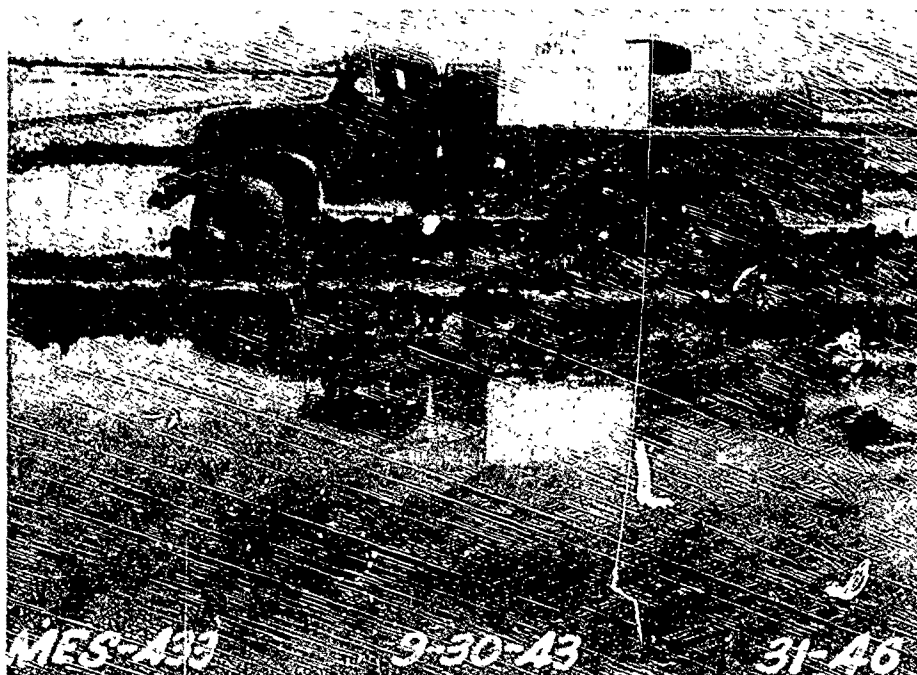
(1) Dynamometer Equipment. The dynamometer used was made by the Martin-Dockor Corporation of Long Beach, California. It is a type that is clamped on a cable to measure cable tension. The capacity of the dynamometer is 20,000 pounds and it has a weight of 12 pounds. The instrument is accurate within a range of plus or minus 5 percent. The force tending to straighten the cable distorts a diaphragm on a liquid-filled case, causing pressure change. It is a force triangle, with the line loads forming two sides, and the pressure exerted by the fluid the other. A dual gauge is used with the dials from 0 to 6000 pounds and 0 to 18,000 pounds. The gauge ranging from 0 to 6000 pounds is used when the load is light because the dial increments are larger. When heavier loads are encountered, the gauge ranging from 0 to 18000 pounds is used. The gauges, which are connected to the diaphragm by non-expanding wire woven hose were mounted in the cab of the truck on which the dynamometer was mounted. The increments on the 6000 pound gauge are 50 pounds and those on the 18000 pound gauge are 200 pounds.



TIRE TESTS IN MUD. General view of mud area at Camp Seeley, before any tests were made.



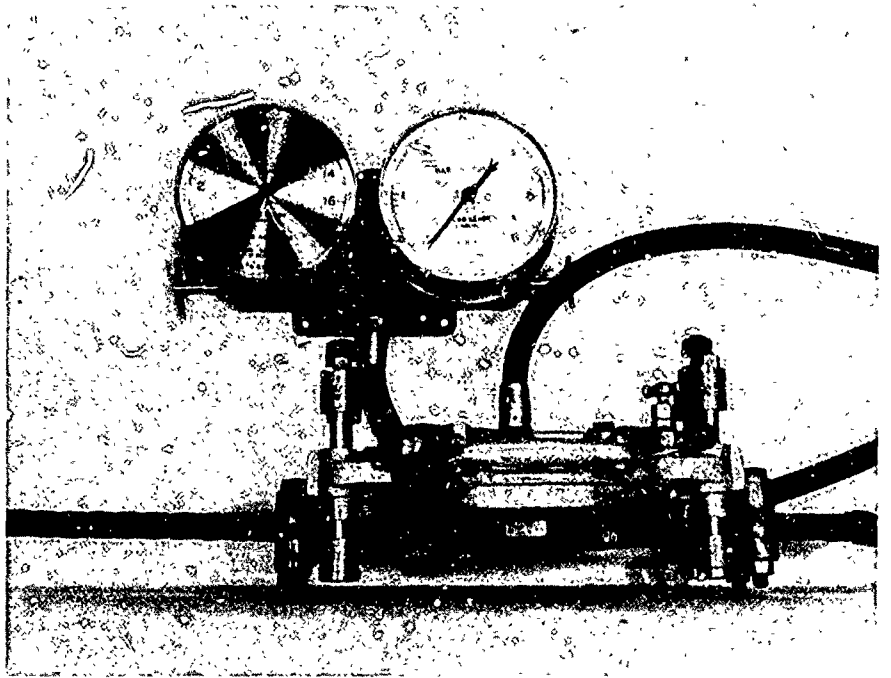
TIRE TESTS IN MUD.  $2\frac{1}{2}$ -ton Studebaker Air Compressor with 11.00-18 tires at Limited Operation inflations stuck in the mud at Camp Seeley.



TIRE TESTS IN MUD. 2½-ton Water Truck with 7.50 x 20 tires; duals in front, at Limited Operation Inflation stuck in the mud at Camp Seeley.



TIRE TESTS IN MUD. General view of mud area at Camp Seeley, at the completion of tests. Note the depth of the tracks made by the trucks.



TIRE TESTS IN MUD. Close up of dynamometer used in tests showing offset in cable and diaphragm.



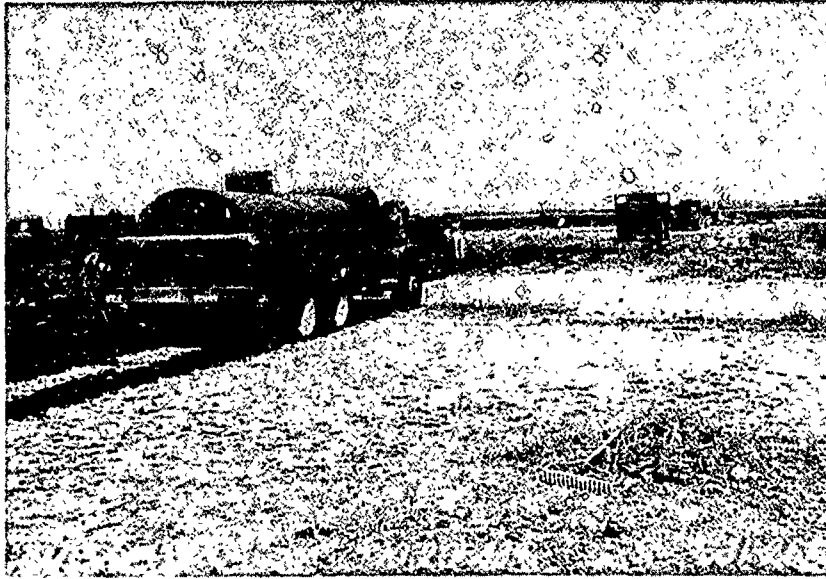
TIRE TESTS IN MUD. View showing dynamometer used in tests and method of mounting dynamometer on dynamometer truck.



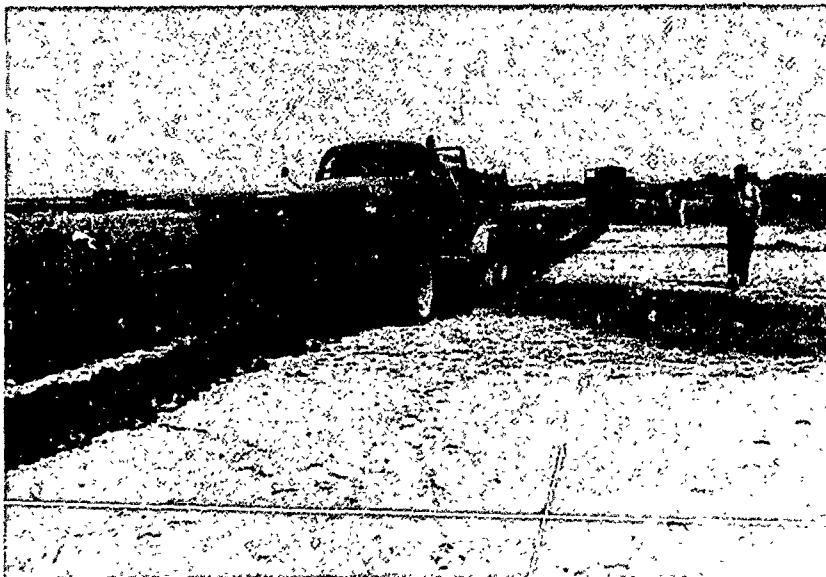
TIRE TESTS IN MUD. View showing gauges of dynamometer and where they were mounted on the dashboard in the cab of the dynamometer truck.

(2) Tractive Effort Tests. The tractive effort tests were made in areas adjacent to those used in the rolling resistance tests. The test trucks were driven forward in the opposite direction from which they were run in making rolling resistance tests. The dynamometer truck supplied the braking load. After the cable was connected between the two trucks, the test vehicle was run in first gear, low range, all wheel drive and the dynamometer truck was driven in an appropriate gear at a progressively slower speed; thereby allowing the compression of the engine to furnish the braking effort. Close control of braking the test vehicle could be obtained in this manner. If the brakes of the dynamometer truck were used, there was a tendency for them to grab. This grabbing invariably caused an impact on the dynamometer which resulted in an abnormally high reading. The trucks were driven in pairs as in the preceding described tests. The trucks with competing tire equipment were driven alternately through the mud, and astride one of the wheel tracks of the preceding vehicle. Approximately five of the highest readings were recorded. The average of the readings on each test is found in Appendix B. Tests were run using the tire equipment combinations outlined in paragraph 9a and at each of the four sets of inflation pressures indicated in Table III.

(3) Rolling Resistance Tests. In making the tests for rolling resistance, a course 100 feet in length was measured off in the muddy area and stakes were placed every 10 feet for use in recording the data. The first test truck was then lined up with the front bumper perpendicular to the line of stakes and about 2 feet distant therefrom. A steel cable, about 100 feet long, was next attached between the test truck and the truck on which the dynamometer was mounted. The dynamometer truck was in turn connected to a third truck equipped with a front-mounted winch, which was employed to winch the dynamometer truck and test truck through the muddy area. The tachometer of the winching truck was held, as nearly as possible, at 900 rpm; thus enabling the test truck to be pulled at a constant rate of speed, approximately 25 feet per minute. Care was exercised to maintain the vehicles in proper alignment with a minimum of steering and as little variation in speed as possible. The winching truck was also kept in proper alignment to insure operation of the winch at a constant rate of speed without stopping to respool the cable. A dynamometer gauge reading was recorded every ten feet. The test procedure was repeated for each test truck. The vehicles were paired as in the preceding described test. The trucks with competing tire equipment were pulled alternately through the mud, and astride one of the



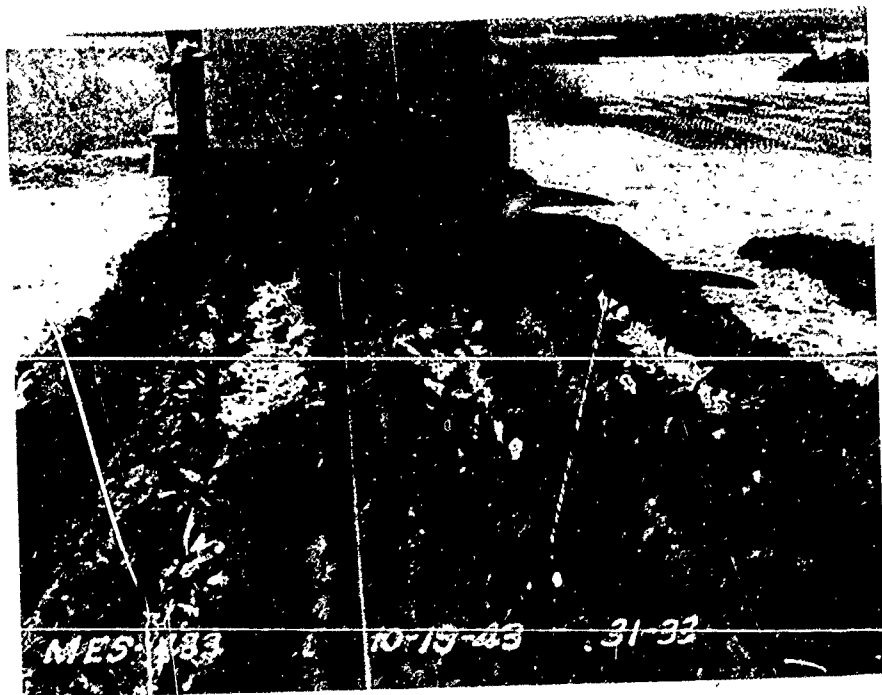
TIRE TESTS IN MUD. General view of method of determining Rolling Resistance. The winch truck in the background pulls the dynamometer truck which in turn pulls the test vehicle through the mud.



TIRE TESTS IN MUD. General view of method of determining Tractive Effort. A cable is connected between the dynamometer and the test vehicle to furnish a lead for developing tractive effort. This cable is long enough to allow the dynamometer truck to stay out of the tracks made by the test vehicle.



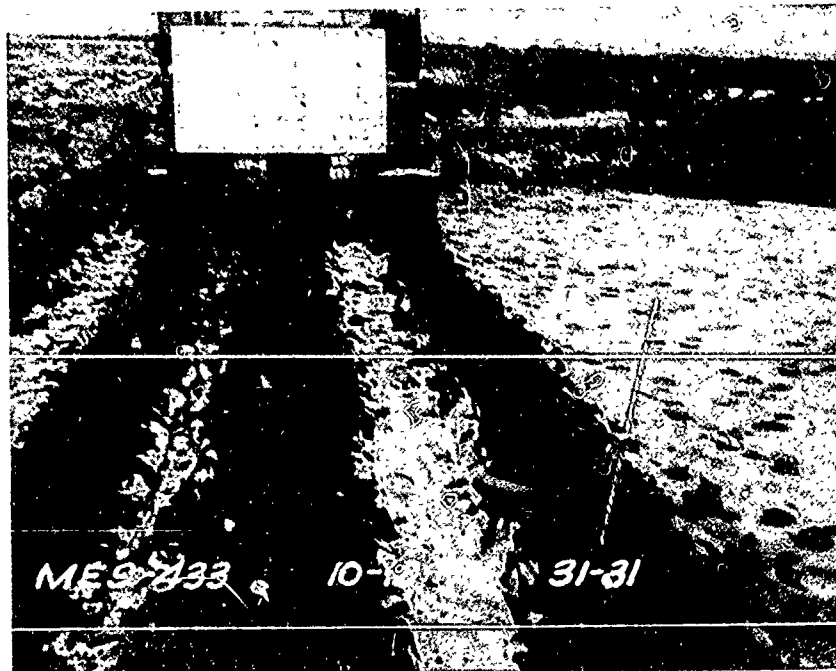
TIRE TESTS IN MUD.  
View of G. M. C. 2 $\frac{1}{2}$ -  
ton Van Body being  
driven through mud  
area to ascertain  
tractive effort.  
The truck is equip-  
ped with 7:50 x 20  
tires and chains at  
Highway Inflatons.



TIRE TESTS IN MUD. Studebaker 2 $\frac{1}{2}$ -ton Air Compressor being driven  
through the mud. It is equipped with 11:00-18 tires and chains at  
Highway Inflatons.



TIRE TESTS IN MUD.  
View of test vehicle  
with 7.50x20 tires  
and chains at High-  
way Inflations. Note  
the width of tracks  
made by this vehicle.  
This truck is being  
pulled through the  
mud area.



TIRE TESTS IN MUD. Studebaker  $2\frac{1}{2}$ -ton Air Compressor being  
pulled through the mud. This truck is equipped with 11.00 x 18  
tires and chains at Highway Inflation.



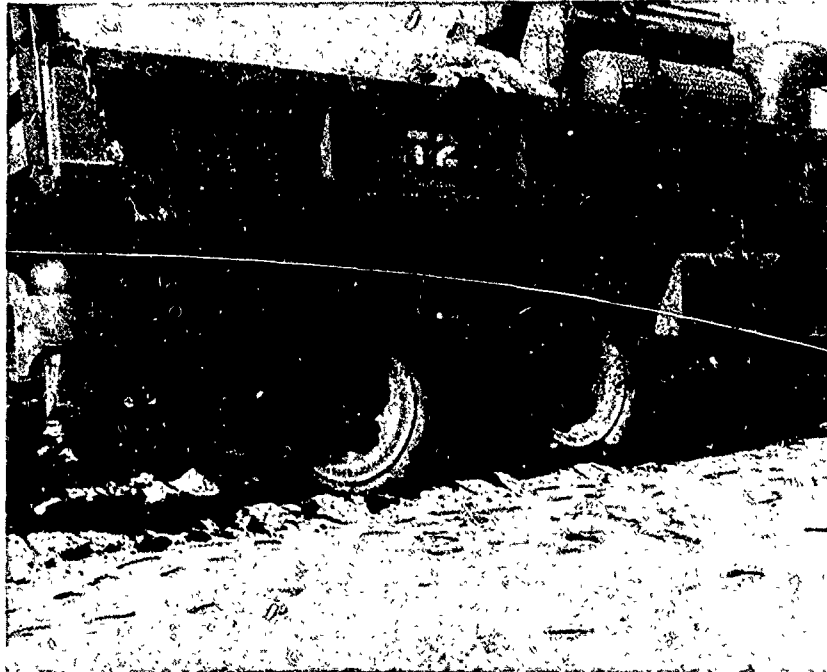
TIRE TESTS IN MUD.  
View of G. M. C.  
2 $\frac{1}{2}$ -ton Water Truck  
with 7.50 x 20 tires  
and duals on front.  
The truck is being  
driven through the  
mud to ascertain  
the tractive effort.  
The tires are at  
25 MPH Inflatations.



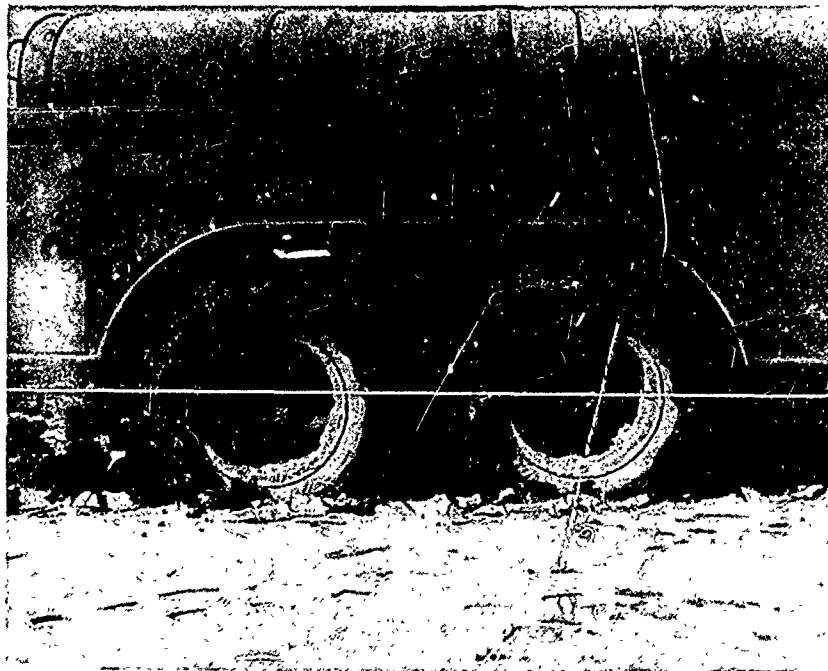
TIRE TESTS IN MUD. View of G. M. C. 2 $\frac{1}{2}$ -ton Dump Truck at 25 MPH Inflatations being driven through the mud on tractive effort tests. This truck is equipped with 11.00-18 low pressure tires. The tracks made by the water truck as described above can be seen in the center of the picture.



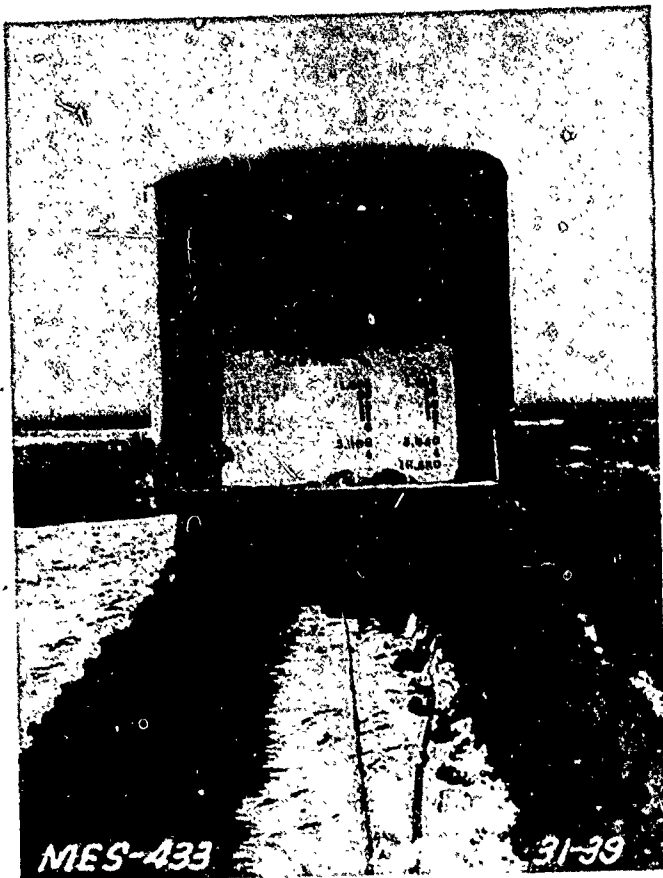
TIRE TESTS IN MUD. View of the tracks made by the four test trucks when being pulled through the mud area. The trucks were at Limited Operation Inflatons.



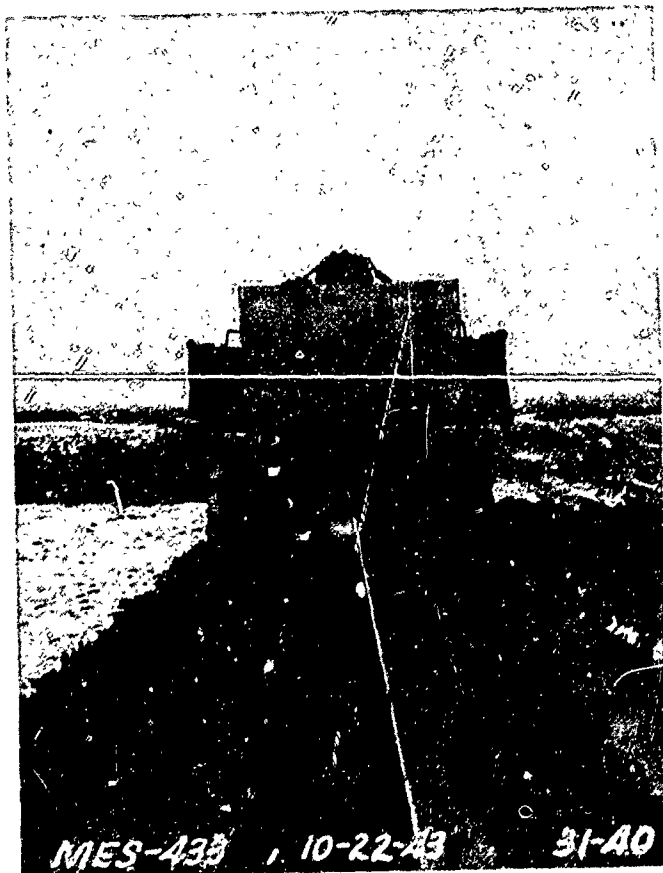
TIRE TESTS IN MUD. View showing Dump Truck with 11.00-18 tires and chains being pulled through the mud and the way the mud gathers on the tires.



TIRE TESTS IN MUD. View of a truck with 7.50 x 20 tires and chains being pulled through the mud and the way the mud gathers on the chains.



TIRE TESTS IN MUD.  
G. M. C. 2 $\frac{1}{2}$ -ton Van  
Body being driven  
through on tractive  
effort tests. The  
Truck has 7.50 x 20  
tires and chains  
at Ordnance Sand  
Minimum Inflation.

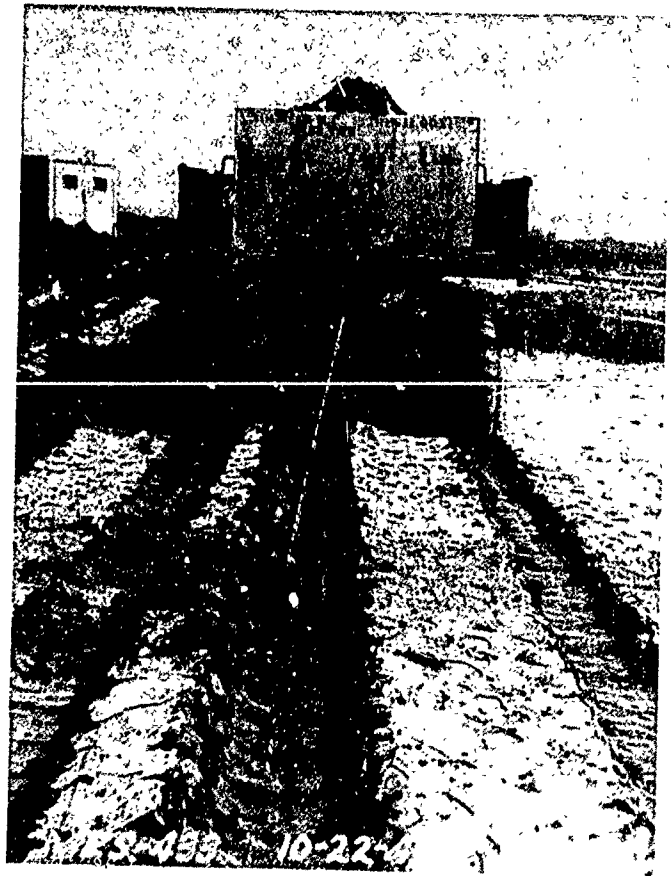


TIRE TESTS IN MUD.  
View of Dump Truck  
with 11.00-18 tires  
and chains at Ord-  
nance Sand Minimum  
Inflation. The  
truck is being driven  
through the mud on  
tractive effort tests.



TIRE TESTS IN MUD.  
 G. M. C. 2 1/2-ton Van  
 Body being pulled  
 through the mud.  
 The truck is equip-  
 ped with 7.50 x 20  
 tires and chains  
 at Ordnance Sand  
 Minimum Inflation.

TIRE TESTS IN MUD.  
 View of Dump Truck  
 with 11.00-18 tires  
 and chains at Ord-  
 nance Sand Minimum  
 Inflation. The  
 truck is on rolling  
 resistance tests.



wheel tracks of the preceding vehicle. Tests were run using the tire equipment combinations outlined in paragraph 9a and at each of the four sets of inflation pressures indicated in Table III. The data on these tests are attached to this report as Appendix B.

d. Comparative Hill Climbing Tests. Comparative hill climbing tests were conducted in the sand-clay hill area about four miles east of Thermal. The test ramps, each about 110 feet in length, were wetted with water in an attempt to create a slippery condition on the approximately twenty percent slope. The trucks were then driven up the ramps with the succeeding trucks running in the tracks made by the first vehicle. In each test the vehicles were alternated. The trucks were started from the same place at the bottom of the ramp and run in low gear, low range and all wheel drive. The distance the trucks were able to climb up the slope and the ease in which they negotiated the ramp was recorded. Tests were run using different tire combinations and the four sets of inflation pressures indicated in Table III.

e. Service Durability Tests. The tests covered under this heading consisted of the accumulated mileage put on the test trucks during the entire testing period. They were carried on incidental to the previously described tests, being largely a result of the distances traveled between the test areas and the Desert Warfare Section headquarters. Approximately 75 percent of this travel was on paved highways and the balance on graded desert roads and in the mud test areas. Speedometer readings, for each test vehicle, were recorded at the start of the test program and again at the conclusion of the tests. All highway travel was made using the "Highway Inflation" given in Table III. About 12 percent of the travel with the standard 7.50 x 20 tires was with duals all around. The total mileage covered by all the test trucks was 5670 miles. A tabulation of the mileages for each test truck is included in Appendix B attached to this report.

f. Relative Mobility Tests. The trucks were run from the same starting point and as close together as possible so the conditions would be comparable. As the trucks advanced the mud conditions became progressively worse. The distance each truck traveled before becoming immobile was recorded. The results of these tests are attached to this report as Appendix B.

#### 11. Physical Characteristics of Mud.

a. Soil Analysis. Frequent mud samples were obtained from which the physical properties of the soil were determined. Grain sizes and grading of the materials were determined by mechanical analysis. Moisture content was ascertained from

samples taken from the bottom of the tire tracks and sealed in water tight containers. Other characteristics determined were plastic limit, liquid limit and plasticity index. All samples were submitted to the Los Angeles District Engineer Office. The results of the soil tests are included on the data sheets, for the respective tests, in Appendix B attached to this report.

b. Penetrometer Tests. Penetrometer readings were taken at frequent intervals on each test course before and in some cases after the tire tests. The readings provided an index of the relative stability of the mud. The device used was a Proctor penetrometer with a modified needle, which measures the force necessary to push a small diameter metal rod (the needle) a given depth in the mud. Readings were observed at 3, 6, 8 and 12 inch depths. Recordings of the penetrometer readings for the majority of the test courses are included on the data sheets attached to this report as Appendix B.

## 12. Weather, Temperature and Humidity.

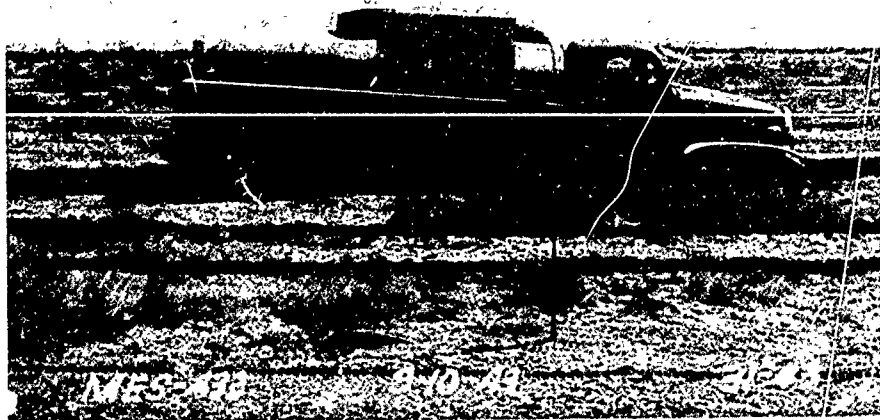
a. General Weather Conditions. Weather conditions, during the test period, were quite constant. There were no high winds and only two slight rains occurred, neither of which affected the tests materially.

b. Temperature. Ambient air temperatures observed during the test period averaged approximately 105 degrees Fahrenheit, with a minimum of 93 degrees and a maximum of 113 degrees during the hours of testing.

c. Humidity. For the test period the average humidity was 50 percent, with a minimum of 46 percent and a maximum of 54 percent.



TIRE TESTS IN MUD. View of G. M. C. 2 $\frac{1}{2}$ -ton Van Body Truck with the front wheels practically buried in the mud. Trucks with standard tires invariably get stuck in mud with the front wheels buried.



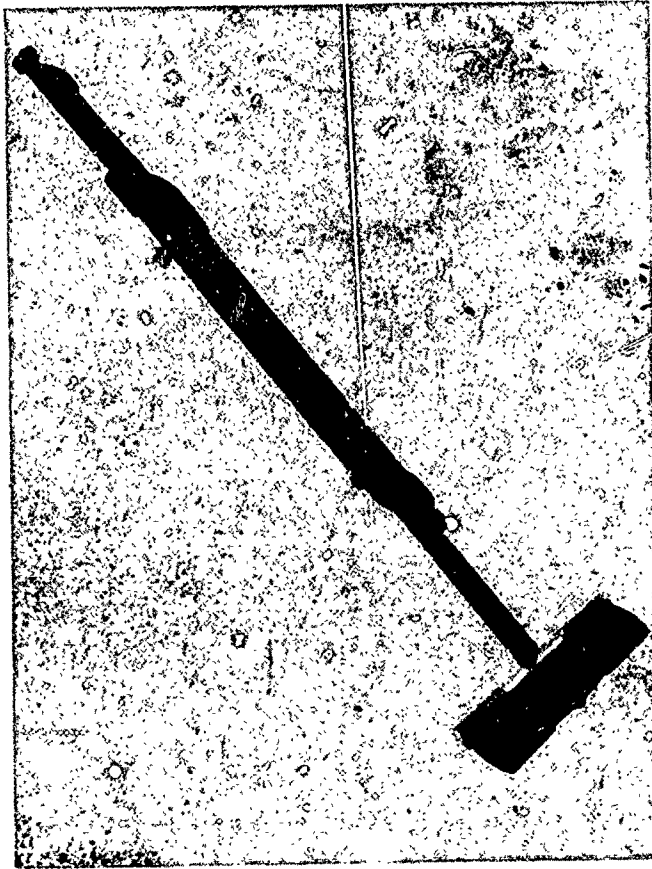
TIRE TESTS IN MUD. G. M. C. 2 $\frac{1}{2}$ -ton Water Truck stuck in the mud with the front axle dragging. The loadings on the front end of the test vehicles caused them to drag on the front axle. When duals were put on the front due to the pressure of better flotation, whenever the trucks bogged down it was in the rear.



TIRE TESTS IN MUD. View of G. M. C. 2 $\frac{1}{2}$ -ton Water Truck stuck in mud. This truck is equipped with 7.50 x 20 tires and is at Limited Operations Inflation. The truck in this picture is dragging on both axles.



TIRE TESTS IN MUD. View of test vehicle stuck in the mud. This truck is equipped with 7.50 x 20 tires; duals in front, with 25 MPH Inflation pressures. Note how deep the truck has sunk in the mud.



TIRE TESTS IN MUD.  
Penetrometer used to determine softness of mud. The penetrometer consists of two parts, the stock and the needle. In this picture a short needle is attached to the stock, while in most cases in mud a needle 12" long, with a head of  $\frac{1}{2}$  sq. in. cross sectional area was used.

TIRE TESTS IN MUD.  
View showing method of using penetrometer. One man uses penetrometer and another records the readings.



13. SUMMARY AND ANALYSIS OF RESULTS

GO-NO-GO TESTS

Tire Size	Type of Mounting	Inflation	Repeated Trips			Camp Seeley			Totals		
			No. of Tests	Feet Traveled	% Dif-ference	No. of Tests	Feet Traveled	% Dif-ference	No. of Tests	Feet Traveled	% Dif-ference
7.50-20 11.00-18	Standard Singles	Highway	3	1,635	30	2	197	14	5	1,832	28
			3	2,120		2	224		5	2,344	
7.50-20 11.00-18	Standard Singles	25 m.p.h. 25 m.p.h.	3	1,425	28	2	145	5	5	1,570	24
			3	1,110		2	152		5	1,262	
7.50-20 11.00-18	Standard Singles	Limited Oper.	4	1,805	1	1	122	117	5	1,927	8
			4	1,825		1	265		5	2,090	
7.50-20 11.00-18	Standard Singles	Ord. Sand Min.	3	1,400	4	1	124	48	4	1,524	8
			3	1,458		1	184		4	1,642	
7.50-20 11.00-18	Duals All Around Singles	Highway	4	1,140	37	1	92	1	5	1,232	34
			4	1,557		1	91		5	1,648	
7.50-20 11.00-18	Duals All Around Singles	25 m.p.h. 25 m.p.h.	4	1,911	0.2	2	299	9	6	2,210	1
			4	1,907		2	274		6	2,181	
7.50-20 11.00-18	Duals All Around Singles	Limited Oper.	3	1,387	30	1	312	74	4	1,699	16
			3	1,798		1	179		4	1,977	
7.50-20 11.00-18	Duals All Around Singles	Ord. Sand Min.	5	1,698	51	1	182	1	6	1,880	46
			5	2,561		1	184		6	2,745	

GO-NO-GO TESTS

Tire Size	Type of Mounting	Inflation	Repeated Trips			Camp Seeley			Totals		
			No. of Tests	Feet Traveled	% Dif-ference	No. of Tests	Feet Traveled	% Dif-ference	No. of Tests	Feet Traveled	% Dif-ference
7.50-20	Chains	Highway	3	1,029		1	63		4	1,092	
11.00-18	Chains	Highway	3	1,269	23	1	152	141	4	1,421	30
7.50-20	Chains	25 m.p.h.	6	2,528		1	53		7	2,581	
11.00-18	Chains	25 m.p.h.	6	2,691	6	1	133	151	7	2,824	9
7.50-20	Chains	Limited	6	2,431	0.7	1	71		7	2,502	
11.00-18	Chains	Oper.	6	2,415		1	202	185	7	2,617	5
7.50-20	Chains	Ord. Sand	6	2,229		1	63		7	2,292	
11.00-18	Chains	Min.	6	2,280	2	1	182	189	7	2,462	7

\* % Difference is calculated using smaller figure as 100%.

## IV DISCUSSION

### 14. General.

a. Tire Gauges. Tire inflation pressures were checked frequently with small Bourdon spring-type gauges. Three of the gauges used were calibrated by the City of Los Angeles, Department of Public Works, Bureau of Standards. The results of the calibration tests are attached as Appendix C. The largest of these gauges was kept as a standard gauge in a box in the office so that it would not be subjected to injury. Two other gauges were calibrated using this standard gauge and weekly all the gauges were checked against this standard gauge.

b. Condition of Mud. It must be remembered in reviewing the data and results of these tests that mud varies from one location to another. Tests were made under only two varying conditions of mud; therefore they cannot be considered as conclusive of the performance of these tires under all mud conditions. Every test should be considered as complete in itself. The condition of all mud changes so rapidly from one location to another that the mud conditions must be analyzed before tests may be compared.

### 15. Analyses of Data.

#### a. Go-No-Go Tests.

(1) The Go-No-Go type of tests are considered as most valid. In these tests, the mud conditions were controlled, hence were as nearly consistent as possible. This type of test is believed to give the most conclusive results of mobility, and will be used extensively with varying mud conditions in future testing. It was found that the trucks irrespectively of the size tires with which they were equipped would travel farther in mud if the front wheels were slightly and slowly oscillated from side to side.

(2) In the Straight Track, Repeated Trip Tests, the distance traveled in the initial trip may be considered as Go-No-Go tests. An analysis of the Go-No-Go tests and of the initial trips of the Repeated Trip, Straight Track tests is made in the Summary and Analysis of Results. The percentage difference between the results of the two tire sizes at a given inflation and tire mounting was calculated, using the smaller figure as 100%. Three trucks instead of four were used in a few tests. In these tests only two trucks were compared. In any one comparison the same two trucks were always used.

b. The following tests are considered to be of little value.

(1) Repeated Trip Tests. This type of test was devised to simulate the convoy conditions of trucks following in the same tracks of preceding vehicles.

(a) Circular Tracks. The circular tracks were utilized to allow the trucks to always run forward. It was found that the trucks on the inside course became stuck more frequently than the others, due to their having to make the sharpest turn. The results are not considered pertinent because of the variation in sharpness of the turnings to which all the trucks were subjected. It is suggested that no future tire testing be made utilizing circular tracks. The test area used contained numerous soft spots which caused the trucks to become stuck prematurely. Therefore, the results have not been considered in making the conclusions.

(b) Straight Tracks. Straight tracks were used to eliminate the turning necessary on circular tracks. In this test the length of the course for each truck was not equal, and the mud conditions varied greatly, becoming more severe as the length of the course increased. Therefore, the results of the repeated trip tests cannot be considered pertinent although the initial trips have been considered as valid Go-No-Go tests. If, in future testing, the straight track repeated trip type tests are to be used, it would be advisable to run the trucks over the same length course and in one direction only. In backing through the original tracks, it was noted that the rear wheels seem to do more compacting than if the truck were only being run in one direction.

(2) Dynamometer Tests. An area was used in which all the trucks were able to travel at least 100 feet. The mud condition was much less severe than encountered during the other type tests; hence did not provide an adequate test for the low pressure tires. It is possible that the gear ratio of the trucks equipped with 11.00 x 18 tires should be changed to accommodate the larger tires. Therefore the results of these tests are believed to be invalid.

(3) Comparative Hill Climbing Tests. In addition to the mud flotation and traction tests, hill climbing trials were made. The trucks were run on a twenty percent slope. The ramps were composed of sandy clay soil. The consistency of the mud on the ramps was changed from time to time by artificial wetting. The results cannot therefore be compared

except where the conditions were the same, as noted on the data sheets in Appendix B. The results of these tests show that it did not improve hill climbing ability when lower inflation pressures were used, but that when the trucks were equipped with chains, their mobility on slopes is greatly increased.

16. Mobility of Trucks.

a. The mounting of duals on the front of the truck equipped with 7.50 x 20 tires increased the mobility 44 percent. The flotation is greatly increased when duals are mounted all around.

b. The mobility of the trucks was increased from 16 to 40 percent when the inflation pressures were lowered. The gross contact area of the tire is increased by lowering the inflation pressures and therefore better flotation can be expected.

17. Advantages of Chains. Standard 7.50 x 20 chains were used on the 7.50 x 20 tires and 9.00 x 20 chains were used on the 11.00 x 18 tires. It was found that a truck equipped with chains went 120 percent farther than a truck without chains. The use of chains all around affords a noticeable increase in traction because the flexing action of loosely fitted chains cleans the tire of mud.

18. Piling up of Mud. It was noted that mud has a tendency to continually pile up ahead of the center duals on trucks equipped with 7.50 x 20 tires. This condition invariably resulted in quicker immobility of the vehicle than resulted with the 11.00 x 18 tired trucks when the conditions were the same.

19. Ease of Steering. Steering on pavements or hard surfaced roads was found to be slightly easier with a truck equipped with standard 7.50 x 20 tires as compared with a truck equipped with 11.00 x 18 tires. When operating off-road, in mud or loose material of any sort, steering was easier with trucks equipped with 11.00 x 18 low pressure tires as against 7.50 x 20 tires, either singles or duals on front.

20. Fender Clearance. In operating over extremely rough terrain, it was noted that the tires would rub on the fenders of trucks equipped with 11.00 x 18 tires, due to the bogie action of the rear wheels.

21. Service Durability Tests. In the total of 5,690 miles traveled with the test trucks not a single tire failure occurred. No premature tube failures resulted even though the tires were deflated to the Ordnance Sand Minimum inflations during a considerable portion of the test period. The tires did not slip on the rims, even after all the trucks had been driven at a rate of 16 mph for 2 miles at Ordnance Sand Minimum inflations. No tires or tube slippage was noted during the tests. It is believed by the writers that when bead rings are used, it is feasible to use these low pressures without premature tire or tube failures.

## V CONCLUSIONS

22. Based on the results of the tests covered in this report and on tests previously conducted in sand by this Section, it is concluded that:

- a. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck is better when equipped with 11.00 x 18 low-pressure tires than when equipped with 7.50 x 20 8-ply standard military tires, singles on the front wheels.
- b. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck with 7.50 x 20 tires is improved by dualing the front wheels.
- c. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck equipped with either 7.50 x 20 or 11.00 x 18 tires is increased with reduction of tire pressures.
- d. "Mud-mobility" of the standard  $2\frac{1}{2}$ -ton truck equipped with either 7.50 x 20 or 11.00 x 18 low pressure tires is improved by the use of tire chains.
- e. The standard  $2\frac{1}{2}$ -ton truck, without modifications, is easier to steer cross country, when equipped with 11.00 x 18 tires.
- f. The standard  $2\frac{1}{2}$ -ton truck, without modifications, is easier to steer on the highway, when equipped with 7.50 x 20 tires.
- g. The use of the Firestone taper wedge bead ring allows both the 7.50 x 20 and 11.00 x 18 tire to be run at Ordnance Sand Minimum Inflation for emergency operation, without premature tire or tube failure.
- h. The standard  $2\frac{1}{2}$ -ton truck should be modified to give additional fender clearance to adequately accommodate the 11.00 x 18 tire.
- i. Tests by the Desert Warfare Section under the conditions available indicate that the only satisfactory method for determining the relative performance in mud of the standard  $2\frac{1}{2}$ -ton truck, with various tire combinations, is the "go-no-go method".
- j. The standard  $2\frac{1}{2}$ -ton truck, with rated payload, when equipped with 11.00 x 18 tires can negotiate a 23 percent grade in dry dune sand; whereas the same truck when equipped with 7.50 x 20 tires can barely negotiate a flat stretch of flat dry dune sand.

k. The standard 2½-ton truck has greater clearance when equipped with 11.00 x 18 tires than with 7.50 x 20 tires; therefore allowing better mobility for any operation other than highway.

## VI. RECOMMENDATIONS

23. It is recommended that:

a. To improve the performance of 2½-ton, 6x6 trucks in mud of the type in which the tests were made, 11.00 x 18 10-ply non-directional tires be used in preference to 7.50 x 20 8-ply non-directional tires.

b. If trucks are supplied with standard 7.50 x 20 tires the front wheels be dualled for increased "mud-mobility".

c. Chains be used on both 7.50 x 20 tires and 11.00 x 18 tires to give added "mud-mobility".

d. Reduced tire inflation pressures be used for increased "mud-mobility".

*C. C. Huskison*  
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Engineer (Civil)

*Martin R. Leidig*  
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Asst. Engineer (Civil)

*John MacClarence*  
John MacClarence, Major, C.E.  
Chief, Desert Warfare Section

APPENDIX "A"

Directive  
Authorizing  
Testing of 11.00 x 18 10-ply  
Low Pressure Tires

TECHNICAL DIVISION IV  
THE ENGINEER BOARD  
FORT BELVOIR, VIRGINIA

Date: 11 August 1943

Serial No: 36

E. B. Form No. 104.3.

Subject: Directive for (Desert Warfare ) Section.

A (written directive signed by) Captain Glenn D. Ferguson

was received this date from Technical Division III

Authority: Letter from OCE to EB dated 5/28/43, file CE 451.92, EB 400.1  
(MES 433), subject: Service on Tires.

requesting that the following work be done under

<u>Project No:</u>	<u>File No:</u>	<u>Date</u>
MES 433	400.1 (MES 433)	2 August 1943

Directive: Desert Warfare Section to assist the Transportation Development Branch of the Engineer Board in testing of 14:00 x 20-12 ply and 11:00 x 18-10 ply low pressure tires. Schedule of test program is being prepared jointly by Transportation Development Branch and Desert Warfare Section and will be forwarded to Technical Division IV for approval when completed.

Completion Date: Funds Authorized: None other than  
MES 433

Date Received (Desert Warfare Section) : 17 August 1943

Estimated Completion Date: 1 Dec 1943 Persons Assigned to Job:

Date Completed:

Mr. R. C. Kerr  
Mr. C. C. Huskisch  
Mr. M. R. Leidig

RETURN TO TECHNICAL DIVISION IV UPON COMPLETION OR CANCELLATION OF PROJECT

Distribution:  Colonel Goerz

Director, Technical Division I  
Director, Technical Division II  
 Director, Technical Division III  
 Director, Technical Division IV  
Director, Service, Admin., & Supply Division  
 Chief, Desert Warfare Section (6)  
Chief, Mountain Warfare Section  
 Control and Reports Branch

C O P Y

APPENDIX "B"

Test Data

Of Tire Tests in Mud  
With 7.50 x 20 8-ply and  
11.00 x 18 10-ply Tires.

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Supplementary Data	111

SUMMARY OF DATA OF TESTS NOS. 1 - 93

Tire Size	Type of Mounting	Inflation	Repeated Trips		Repeated Trips		Repeated Trips		Repeated Trips		Go-No-Go	
			No. of Trucks	No. of Trips	No. of Trucks	No. of Trips	No. of Trucks	No. of Trips	No. of Trucks	No. of Trips	No. of Trucks	No. of Trips
7.50-20	Standard	Highway	8	87.75	5	28,035	-	-	-	-	4	197
11.00-18	Singles	"	9	145.41	6	20,545	-	-	-	-	4	224
7.50-20	Standard	25 m.p.h.	5	65.5	5	11,750	-	-	-	-	4	145
11.00-18	Singles	"	5	25.0	4	8,795	-	-	-	-	4	152
7.50-20	Standard	Limited	8	87.875	7	40,165	-	-	-	-	2	122
11.00-18	Singles	Oper.	8	156.25	8	79,915	-	-	-	-	2	265
7.50-20	Standard	Ord. Sand	6	79.5	5	32,540	-	-	-	-	2	124
11.00-18	Singles	Min.	6	139.5	6	40,413	-	-	-	-	2	184
7.50-20	Duals All	Highway	-	-	1	240	3	1,710	-	-	2	92
11.00-18	Around	"	-	-	2	390	6	5,355	-	-	2	91
7.50-20	Duals All	25 m.p.h.	-	-	1	8,743	3	2,782	-	-	4	299
11.00-18	Around	"	-	-	2	17,249	5	4,847	-	-	4	274
7.50-20	Duals All	Limited	-	-	1	11,975	2	1,690	-	-	2	112
11.00-18	Around	Oper.	-	-	2	18,040	4	4,712	-	-	2	179
7.50-20	Duals All	Ord. Sand	-	-	1	6,382	2	878	-	-	2	182
11.00-18	Around	Min.	-	-	2	15,847	4	2,742	-	-	2	184

SUMMARY OF RESULTS

Tire Size	Type of Mounting	Inflation	Repeated Trips		Repeated Trips		Repeated Trips		Go-No-Go	
			Circular Tracks	Straight Tracks	Straight Tracks	Straight Tracks	Straight Tracks	Straight Tracks	Constant Press.	Constant Press.
			No. of Trips	No. of Feet	No. of Feet	No. of Feet	No. of Feet	No. of Feet	No. of Feet	No. of Feet
7.50-20	Chains	Highway	-	-	3	1,371	-	-	2	63
11.00-18	"	"	-	-	6	2,392	-	-	2	152
7.50-20	Chains	25 m.p.h.	-	-	6	3,053	5	23,367	2	53
11.00-18	"	"	-	-	12	4,891	5	21,631	2	133
7.50-20	Chains	Limited	-	-	6	2,431	3	11,953	2	71
11.00-18	"	Oper.	-	-	12	4,364	3	10,217	2	202
7.50-20	Chains	Ord. Sand	-	-	5	2,229	-	-	2	63
11.00-18	"	Min.	-	-	12	4,153	-	-	2	182

\*Trucks run as far as possible at Highway Inflation; then backed up, pressure lowered to 25 m.p.h. inflation and driven in the same tracks until stuck. Procedure repeated for Limited Operation and Ordnance Sand Minimum Inflation.

\*\*If truck not stuck after having completed predetermined course, it was stopped, backed to start and repeated trips made.

SUMMARY OF RESULTS

Dynamometer Tests

<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>No. of Tests</u>	<u>Tractive Effort</u>	<u>Rolling Resistance</u>
7.50-20 11.00-18	Standard Singles	Highway "	4 4	9,935 9,150	9,248 6,336
7.50-20 11.00-18	Standard Singles	25 m.p.h. "	4 4	13,166 10,869	9,576 6,145
7.50-20 11.00-18	Standard Singles	Limited Oper. "	4 4	5,360 5,853	13,035 8,555
7.50-20 11.00-18	Standard Singles	Ord. Sand Min. "	4 4	7,670 7,689	11,000 6,843
7.50-20 11.00-18	Duals All Around Singles	Highway "	4 4	8,030 5,341	9,170 7,770
7.50-20 11.00-18	Duals All Around Singles	25 m.p.h. "	4 4	7,793 6,115	8,990 7,625
7.50-20 11.00-18	Duals All Around Singles	Limited Oper. "	4 4	6,505 4,825	8,405 6,400
7.50-20 11.00-18	Duals All Around Singles	Ord. Sand Min. "	4 4	9,355 7,160	10,275 9,275

SUMMARY OF RESULTS

Dynamometer Tests

<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>No. of Tests</u>	<u>Tractive Effort</u>	<u>Rolling Resistance</u>
7.50-20 11.00-18	Chains "	Highway "	4 4	7,822 9,430	12,625 9,965
7.50-20 11.00-18	Chains "	25 m.p.h. "	4 4	8,472 8,700	14,195 9,780
7.50-20 11.00-18	Chains "	Limited Oper. "	4 4	8,451 8,635	15,300 9,290
7.50-20 11.00-18	Chains "	Ord. Sand l.n. "	4 4	1,285 1,770	12,845 7,920

REPEATED TRIPS CIRCULAR TRACKS

Test No.	Date 1943	Time	Site	Inflation	Truck	Dia. of Track	Circumference Ft.	No. of Trips	Total No. of Feet Traveled	Aver. Pen. Depth Inches	Stuck at Sta. Number	Penetrometer Readings												Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index												
												Before Test			At Bottom of Track																								
											Sta No.	3"	6"	9"	12"	15"	18"	21"	24"	27"	30"	33"	36"	39"	42"	45"	48"	51"	54"	57"	60"								
1	13	7:50-20	Hwy	Hwy (Opt'l)	GMC Van	125.0	392.70	14.0	5,497.8	13.0	Between #1 & #6	1	48	110	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	32.0	35.9	21.9	14.0				
1	13	7:50-20	Hwy	Hwy (Opt'l)	GMC Van	174.5	538.78	21.0	11,314.4	9.5	Between #5 & #6	5	30	54	104	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	29.8	25.5					
1	13	11:00-18	Hwy	Hwy	GMC Dump	152.0	477.52	45**	24,831.0	15.0	None	5*	28	40	60	92	110	128	140	140	140	140	140	140	140	140	140	140	140	140	140	27.1	33.8	22.5	11.3				
2	14	7:50-20	25 MPH	25 MPH	GMC Van	113.0	355.00	16.0	5,680.0	9.0	None	2	30	60	74	102	140	140	140	140	140	140	140	140	140	140	140	140	140	140	26.0	31.8							
2	14	7:50-20	25 MPH	25 MPH	GMC Tank	165.0	438.36	45**	23,226.2	11.0	None	2	30	30	92	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	32.3	38.1	25.4	12.7				
3	16	7:50-20	Ltd. Oper	Ltd. Oper	GMC Van	184.5	579.63	0.12	72.5		Between #1 & #2	1	38	84	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	26.6							
3	16	7:50-20	Ltd. Oper	Ltd. Oper	GMC Tank	131.0	411.55	1.5	617.3	5.0	Between #2 & #3	2	18	115	130(8*)	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	28.5							
3	16	11:00-18	Ltd. Oper	Ltd. Oper	GMC Dump	109.5	344.00	3.5	1,204.0	5.5	Between #5 & #6	5	25	41	76	130(10*)	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	30.8							
3	16	11:00-18	Ltd. Oper	Ltd. Oper	Stude Coup	159.5	501.09	5.25	2,630.7	9.0	Between #3 & #4	4	32	40	120	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	30.4	37.1	23.9	13.2				
4	17	7:50-20	Ord. Sand	Ord. Sand	GMC Van	190.5	598.47	0.25	149.6	8.5	None	1	28	50	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140				
4	17	7:50-20	Ord. Sand	Ord. Sand	GMC Tank	134.0	420.57	6.75	2,841.5	7.0	None	6	20	20	62	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140			
4	17	11:00-18	Ord. Sand	Ord. Sand	GMC Dump	152.0	477.52	4.0	1,901.1	6.5	None	0	28	44	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140			
4	17	11:00-18	Ord. Sand	Ord. Sand	Stude Coup	173.0	543.50	11.0	5,978.5	7.0	None	0	10	20	100	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140			
Test No. 5 Incomplete																																							
Test No. 6 Incomplete																																							
7	19	7:50-20	Ltd. Oper	Ltd. Oper	GMC Van	183.0	574.91	0	0	13.5	Between #1 & #2	1	24	30	70	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140			
7	19	7:50-20	Ltd. Oper	Ltd. Oper	GMC Tank	135.5	425.69	9.25	3,937.6	8.0	Between #2 & #3	4	34	40	50	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140		
7	19	11:00-18	Ltd. Oper	Ltd. Oper	GMC Dump	156.5	491.66	45**	22,124.7	11.75	None	1*	32	48	50	70	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140		
7	19	11:00-18	Ltd. Oper	Ltd. Oper	Stude Coup	109.5	344.00	11.25	3,870.0	9.0	None	4	36	44	96	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140		
8	20	7:50-20	25 MPH	25 MPH	GMC Van	105.5	331.44	0.5	165.7	5.5	Between #1 & #2	4	46	56	88	128	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140		
8	20	7:50-20	25 MPH	25 MPH	GMC Tank	142.0	416.11	4.5	2,007.5	8.0	Between #2 & #3	4	32	52	100	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	
8	20	11:00-18	25 MPH	25 MPH	GMC Dump	172.0	540.55	7.5	4,052.6	10.0	Between #3 & #4	4	36	58	112	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	
8	20	11:00-18	25 MPH	25 MPH	Stude Coup	129.5	406.64	1.5	610.3	9.5	Between #1 & #2	4	34	44	50	56	96	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	
9	21	7:50-20	Hwy	Hwy	GMC Van	108.0	339.59	16.75	5,683.1	13.0	Between #1 & #2	6	30	36	40	42	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	
9	21	7:50-20	Hwy	Hwy	GMC Tank	161.0	505.60	0.25	126.5	14.5	Between #1 & #2	1	52	60	66	72	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	
9	21	11:00-18	Hwy	Hwy	GMC Dump	133.0	417.63	0.33	197.9	11.5	Between #1 & #2	3	40	60	130	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140



REPEATED TRIPS STRAIGHT TRACKS

Test No.	Date 1943	Time	Inflation	Truck	Total No. of Trips	1st Trip Ft.	No. of Feet Backed	Re-peated Trips Stopped at	Feet Traveled in Repeated Tracks	Total No. of Feet Traveled	Aver. Pen. Depth Inches	Penetrometer Readings At Bottom of Track												Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index		
												Before Test						After Test											
												3"		6"		9"		12"		15"		18"							
18	2	7:50-20	25 MPH	GMC Van	8	425	125	0	4200	4750	-	47	76	130	-	67	78	-	-	-	-	-	-	19.3	17.2	NP	NP		
18	2	11:00-18	25 MPH	GMC Dump	6.5	475	100	0	3300	3875	-	62	86	40	30	28	32	-	-	-	-	-	-	17.6					
18	2	11:00-18	25 MPH	Stude Comp	8.25	285	285	0	2900	2470	-	0	34	76	114	130	53	60	-	-	-	-	-	21.1					
19	2	7:50-20	Ord Sand	GMC Van	1	400	0	0	0	400	-	61	90	91	112	66	130	-	-	-	-	-	-	0.6	18.0	NP	NP		
19	2	11:00-18	Ord Sand	GMC Dump	1	500	125	0	0	625	-	50	74	130	-	79	28	-	-	-	-	-	-	5.3					
19	2	11:00-18	Ord Sand	Stude Comp	1	535	0	0	0	535	-	400	50	74	130	100	130	-	-	-	-	-	-	16.6					
20	3	7:50-20	Ltd. Oper	GMC Van	1	380	220	0	0	600	-	20	76	78	-	68	86	-	-	-	-	-	-	15.1	18.0	NP	NP		
20	3	11:00-18	Ltd. Oper	GMC Dump	1	360	185	0	0	545	-	150	64	82	46	50	12	34	-	-	-	-	-	16.4					
20	3	11:00-18	Ltd. Oper	Stude Comp	1	500	140	0	0	640	-	350	46	97	130	61	130	-	-	-	-	-	-	15.4					
21	3	7:50-20	Hwy	GMC Van	2	380	380	370	370	1130	-	400	64	115	130	-	80	130	-	-	-	-	-	48.7	16.0	NP	NP		
21	3	11:00-18	Hwy	GMC Dump	2	575	575	400	725	1875	-	350	59	24	80	102	55	74	-	-	-	-	-	27.2					
21	3	11:00-18	Hwy	Stude Comp	1	600	0	0	0	600	-	100	72	122	130	-	44	70	-	-	-	-	-	16.1					



REPEATED TRIPS STRAIGHT TRACKS

Test No.	Date 1943	Tire Size	Inflation	Truck 2 1/2 ton	Total No. of Trips	Let Trip Feet	No. of Feet Backed	Re-peated Trips Stopped at	Feet Traveled in Repeated Tracks	Total No. of Feet Traveled	Aver. Pen. Depth Inches	Penetrometer Readings												Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index					
												Before Test						At Bottom of Track														
												Sta. No.	3"	6"	9"	12"	3"	6"	9"	12"	3"	6"	9"	12"								
26	8	7:50-20	Hwy	GMC Tank	6	380	380	100	3450	4210	8.0	400	22	55	47	47	24	22	22	-	-	-	-	-	-	-	-	-	-	-		
26	8	11:00-18	Hwy	GMC Pump	8.1	350	350	12	4562	5262	6.5	350	43	64	70	50	80	82	82	-	-	-	-	-	-	-	-	-	-	-		
26	8	11:00-18	Hwy	Stude Comp	4.33	410	410	260	2600	3420	6.0	450	11	73	80	103	-	106	130	-	-	-	-	-	-	-	-	-	-	-		
27	8	7:50-20	Hwy	GMC Van	4.1	300	300	35	9565	10165	11.5	300	18	33	50	50	40	40	20	20	20	20	20	20	20	20	20	20	20	20	NP	
27	8	7:50-20	Hwy	GMC Tank	25	300	900	165	7820	8420	6.0	300	60	68	50	50	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	
27	8	11:00-18	Hwy	GMC Dump	16	335	735	7	6993	7263	12.0	100	130	65	60	40	50	40	40	40	40	40	40	40	40	40	40	40	40	40	40	
27	8	11:00-18	Hwy	Stude Comp	3	425	425	325	1275	2125	5.5	50	60	120	90	50	130	90	130	90	130	90	130	90	130	90	130	90	130	90	130	90
28	9	7:50-20	Ltd. Oper	GMC Van	4.0	150	150	150	11450	11850	11.0	150	42	98	78	80	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	
28	9	7:50-20	Ltd. Oper	GMC Tank	3.3	200	200	100	4700	5100	5.0	200	40	38	44	34	50	50	63	63	63	63	63	63	63	63	63	63	63	63	63	63
28	9	11:00-18	Ltd. Oper	GMC Dump	3.1	175	175	170	10330	10680	12.5	200	22	53	103	99	18	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
28	9	11:00-18	Ltd. Oper	Stude Comp	8	150	150	100	2000	2300	10.0	150	34	40	66	100	40	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
29	9	7:50-20	Ltd. Oper	GMC Van	4.5	350	350	275	2550	3250	8.5	350	28	36	100	124	40	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
29	9	7:50-20	Ltd. Oper	GMC Tank	23	350	350	0	13640	14340	9.5	350	18	46	48	52	130	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
29	9	11:00-18	Ltd. Oper	GMC Dump	63	300	300	-	34100	34700	10.0	300	16	62	58	34	22	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
29	9	11:00-18	Ltd. Oper	Stude Comp	49	300	300	35	27325	27925	11.0	300	30	50	48	54	100	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130



REPEATED TRIPS STRAIGHT TRACKS

Test No.	Date 1943	Tire Size	Inflation	Truck 2 1/2 ton	Total No. of Trips	Lat Trip Feet	No. of Feet Backed	Re-peated Trips Stopped at	Feet Traveled in Repeated Tracks	Total No. of Feet Traveled	Aver. Pen. Depth Inches	Penetrometer Readings												Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index		
												Before Test						At Bottom of Track											
												3"		6"		9"		12"											
												Sta No.		3"		6"		9"		12"									
34	15	7:50-20	Ord Sand	GMC Van	8.5	385	385	312	5562	6332	7.5	400	8	10	58	60	18	48	-	-	-	-	-	23.5	16.5	MP	MP		
												350	50	108	198	-	30	78	-	-	-	-	-						
												300	44	62	68	68	58	90	-	-	-	-	-						
34	15	11:00-18	Ord Sand	GMC Dump	11.5	465	465	310	6510	7440	7.5	450	24	16	36	109	42	48	-	-	-	-	22.3						
												350	46	104	130	-	130	-	-	-	-	-	-						
												300	71	130	-	130	-	-	-	-	-	-	-						
34	15	11:00-18	Ord Sand	Stude Comp	11.5	540*	540	227	7327	8407		550	30	40	76	88	30	56	-	-	-	-	27.1						
												500	20	44	58	54	52	62	-	-	-	-	-						
												400	20	40	60	54	22	52	-	-	-	-	-						
												350	18	32	114	130	24	52	-	-	-	-	-						
												250	90	114	80	60	64	106	-	-	-	-	-						
												200	68	98	70	46	68	-	-	-	-	-	-						
35	15	7:50-20	Ord Sand	GMC Van	8	360	360	0	5040	5760	15.5	400	76	118	130	-	54	96	-	-	-	-	19.0	19.2	MP	MP	1.9		
												350	56	73	96	130	52	58	-	-	-	-	-						
												400	76	118	130	-	54	96	-	-	-	-	-						
35	15	11:00-18	Ord Sand	Stude Comp	2.5	360	360	360	1080	1800	15.5	350	56	73	96	110	52	58	-	-	-	-	-						
												400	76	118	130	-	54	96	-	-	-	-	-						
												350	56	73	96	110	52	58	-	-	-	-	-						
36	16	7:50-20	Ord Sand	GMC Van	8.625	430	430	405	6470	7330	11.5	420	98	130	-	56	48	-	-	-	-	-	24.2	19.5	MP	MP			
												400	52	50	36	38	43	40	-	-	-	-	-						
												420	98	130	-	56	48	-	-	-	-	-	-						
36	16	11:00-18	Ord Sand	GMC Dump	6.75	430	430	405	4750	5610	11.5	480	52	50	36	38	43	40	-	-	-	-	-						
												450	24	110	130	-	54	96	-	-	-	-	-						
37A	16	7:50-20	Hay	GMC Van	1	465	465	0	0	930	4.25	450	24	110	130	-	54	96	-	-	-	-	29.0	27.4	MP	MP	4.9		
37A	16	11:00-18	Hay	GMC Dump	1	550	0	0	0	550	6.25	500	20	36	130	-	54	96	-	-	-	-	45.0	22.5	MP	MP			
37A	16	11:00-18	Hay	Stude Comp	1	235	0	0	0	235	4.5	475	42	26	26	28	-	-	-	-	-	-	19.0						
37B	16	7:50-20	25 MPH	GMC Van	1	477	477	0	0	954	4.25	450	28	110	130	-	54	96	-	-	-	-	-						
37B	16	11:00-18	25 MPH	GMC Dump	1	547	0	0	0	547	6.25	500	20	36	130	-	54	96	-	-	-	-	-						
38A	17	7:50-20	Hay	GMC Van	1	275	275	0	0	550	9.0	300	54	60	130	-	54	96	-	-	-	-	21.8	17.5	MP	MP			
38A	17	11:00-18	Hay	GMC Dump	1	615*	615	0	0	1230	8.5	300	40	74	90	90	78	90	105	-	-	-	20.5						
38A	17	11:00-18	Hay	Stude Comp	1	290	290	0	0	580	9.5	300	24	94	116	130	-	-	-	-	-	-	21.1						
38B	17	7:50-20	25 MPH	GMC Van	1	299	299	0	0	598	9.0	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above							
38B	17	11:00-18	25 MPH	GMC Dump	1	615*	615	0	0	1230	8.5	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above							
38B	17	11:00-18	25 MPH	Stude Comp	1	305	305	0	0	610	9.5	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above							
38C	17	7:50-20	Ltd. Oper	GMC Van	1	335	335	0	0	670	9.0	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above							
38C	17	11:00-18	Ltd. Oper	GMC Dump	1	615*	615	0	0	1020	8.5	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above							
38C	17	11:00-18	Ltd. Oper	Stude Comp	1	616*	616	0	0	1232	9.5	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above							
38D	17	7:50-20	Ord Sand	GMC Van	1	355	355	0	0	710	9.0	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above	See above							

REPEATED TRIPS STRAIGHT TRACKS

Test No.	Date	Tire Size	Inflation	Truck	Total No. of Trips	1st Trip Feet	No. of Feet Backed	Re-peated Trips Stopped at	Feet Traveled in Repeated Tracks	Total No. of Feet Traveled	Aver. Pen. Depth Inches	Penetration Readings						Moisture Content	Liquid Plastic Limit	Plas. Ratio Index		
												Before Test		At Bottom of Track							9"	12"
												Site No.	3"	6"	9"	12"						
38D	17	11:00-18	Ord Sand	GMC Dump	1	210	0	0	0	210	8.5	See above										
38D	17	11:00-18	Ord Sand	Stude Comp	1	616	326	0	0	942	9.0	See above										
39A	17	7:50-20	Hwy	GMC Van	1	230	0	0	0	230	6.0	250	20	60	74	88						MP
39A	17	11:00-18	Hwy	GMC Dump	1	615	615	0	0	1230	9.0	500	24	34	72	56						MP
39A	17	11:00-18	Hwy	GMC Dump	1	615	615	0	0	1230	9.0	500	24	34	72	56						MP
39A	17	11:00-18	Hwy	Stude Comp	1	615	615	0	0	1230	11.25	500	50	100	130							13.3
39B	17	7:50-20	25 MPH	GMC Van	1	615	615	0	0	1230	6.0	See above										
39B	17	11:00-18	25 MPH	GMC Dump	1	615	615	0	0	1230	9.0	See above										
39B	17	11:00-18	25 MPH	Stude Comp	1	615	615	0	0	1230	11.25	See above										
39C	17	7:50-20	Ltd. Oper	GMC Van	1	615	405	0	0	1020	6.0	250	20	60	74	88						
39C	17	11:00-18	Ltd. Oper	GMC Dump	1	615	615	0	0	1230	9.0	See above										
39C	17	11:00-18	Ltd. Oper	Stude Comp	1	615	615	0	0	1230	11.25	See above										
39D	17	7:50-20	Ord Sand	GMC Van	1	360	0	0	0	360	9.0	400	90	112	88	90						
39D	17	11:00-18	Ord Sand	GMC Dump	1	360	0	0	0	360	9.0	400	90	112	88	90						
39D	17	11:00-18	Ord Sand	Stude Comp	1	615	615	0	0	1230	11.25	See above										
ALL TRUCKS EQUIPPED WITH CHAINS																						
40A	18	11:00-18	Hwy	GMC Dump	1	615	615	0	0	1230	6.5	550	18	32	72	92						
40A	18	11:00-18	Hwy	Stude Comp	1	615	615	0	0	1230	10.75	550	34	42	36	52						19.6
40B	18	11:00-18	25 MPH	GMC Dump	1	615	615	0	0	1230	6.5	See above										20.8
40B	18	11:00-18	25 MPH	Stude Comp	1	615	615	0	0	1230	10.75	See above										
40C	18	11:00-18	Ltd. Oper	GMC Dump	1	615	615	0	0	1230	6.5	See above										
40C	18	11:00-18	Ltd. Oper	Stude Comp	1	615	615	0	0	1230	10.75	See above										
40D	18	11:00-18	Ord. Sand	GMC Dump	1	615	615	0	0	1230	6.5	See above										
40D	18	11:00-18	Ord Sand	Stude Comp	1	615	615	0	0	1230	10.75	See above										
41A	20	7:50-20	Hwy	GMC Van	1	285	0	0	0	285	8.5	800	28	52	32	40						23.8
41A	20	11:00-18	Hwy	GMC Dump	1	260	0	0	0	260	9.0	250	28	74	100	110						28.5
41A	20	11:00-18	Hwy	Stude Comp	1	393	0	0	0	393	10.75	250	8	42	30	54						20.7
41B	20	7:50-20	25 MPH	GMC Van	1	295	0	0	0	295	8.5	See above										
41B	20	11:00-18	25 MPH	GMC Dump	1	265	0	0	0	265	9.0	200	82	130								
41B	20	11:00-18	25 MPH	Stude Comp	1	265	0	0	0	265	10.75	300	8	16	52							
41B	20	11:00-18	25 MPH	Stude Comp	1	265	0	0	0	265	10.75	250	88	130								



REPEATED TRIPS STRAIGHT TRACKS

Test No.	Date	Time	Inflation	Track	Total No. of Trips	1st Trip Feet Backed	No. of Repeated Truck Flats	Repeated Trips Stopped at	Feet Traveled in Repeated Tracks	Total No. of Feet Traveled	Aver. Pen. Depth Inches	Penetrometer Readings At Bottom of Track						Moisture Content	Liquid Plastic Limit	Plasticity Index
												3"	6"	9"	12"	3"	6"			
44A	21	11:00-18	25 MPH	Stude Comp	1	420	0	0	0	520	8.5	400	8	66	64	70		25.5		
44B	21	7:50-20	14.4 Oper	GMC Van	1	365	0	0	0	365	6.25	See above								
44C	21	11:00-18	14.4 Oper	GMC Van	1	318	0	0	0	318	5.0	See above								
44D	21	11:00-18	14.4 Oper	Stude Comp	1	325	0	0	0	325	8.5	See above								
44E	21	7:50-20	14.4 Oper	GMC Van	1	368	0	0	0	368	6.25	See above								
44F	21	11:00-18	14.4 Oper	GMC Van	1	310	0	0	0	310	5.0	See above								
44G	21	11:00-18	14.4 Oper	Stude Comp	1	430	0	0	0	430	8.5	See above								
45A	22	7:50-20	25 MPH	GMC Van	1	507	0	0	0	507	11.5	500	34	22	26	26		21.4		
45B	22	11:00-18	25 MPH	GMC Van	1	507	0	0	0	507	11.5	450	44	32	32	26		9.0		
45C	22	11:00-18	25 MPH	Stude Comp	1	507	0	0	0	507	11.5	500	56	58	36	32		23.1		
45D	22	7:50-20	14.4 Oper	GMC Van	1	504	0	0	0	504	11.5	See above								
45E	22	11:00-18	14.4 Oper	GMC Van	1	398	0	0	0	398	14.5	348	184	130	72	68				
45F	22	11:00-18	14.4 Oper	Stude Comp	1	484	0	0	0	484	11.0	420	64	54	72	68				
45G	22	7:50-20	14.4 Oper	GMC Van	1	424	0	0	0	424	11.5	450	44	54	56	48				
45H	22	11:00-18	14.4 Oper	GMC Van	1	390	0	0	0	390	14.5	See above								
45I	22	11:00-18	14.4 Oper	Stude Comp	1	425	0	0	0	425	11.0	400	68	82	88	108				
46A	23	7:50-20	25 MPH	GMC Van	1	468	0	0	0	468	9.1	50	20	20	22	18				
46B	23	11:00-18	25 MPH	GMC Van	1	535	0	0	0	535	11.0	520	34	32	40	22				
46C	23	11:00-18	25 MPH	Stude Comp	1	550	0	0	0	550	3.0	500	42	80	62	50				
46D	23	7:50-20	14.4 Oper	GMC Van	1	437	0	0	0	437	9.0	400	78	74	56	106				
46E	23	11:00-18	14.4 Oper	GMC Van	1	422	0	0	0	422	11.0	450	36	30	30	42				
46F	23	11:00-18	14.4 Oper	GMC Van	1	425	0	0	0	425	8.0	450	44	70	74	76				
46G	23	11:00-18	14.4 Oper	Stude Comp	1	425	0	0	0	425	9.0	See above								
46H	23	7:50-20	14.4 Oper	GMC Van	1	425	0	0	0	425	11.0	390	68	80	84	86				
46I	23	11:00-18	14.4 Oper	GMC Van	1	400	0	0	0	400	8.0	See above								
46J	23	7:50-20	25 MPH	GMC Van	4.5	225	225	200	1550	2000	10.5	250	82	78	76	78		24.0		
47	23	11:00-18	25 MPH	Stude Comp	5	225	225	0	1880	2250	10.5	Same as above								
48	24	7:50-20	25 MPH	GMC Van	5.5	242	242	234	2173	2657	12.5	210	100	102	130					
49	24	11:00-18	25 MPH	GMC Van	4.9	242	242	5	1931	2415	12.5	Same as above						19.0		
49	24	7:50-20	25 MPH	GMC Van	8.1	232	232	5	3253	3717	13.0	225	14	8	8					



OO-NO-GO TESTS - CAMP SHERMAN

Test No.	Date 1943	Time	Inflation	Truck	Total Feet Traveled	Depth of Mud Inches	Penetration Resistance					Area	Location	Moisture Content	Liquid Limit	Plasticity Index
							No.	1st	2nd	3rd	4th					
55	28	7:50-20	Brk	GMC Van	25	23.0	25	0	10	22	34	1	-	40.2		
55	28	7:50-20	Brk	GMC Tank	26	23.0	26	0	10	18	29	1	-	37.1		
55	28	11:00-18	Brk	GMC Dump	30	23.0	30	0	8	18	22	1	-			
55	28	11:00-18	Brk	Stude Comp	23	23.0	23	0	0	16	19	-				
56	28	7:50-20	25 MPH	GMC Van	25	23.0	25	0	8	17	21					
56	28	7:50-20	25 MPH	GMC Tank	27	23.0	27	0	14	22	20					
56	28	11:00-18	25 MPH	GMC Dump	25	23.0	25	0	6	14	30					
56	28	11:00-18	25 MPH	Stude Comp	26	23.0	26	0	10	18	30					
57	28	7:50-20	Ltd. Oper	GMC Van	60	10.0	60	0	20	48	130	2	1	67.4		
57	28	7:50-20	Ltd. Oper	GMC Tank	62	9.0	62	0	18	190						
57	28	11:00-18	Ltd. Oper	GMC Dump	159	13.0	159	0	10	24	40					
57	28	11:00-18	Ltd. Oper	Stude Comp	106	13.0	106	0	12	24	130					
58	29	7:50-20	Ord Sand	GMC Van	51	9.5	51	22	32	82	130	2	5	39.9		
58	29	7:50-20	Ord Sand	GMC Tank	73	5.0	73	34	130	24	92					
58	29	11:00-18	Ord Sand	GMC Dump	94	8.0	94	100	10	25	60					
58	29	11:00-18	Ord Sand	Stude Comp	90	8.0	90	100	12	22	40					
59	29	7:50-20	Brk	GMC Van	71	5.0	71	100	12	19	34					
59	29	7:50-20	Brk	GMC Tank	75	3.0	75	100	8	17	33					
59	29	11:00-18	Brk	GMC Dump	87	4.5	87	100	9	27	42					
59	29	11:00-18	Brk	Stude Comp	84	4.0	84	100	10	20	33					
RESULTS ON FRONT OF TRUCKS EQUIPPED WITH 2-50-20 TIRES																
60	29	7:50-20	Brk	GMC Van	92	-	92	100	12	22	32	2	13	38.4		
60	29	11:00-18	Brk	GMC Dump	91	-	91	100	8	20	25					
61	29	7:50-20	25 MPH	GMC Van	94	-	94	100	22	24	30					
61	29	11:00-18	25 MPH	GMC Dump	90	-	90	100	16	24	32					
ALL TRUCKS EQUIPPED WITH CHAINS																
62	29	7:50-20	Brk	GMC Van	24	-	24	25	10	20	25	3	2	33.9		
62	29	7:50-20	Brk	GMC Tank	39	-	39	50	16	27	32	3	3	43.8		
62	29	11:00-18	Brk	GMC Dump	37	-	37	50	8	18	25					
62	29	11:00-18	Brk	Stude Comp	115	-	115	100	6	17	22	3	1	35.6		
63	29	7:50-20	25 MPH	GMC Van	22	-	22	25	12	19	26					
63	29	7:50-20	25 MPH	GMC Tank	31	-	31	25	16	18	20					
63	29	11:00-18	25 MPH	GMC Dump	35	-	35	25	15	20	27					
63	29	11:00-18	25 MPH	Stude Comp	98	-	98	100	8	13	26					

GO-NO-GO TESTS - CAMP SELLER

Test No.	Date 1943	Tire Size	Inflation	Truck 2 1/2 ton	Total Feet Traveled	Depth of Mud Inches	Penetrometer Readings					Area	Location	Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index
							Ft.	3"	6"	9"	12"						
64	30	7:50-20	Ltd. Oper	GMC Van	26	13.0	25	14	18	28	82	-	-	-	-	-	
64	30	7:50-20	Ltd. Oper	GMC Tank	45	13.0	50	13	18	23	29	-	-	-	-	-	
64	30	11:00-18	Ltd. Oper	GMC Dump	40	13.0	50	8	14	23	40	-	-	-	-	-	
64	30	11:00-18	Ltd. Oper	Stude Comp	162	13.0	100	8	18	28	32	-	-	-	-	-	
65	30	7:50-20	Ord. Sand	GMC Van	38	13.0	50	8	17	24	54	-	-	-	-	-	
65	30	7:50-20	Ord. Sand	GMC Truck	25	13.0	25	16	24	32	49	-	-	-	-	-	
65	30	11:00-18	Ord. Sand	GMC Dump	20	13.0	25	12	25	29	30	-	-	-	-	-	
65	30	11:00-18	Ord. Sand	Stude Comp	162	13.0	100	10	18	24	26	-	-	-	-	-	
DUALS ON FRONT OF TRUCKS EQUIPPED WITH 7:50-20 TIRES																	
66	30	7:50-20	25 MPH	GMC Van	75	10.0	100	8	12	26	57	-	-	-	-	-	
66	30	7:50-20	25 MPH	GMC Tank	130	8.0	100	22	27	39	130	-	-	-	-	-	
66	30	11:00-18	25 MPH	GMC Dump	130	7.0	50	19	26	68	190	-	-	-	-	-	
66	30	11:00-18	25 MPH	Stude Comp	54	10.0	50	6	17	35	96	-	-	-	-	-	
67	30	7:50-20	Ltd. Oper	GMC Van	169	12.0	100	11	13	37	110	-	-	-	-	-	
67	30	7:50-20	Ltd. Oper	GMC Tank	149	13.0	100	7	18	23	25	-	-	-	-	-	
67	30	11:00-18	Ltd. Oper	GMC Dump	74	13.0	100	11	29	30	39	-	-	-	-	-	
67	30	11:00-18	Ltd. Oper	Stude Comp	105	13.0	100	12	18	31	55	-	-	-	-	-	
68	30	7:50-20	Ord. Sand	GMC Van	99	11.0	100	13	26	57	63	-	-	-	-	-	
68	30	7:50-20	Ord. Sand	GMC Tank	83	10.5	100	14	22	40	70	-	-	-	-	-	
68	30	11:00-18	Ord. Sand	GMC Dump	83	8.0	100	11	17	33	44	-	-	-	-	-	
68	30	11:00-18	Ord. Sand	Stude Comp	101	9.5	100	8	13	25	34	-	-	-	-	-	
69	30	7:50-20	25 MPH	GMC Van	26	13.0	25	16	26	39	104	4	15	35.5	-	-	
69	30	7:50-20	25 MPH	GMC Tank	67	7.0	75	12	18	28	41	4	12	36.1	-	-	
69	30	11:00-18	25 MPH	GMC Dump	26	13.0	25	14	20	38	58	-	-	-	-	-	
69	30	11:00-18	25 MPH	Stude Comp	75	10.5	75	8	16	23	47	4	14	37.2	-	-	

Test # 69 standard tire combination.

DYNAMETER TESTS

Test No.	Date 1943	Truck Size	Inflation	Truck 2 1/2 ton	Rolling Resistance	No. of Readings	Tractive Effort	No. of Readings	Pneumatic Readings												Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index					
									Rolling Resistance			Tractive Effort			Moisture Content			Liquid Limit							Plastic Limit				
									Sta. No.	3"	6"	9"	12"	15"	18"	21"	24"	27"	30"	33"	36"	39"	42"	E.R. %	R.P. %	T.E. %	R.R. %	T.E. %	
70	5	7:50-20	Hvy	GMC Van	2260	10	1975	4	2	25	35	100	130	4	40	50	60	65											
70	5	7:50-20	Hvy	GMC Tank	2240	10	2800	3	3	29	45	80	130	1	28	31	95	130											
70	5	11:00-18	Hvy	GMC Dump	1590	10	1900	3	4	32	30	40	130	3	35	43	105	130											
70	5	11:00-18	Hvy	Stude Comp	1460	10	1900	4	5	30	49	54	58	1	40	38	60	78											
71	6	7:50-20	Hvy	GMC Van	2515	10	2760	5	4	45	70	90	80	6	36	60	130	-											
71	6	7:50-20	Hvy	GMC Tank	2235	10	2600	4	8	45	50	95	100	4	55	85	95	95											
71	6	11:00-18	Hvy	GMC Dump	1998	9	2475	4	1	30	50	60	100	8	44	64	114	110											
71	6	11:00-18	Hvy	Stude Comp	1330	10	2875	4	3	50	60	100	80	4	30	40	56	70											
72	7	7:50-20	25 MPH	GMC Van	2700	10	3600	7	4	48	76	114	120	2	35	48	65	72											
72	7	7:50-20	25 MPH	GMC Tank	2200	10	3700	7	4	40	60	70	120	2	56	60	60	100											
72	7	11:00-18	25 MPH	GMC Dump	1395	10	2900	5	3	45	45	65	108	8	30	50	60	95											
72	7	11:00-18	25 MPH	Stude Comp	1425	10	3286	7	8	40	65	80	100	1	55	60	90	100											
73	7	7:50-20	25 MPH	GMC Van	2338	8	2733	6	3	40	82	90	-	2	40	46	120	120											
73	7	7:50-20	25 MPH	GMC Tank	2438	8	3133	6	2	40	60	70	120	2	56	60	60	100											
73	7	11:00-18	25 MPH	GMC Dump	1725	8	2300	6	2	34	40	60	130	2	60	40	50	90											
73	7	11:00-18	25 MPH	Stude Comp	1600	8	2383	6	6	40	76	90	130	9	38	50	65	130											
74	8	7:50-20	Ltd. Oper	GMC Van	3580	10	1533	3	1	22	24	38	60	8	30	20	40	50											
74	8	7:50-20	Ltd. Oper	GMC Tank	2248	10	1600	1	1	28	26	40	44	1	40	22	22	22											
74	8	11:00-18	Ltd. Oper	GMC Dump	2430	10	1600	4	4	40	20	18	32	2	44	32	26	46											
74	8	11:00-18	Ltd. Oper	Stude Comp	2090	10	1380	5	1	26	14	20	24	1	26	20	28	80											
75	8	7:50-20	Ltd. Oper	GMC Van	3350	10	910	5	3	40	20	28	30	8	36	20	16	30											
75	8	7:50-20	Ltd. Oper	GMC Tank	2065	10	1317	6	6	35	25	34	55	8	18	20	30	92											
75	8	11:00-18	Ltd. Oper	GMC Dump	1910	10	1483	6	8	20	18	36	50	7	40	12	18	20											
75	8	11:00-18	Ltd. Oper	Stude Comp	2095	10	1410	5	7	31	30	30	38	5	46	28	26	24											
76	11	7:50-20	Ord Sand	GMC Van	3035	10	1975	6	2	38	40	20	22	4	36	30	34	56											
76	11	7:50-20	Ord Sand	GMC Tank	3605	10	1400	1	8	30	32	25	30	3	28	30	22	26											
76	11	11:00-18	Ord Sand	GMC Dump	2013	8	1700	1	9	25	24	28	44	9	20	26	30	90											
76	11	11:00-18	Ord Sand	Stude Comp	1995	10	2429	7	9	30	20	20	42	8	40	28	30	44											
77	12	7:50-20	Ord Sand	GMC Van	2505	10	2240	10	8	30	40	18	26	8	36	28	40	50											
77	12	7:50-20	Ord Sand	GMC Tank	2955	10	2055	10	4	30	32	34	30	5	28	28	32	68											
77	12	11:00-18	Ord Sand	GMC Dump	1290	10	2185	10	8	58	44	34	50	5	20	22	30	34											
77	12	11:00-18	Ord Sand	Stude Comp	1545	10	1675	10	4	28	16	24	30	4	30	38	36	68											
DUALS ON FRONT OF TRUCKS EQUIPPED WITH 7:50-20 TIRES																													
78	12	7:50-20	Ord Sand	GMC Van	3140	10	2030	10	5	20	26	28	26	20	32	20	18	20											
78	12	7:50-20	Ord Sand	GMC Tank	2475	10	1585	10	6	30	28	26	20	3	20	18	18	20											

DYNAMOMETER TESTS

Test No.	Date 1943	Fire Size	Inflation	Truck 2 1/2 ton	Rolling Resistances	No. of Readings	Tractive Effort	No. of Readings	Penetrometer Readings										Moisture Content R.R. T.E.	Liquid Limit R.R. T.E.	Plastic Limit R.R. T.E.	Plasticity Index R.R. T.E.																					
									Rolling Resistance					Tractive Effort																													
										3"	6"	9"	12"	3"	6"	9"	12"	3"	6"	9"	12"																						
78	12	45:00-18	Ord Sand	GMC Dump	2620	10	1600	2	24	30	32	32	28	26	26	24	24	28	26	26	24	32.8	34.3																				
78	12	11:00-18	Ord Sand	Stude Comp	2440	10	1714	7	40	30	30	30	28	30	30	24	20	28	30	24	20	31.3	23.9																				
79	13	7:50-20	Ord Sand	GMC Van	2555	10	2890	10	26	18	16	16	20	20	20	20	20	28	32	20	22	30.0	24.8																				
79	13	7:50-20	Ord Sand	GMC Tank	2065	10	2850	10	32	30	20	20	22	40	40	18	22	22	40	18	22	23.8	26.4																				
79	13	11:00-18	Ord Sand	GMC Dump	1975	10	2321	7	9	20	20	38	28	28	28	22	12	28	22	22	12	26.1	27.0																				
79	13	11:00-18	Ord Sand	Stude Comp	2240	10	1525	10	7	26	24	28	20	36	28	22	22	36	28	22	22	34.0	27.0																				
80	13	7:50-20	Ltd. Oper	GMC Van	2360	10	1800	10	30	40	42	70	30	40	40	36	44	30	40	36	44																						
80	13	7:50-20	Ltd. Oper	GMC Tank	2005	10	1200	10	1	40	20	20	20	20	28	40	110	20	28	40	110																						
80	13	11:00-18	Ltd. Oper	GMC Dump	1695	10	1090	10	3	30	42	50	46	30	30	40	60	30	30	40	60																						
80	13	11:00-18	Ltd. Oper	Stude Comp	1640	10	1435	10	3	30	32	56	86	40	28	30	70	40	28	30	70																						
81	14	7:50-20	Ltd. Oper	GMC Van	2160	10	1510	10	30	38	36	36	28	38	38	38	60	38	38	38	58	60																					
81	14	7:50-20	Ltd. Oper	GMC Tank	1860	10	1995	10	8	32	30	20	20	30	30	28	60	30	30	28	60	88																					
81	14	11:00-18	Ltd. Oper	GMC Dump	1565	10	1130	10	3	30	28	50	70	30	40	36	40	30	40	36	40																						
81	14	11:00-18	Ltd. Oper	Stude Comp	1700	10	1170	10	1	30	30	62	80	9	34	36	46	34	36	46	100																						
82	14	7:50-20	25 MPH	GMC Van	3105	10	963	8	2	30	40	42	50	32	38	40	50	32	38	40	50																						
82	14	7:50-20	25 MPH	GMC Tank	2435	10	1120	10	3	30	30	70	84	7	56	40	32	40	32	40	32	90																					
82	14	11:00-18	25 MPH	GMC Dump	2145	10	1056	10	2	30	38	60	40	1	28	30	74	30	30	74	90																						
82	14	11:00-18	25 MPH	Stude Comp	2230	10	889	9	4	30	38	70	80	1	30	30	50	30	30	50	66																						
83	15	7:50-20	25 MPH	GMC Van	1960	10	2720	10	3	26	50	58	70	3	30	50	92	30	50	92	96																						
83	15	7:50-20	25 MPH	GMC Tank	1690	10	2990	10	2	44	62	60	60	3	40	78	90	40	78	90	96																						
83	15	11:00-18	25 MPH	GMC Dump	1540	10	2100	10	5	30	42	56	60	6	44	56	100	44	56	100	130																						
83	15	11:00-18	25 MPH	Stude Comp	1410	10	2070	10	3	36	70	92	110	2	42	70	60	42	70	60	60																						
84	15	7:50-20	Evry	GMC Van	2085	10	1522	10	3	48	90	70	112	4	30	52	100	30	52	100	100																						
84	15	7:50-20	Evry	GMC Tank	1755	10	2563	8	2	46	74	60	70	2	30	30	114	30	30	30	114																						
84	15	11:00-18	Evry	GMC Dump	1920	10	1363	8	1	36	40	60	72	9	40	40	80	40	40	80	130																						
84	15	11:00-18	Evry	Stude Comp	1705	10	1263	8	1	40	52	70	102	4	36	90	70	62	90	70	60																						
85	18	7:50-20	Evry	GMC Van	2975	10	1829	10	1	40	40	100	90	5	30	42	70	30	42	70	102																						
85	18	7:50-20	Evry	GMC Tank	2355	10	2125	10	2	36	44	40	48	3	40	82	88	40	82	88	96																						
85	18	11:00-18	Evry	GMC Dump	2020	10	1340	10	4	30	60	66	112	2	40	50	50	40	50	50	76																						
85	18	11:00-18	Evry	Stude Comp	2125	10	1375	10	7	40	80	80	80	2	36	50	90	36	50	90	90																						
ALL TRUCKS EQUIPPED WITH CHAINS																																											
86	18	7:50-20	Evry	GMC Van	3055	10	2740	10	7	40	70	60	62	4	40	66	78	40	66	78	124																						
86	18	7:50-20	Evry	GMC Tank	2530	10	2440	10	10	40	60	60	50	3	40	60	104	40	60	104	90																						

DYNAMOMETER TESTS

Test No.	Date 1943	Time	Inflation	Truck 2 1/2 ton	Rolling Resistance	No. of Readings	Tractive Effort	No. of Readings	Penetrometer Readings						Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index				
									Sta No.	3"	6"	9"	12"	Sta No.					3"	6"	9"	12"
86	18	11:00-18	Hay	GMC Dump	2295	10	3080	10	8	32	53	70	110	6	46	50	64	130				
86	18	11:00-18	Hay	Stude Comp	2165	10	2560	10	6	30	50	70	40	8	44	60	90	80				
87	19	7:50-20	Hay	GMC Van	3725	10	1164	7	5	26	48	66	130	2	34	60	70	50	36.7	44.4		
87	19	7:50-20	Hay	GMC Tank	3315	10	1478	9	10	34	48	58	60	5	30	38	40	30.4	26.8			
87	19	11:00-18	Hay	GMC Dump	2800	10	1890	10	8	30	30	96	70	10	40	36	38	44	28.5	26.2		
87	19	11:00-18	Hay	Stude Comp	2705	10	1900	10	7	30	34	90	86	4	32	60	40	58	33.2	27.7		
88	19	7:50-20	25 MPH	GMC Van	3490	10	1990	10	4	30	30	40	70	9	40	50	56	110	34.2	31.8		
88	19	7:50-20	25 MPH	GMC Tank	3170	10	1910	10	2	50	30	42	92	5	30	38	76	130	30.9	28.0		
88	19	11:00-18	25 MPH	GMC Dump	2360	10	1950	10	10	30	50	80	80	2	30	38	70	70	31.1	28.8		
88	19	11:00-18	25 MPH	Stude Comp	2160	10	2260	10	10	26	40	48	58	4	30	32	26	38	29.0	32.5		
89	20	7:50-20	25 MPH	GMC Van	4070	10	1950	10	8	40	40	40	50	5	28	28	96	90	27.0	32.0		
89	20	7:50-20	25 MPH	GMC Tank	3495	10	2622	9	7	40	42	60	72	1	30	42	48	50	28.8	27.7		
89	20	11:00-18	25 MPH	GMC Dump	2550	10	2300	10	6	28	30	40	42	2	30	30	30	130	28.0	27.4		
89	20	11:00-18	25 MPH	Stude Comp	2700	10	2190	10	6	30	30	32	54	1	28	22	30	130	30.7	27.6		
90	20	7:50-20	Ltd. Oper	GMC Van	3805	10	2210	10	8	38	40	50	60	3	22	22	28	40	32.6	27.7		
90	20	7:50-20	Ltd. Oper	GMC Tank	3100	10	2620	10	1	28	34	30	32	3	28	44	44	42	30.8	30.2		
90	20	11:00-18	Ltd. Oper	GMC Dump	2030	10	2270	10	3	22	20	80	92	3	26	20	28	60	32.7	33.8		
90	20	11:00-18	Ltd. Oper	Stude Comp	2420	10	2210	10	2	22	26	46	74	3	20	30	30	40	32.6	30.0		
91	21	7:50-20	Ltd. Oper	GMC Van	4620	10	1671	7	1	22	38	50	50	5	32	32	40	110	31.8	34.9		
91	21	7:50-20	Ltd. Oper	GMC Tank	3775	10	1950	10	3	26	32	86	130	1	28	20	30	60	27.7	27.4		
91	21	11:00-18	Ltd. Oper	GMC Dump	2290	10	1865	10	1	20	26	50	52	7	34	50	60	64	30.6	28.0		
91	21	11:00-18	Ltd. Oper	Stude Comp	2550	10	2290	10	3	20	22	54	80	6	38	40	50	50	29.4	29.3		
92	21	7:50-20	Ord Sand	GMC Van	3670	10	1533	9	6	30	50	50	60	2	18	16	60	60	31.4	34.6		
92	21	7:50-20	Ord Sand	GMC Tank	3090	10	1241	11	1	20	30	40	50	8	20	20	22	60	35.7	29.9		
92	21	11:00-18	Ord Sand	GMC Dump	2055	10	2200	10	5	20	36	78	80	4	50	32	38	34	32.3	29.3		
92	21	11:00-18	Ord Sand	Stude Comp	1970	10	2300	10	5	30	24	40	48	8	30	40	44	46	33.5	32.0		
93	22	7:50-20	Ord Sand	GMC Van	3095	10	667	3	2	30	22	28	26	6	20	18	26	26	27.3	28.9		
93	22	7:50-20	Ord Sand	GMC Tank	2990	10	1700	2	8	28	36	26	18	7	30	20	24	22	27.3	32.7		
93	22	11:00-18	Ord Sand	GMC Dump	2045	10	1900	7	1	26	28	24	24	4	22	20	18	26	29.7	30.0		
93	22	11:00-18	Ord Sand	Stude Comp	1850	10	1250	8	10	28	26	22	34	5	30	16	16	38	30.2	32.6		

COMPARATIVE HILL CLIMBING TESTS

Note: The consistency of the mud changed as the ramps were wotted from time to time. Therefore, the results cannot be compared except in the two tests noted where the test conditions were the same.

<u>Test No.</u>	<u>Vehicle</u>	<u>Inflation</u>	<u>Test Results</u>
94	Van	Highway	Climbed either ramp but spun a little
94	Tanker	Highway	Climbed either ramp with only slight hesitation.
94	Dump	Highway	Climbed either ramp.
95	Tanker	Highway	Went only 63 feet up one ramp.
95	Dump	Highway	Went only 63 feet up same ramp.
96	Tanker	Ord. Sand Min.	Climbed either ramp.
96	Dump	Ord. Sand Min.	Climbed either ramp.
96	Van	Highway	Climbed either ramp
97	Tanker	25 m.p.h.	Went only 55 feet up one ramp
97	Dump	25 m.p.h.	Went 55 feet up same ramp.
97	Van	Highway	Went 55 feet up same ramp.
98	Tanker	Limited Oper.	Went only 55 feet up same ramp as above.
98	Dump	Limited Oper.	Went only 55 feet up same ramp!
99	Tanker	Ord. Sand Min.	Went only 55 feet up one ramp
99	Dump	Ord. Sand Min.	Went 57 feet up same ramp.
100	Tanker	25 m.p.h.	Went only 84 feet up one ramp
100	Dump	Highway	Went 90 feet up same ramp.
101	Tanker	25 m.p.h.	Went only 55 feet up one ramp.
101	Dump	25 m.p.h.	Went only 55 feet up one ramp.
102	Tanker with Chains	25 m.p.h.	Climbed the same ramp as above with case
102	Dump with Chains	25 m.p.h.	Climbed the same ramp with case.

SERVICE DURABILITY TEST

<u>Type Truck</u>	<u>Tire Size</u>	<u>Total Miles</u>	<u>Miles on Hwy</u>	<u>Miles on Roads and Test Areas</u>	<u>Miles Duals All Around</u>
Dump	11.00-18	741	556	185	-
Compressor	11.00-18	1570	1178	392	-
Van	7.50-20	1967	1475	492	236
Tanker	7.50-20	1412	1058	354	170
Totals		5690	4267	1423	406

SUPPLEMENTARY DATA

Effect of Using 7.50 x 20 Duals All Around vs. Standard 7.50 x 20 Tire Equipment at Highway Inflation.

Test No.	Feet Traveled	
	Singles	Duals
1	119	141
2	144	229
3	195	90
4	133	201
5	159	171
6	75	150
7	192	369
8	191	366
9	213	330
Average	158	227 $\frac{1}{2}$

Effect of Lowering Inflation Pressures

Test No.	7.50-20				11.00 x 18	
	Singles		Duals		High-way	Ord. Sand.
	High-way	Ord. Sand Min.	High-way	Ord. Sand Min.		
1	126	267	77	90	243	270
2	243	267	35	45	204	258
3	12	27	139	141	12	10
4	8	28	172	317		
5	45	39				
6	86	151				
7	130	151				
8	84	99				
Average	92	129	106	148	153	179

APPENDIX "C"

Pressure Gauge

Calibration

by

Bureau of Standards

City of Los Angeles

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5" Dial 0 - 60 pounds

115

2 $\frac{1}{2}$ " Dial 0 - 100 pounds

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2 $\frac{1}{2}$ " Dial 0 - 30 pounds

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City of Los Angeles  
Lab. No. 64-356 DEPARTMENT OF PUBLIC WORKS  
Rec'd 8-16-43 Bureau of Standards  
Rep't'd 8-17-43  
To The Engineer Board 826 Yale Street

Report

Test of

PRESSURE GAUGE

A pressure gauge was tested for the Engineer Board,  
Desert Warfare Section, Thermal, California, on August 16, 1943.

Type: Five inch dial

Marked: Marshalltown Gauge

Range: 0 to 60 pounds

<u>Gaugo Reading</u>	<u>Pounds Pressure</u>	<u>Correction (lbs)</u>
13 1/2	10	-3 1/2
23 1/2	20	-3 1/2
33 1/2	30	-3 1/2
43 1/4	40	-3 1/4
53 1/4	50	-3 4
60	57	-3

2:4

/s/ T. A. Fitch  
Director

Lab. No. 64-358  
Rec'd 8-16-43  
Rep't'd 8-17-43  
To The Engineer Board

City of Los Angeles  
DEPARTMENT OF PUBLIC WORKS  
Bureau of Standards

826 Yale Street

Report

Test of

PRESSURE GAUGE

A pressure gauge was tested for the Engineer Board,  
Desert Warfare Section, Thermal, California, on August 16, 1943.

Type: Two and one-half inch dial

Marked: Marshalltown Gauge

Range: 0 to 100 pounds

<u>Gauge Reading</u>	<u>Pounds Pressure</u>	<u>Correction (lbs)</u>
16	10	-6
26	20	-6
36	30	-6
46	40	-6
56	50	-6
66	60	-6
76	70	-6
86	80	-6
96	90	-6
100	94	-6

2:4

/s/ T. A. Fitch  
Director

City of Los Angeles  
DEPARTMENT OF PUBLIC WORKS  
Bureau of Standards  
826 Yale Street

Lab.No. 64-357  
Rec'd 8-16-43  
Rep't'd 8-17-43  
To The Engineer Board

Report

Test of

PRESSURE GAUGE

A pressure gauge was tested for the Engineer Board,  
Desert Warfare Section, Thermal, California, on August 16, 1943.

Type: Two and one-half inch dial

Marked: Marshalltown Gauge

Range: 0 to 25 pounds

<u>Gauge Reading</u>	<u>Pounds Pressure</u>	<u>Correction (lbs)</u>
9	5	-4
14	10	-4
19 $\frac{1}{4}$	15	-4 $\frac{1}{4}$
24 $\frac{1}{4}$	20	-4 $\frac{1}{4}$
28 $\frac{3}{4}$	25	-3 $\frac{3}{4}$

2:4

Director

APPENDIX "D"

Ordnance Desert Proving Grounds

Classification of Mud

ORDNANCE DESERT PROVING GROUNDS  
CLASSIFICATION OF MUD

The Ordnance Desert Proving Grounds report on mud flotation classified mud into several types. Quoted here is section II A from subject report.

"Section II. A. That for the purpose of evaluating the mud mobility of military wheeled vehicles all of the various types of mud that may be encountered fall into two classifications or types.

Type I Mud: Bottomless mud where the consistency is such that the mud will not support a vehicle with standard military tire equipment at 20 pounds tire pressure. The term bottomless implies that a firm sub-surface, if existent, will be at such a depth that the vehicle undercarriage will be buried in mud, preventing forward motion of the vehicle before the driving wheels have contacted the firm sub-surface. \*\*\*\*\*

Type II Mud: A mud top-surface with a firm hard pan at a depth not to exceed the minimum vehicle ground clearance. Under this classification is also included mud where no hard pan exists but where the consistency of the mud is such that compaction will afford a sufficient bearing surface to support a vehicle with standard tire equipment at 20 pounds pressure at a depth of not to exceed the minimum vehicle ground clearance. At the depth of adequate bearing capacity, the mud must have sufficient shear resistance to permit the development of maximum vehicle tractive effort with chain equipment.

1. Type II Mud should be classified as Type IIA, when the mud has a cleaning quality such as the presence of high water content, sand, decayed vegetable matter or other non-adhesive materials which give the mud a cleaning quality. \*\*\*\*\*

2. Type IIB is mud that has no cleaning qualities and is highly adhesive such as gumbo or adobe mud."

APPENDIX B

REPORT OF TESTS OF 14:00 x 20 12-PLY  
AND 9:00 x 20 10-PLY TIRES ON 4-TON  
6 x 6 TRUCK

Desert Warfare Section  
Thermal California

Informal Report No. 181

Part II

TESTS OF 14:00-20, 12 PLY AND  
9:00-20, 10 PLY TIRES IN MUD

Project No. MES 433

Service on Tires  
For Engineer Equipment

15 January 1944

Submitted to

The Technical Staff  
The Engineer Board  
Fort Belvoir, Virginia

Martin R. Leidig  
Asst. Engineer (Civil)

C. C. Huskison  
Engineer (Civil)

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## SYLLABUS

This second Interim Report covers testing by the Desert Warfare Section of standard 9.00-20 tires and 14.00-20 low pressure tires on loaded 4 ton, 6x6, trucks in varying mud conditions. The testing was carried on at the north end of the Salton Sea and at Camp Seeley, California. The report analyzes the data secured from a series of tests made to determine the relative performance of these tires in mud. The period of testing was from 2 November to 31 December 1943.

The conclusions based on results of tests covered in this report and on tests previously conducted in sand by this Section are as follows:

a. "Mud-mobility" of the standard 4 ton, 6x6, truck is better when equipped with 14.00-20 low pressure single tires than when equipped with 9.00-20 standard military tires, with either singles or duals on the front wheels.

b. "Mud-mobility" of the standard 4 ton truck with 9.00-20 tires is improved by dualing of the front wheels.

c. "Mud-mobility" of the standard 4 ton truck equipped with either 9.00-20 or 14.00-20 tires is increased with reduction of tire pressures.

d. "Mud-mobility" of the standard 4 ton truck equipped with either 9.00-20 standard or 14.00-20 low pressure tires is improved by the use of tire chains.

e. "Mud-mobility" of the standard 4 ton truck is better when equipped with 9.00-20 singles in front and chains all around than when equipped with 14.00-20 tires, without chains, at most inflations. When the 14.00-20 tires are at Ordnance Sand Minimum Inflations and the 9.00-20 tires are at Highway Inflations, the 14.00-20 tires give slightly better performance.

f. The standard 4 ton truck, without modifications, is easier to steer cross country when equipped with 14.00-20 tires.

g. The ease of steering of the standard 4 ton truck, without modification, is about the same on the highway, when equipped with either 9.00-20 or 14.00-20 tires.

h. The standard 4 ton truck has greater clearance when equipped with 14.00-20 tires than with 9.00-20 tires; therefore allowing better mobility for any operation other than highway.

i. The 14.00-20 low pressure tires have a greater cleaning action than 9.00-20 standard tires.

j. Mud piling up in front of the duals of the 9.00-20 tires, more than any other factor, causes trucks equipped with 9.00-20 tires to have less mobility than trucks equipped with 14.00-20 tires.

k. In severe mud a truck equipped with 14.00-20 tires has higher tractive effort than the same size truck equipped with 9.00-20 tires.

l. The rolling resistance of a truck equipped with 14.00-20 tires is always less in mud than it is for the same size truck equipped with 9.00-20 tires.

The report recommends that:

a. To improve the performance of 4 ton, 6x6, trucks in mud of the type in which the tests were made, 14.00-20, 12-ply low pressure single tires be used in preference to 9.00-20, 10 ply standard dual military tires.

b. If trucks are supplied with standard military non-directional 9.00-20 tires, the front wheels be dualled for increased "mud-mobility" in emergencies.

c. Chains be used on both 9.00-20 tires and 14.00-20 tires to give added "mud-mobility".

d. Reduced tire inflation pressures be used for increased "mud-mobility".

e. On trailers 14.00-20 singles be used in preference to 9.00-20 duals, if the fender clearances will allow.

DESERT WARFARE SECTION  
SECOND INTERIM REPORT NO. 181  
PART II

15 January 1944

TITLE: Tests of 14.00-20, 12 ply and 9.00-20, 10 ply Tires in Mud.

PROJECT NO: MES 433, Service on Tires for Engineer Equipment.

I. SUBJECT

1. This report covers special traction and flotation tests in mud of 14.00-20, 12 ply low pressure tires and 9.00-20, 10 ply standard military tires. Tests were conducted by the Desert Warfare Section during the period 2 November 1943 to 31 December 1943, in mud areas at the Salton Sea and Camp Seeley, California.

II. AUTHORITY

2. Engineer Board Form 104.3, Serial No. 36, dated 11 August 1943,

3. A letter dated 28 May 1943 from the Office, Chief of Engineers directing the Engineer Board to test the military low pressure type tires for traction, flotation, and general service durability with special emphasis on performance in mud. Reference OCE file 400.112 (Tires) SPEED.

III. INVESTIGATION

4. Previous Investigation. The following reports covering this subject and related to this subject are known to the writers.

a. Desert Test Branch Report No. 132, Second Interim Report, Test of Expedients, Road, Mud Operation, dated 26 May 1943.

b. Desert Warfare Section Report No. 182, Interim Report, Tests of 11.00-18, 10 ply and 7.50-20 8 ply Tires in Mud, dated 15 December 1943.

c. B. F. Goodrich Company report on "Ordnance Mud Flotation and Traction Tests", dated 6 June 1943. The tests were conducted and the report written at the request of the Ordnance Department, Tank Automotive Center, Rubber Development Branch, Detroit, Michigan. The testing was carried on in the vicinity of Akron, Ohio. The pertinent conclusions and classification of "Types of Mud" from this report are presented in Appendix D.

d. Ordnance Desert Proving Grounds report on "Mud Tests", dated April 1943, signed by Lt. Col. J. E. Engler. The tests described in this report were carried on at Camp Seeley, Camp Pendleton and in the vicinity of Johnsondale, California. They were similar to those conducted by the B. F. Goodrich Company and substantially the same results and conclusions were reached. The Ordnance report was briefly consulted by the writers before the period the subject tests were being made, but a copy of the report was not available at the time this report was written.

5. Acknowledgments.

a. Technical Assistance. Acknowledgment is hereby made to:

(1) Mr. R. C. Kerr, Senior Engineer (Automotive), who outlined the types of testing to be conducted, aided in locating the test area and gave helpful advice during the conduct of the test.

(2) Miss Loring Nicholson, Assistant Engineer of this Section, for her work in calculating and compiling the data.

(3) Lt. Col. J. E. Engler, Ordnance Desert Proving Ground, for his courtesy in giving valuable information concerning previous tests and in allowing use of the mud test pit at Camp Seeley.

b. Cooperation of Troops. The following troop units furnished enlisted men at various periods to assist in making the tests.

(1) 90th Infantry Division, eight enlisted men for six weeks.

(2) 104th Infantry Division, eight enlisted men for two weeks.

6. Purpose of Tests. The purpose of these tests was to compare the performance in mud of the standard military 9.00-20, 10 ply tire with that of the low pressure 14.00-20, 12 ply tire, also to determine the comparative mud flotation and tractive ability of standard 4 ton, 6x6, trucks, carrying a full payload, equipped with standard 9.00-20 tires or 14.00-20 low pressure tires. A similar test program on the comparative performance of standard military 7.50-20, 8 ply and low pressure 11.00-18, 10 ply tires has been completed. These tests were covered in a previous report.

7. Location and Description of Test Areas. Tests were made at the following places.

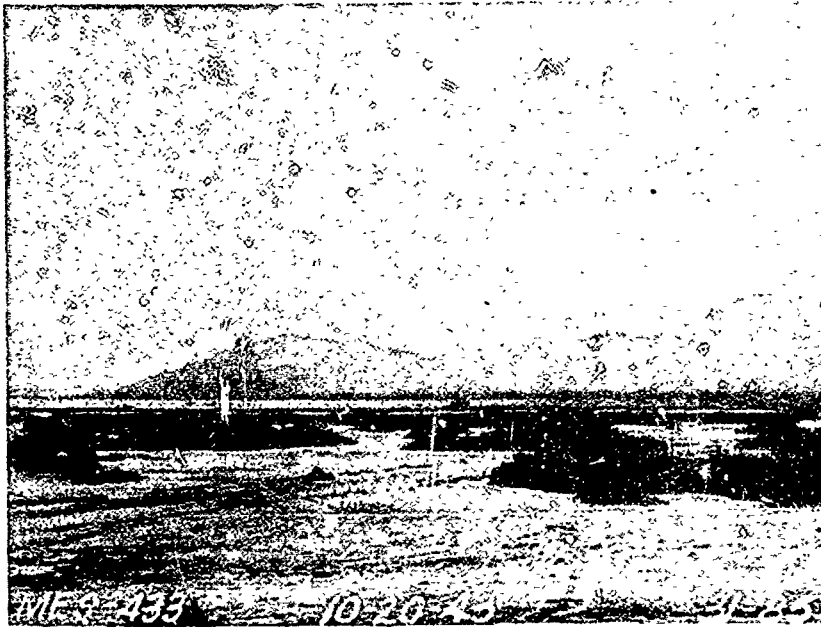
a. North end of Salton Sea.

(1) Dynamometer Tests. These tests were made in areas in which the native salt brush was cleared away. A salt crust that averaged about 1/8 of an inch in thickness covered the entire area and tended to seal the moisture in the mud. The elevation at this location is approximately 250 feet below sea level. The depth of the water table was not determined, but it was fairly close to the surface, because in many instances, water was present in the bottom of the deeper tire tracks. The mud at this point is natural and is about as uniform as it was possible to find in this vicinity. The Ordnance Desert Proving Grounds has classified mud into two types in its report on mud flotation tests. These classifications as taken from the B. F. Goodrich Company report are quoted in Appendix D. In general, the mud in this area can be classified under the definition of Type IIA.

(2) Repeated Trip Test. This test was made in an area where there was either very little or no brush. In general, the mud in this area can be classified under the definition of Type II A. There are spots however, that should be classified as Type I.

(3) Distance Tests. These tests were made in areas in which there was no brush and the mud there could be classified as Type II A.

b. Camp Seeley. Distance tests were made at Camp Seeley. Areas that had been previously laid off and bordered were flooded. In several of the areas the entire area within the borders was covered with two or three inches of water when tests were run. This is the same location at which the tests were made by the Ordnance Desert Proving Grounds. This mud can be classified as Type II B. (See Appendix D). It is a thin slippery slimy layer over a firm base which does not build up excessively on the tires but does form a slick lubricated surface that promotes tire slippages.



TIRE TESTS IN MUD. View of test area at the North end of the Salton Sea showing the sea in the background.

TIRE TESTS IN MUD.  
View of test area at  
Camp Seeley before  
tests were made. The  
depth of water was  
between 4 and 10  
inches.



8. Test Equipment Data.

a. Vehicle Equipment. Four test vehicles were fitted with tire, rim and wheel equipment as listed below:

TABLE I

VEHICLE EQUIPMENT

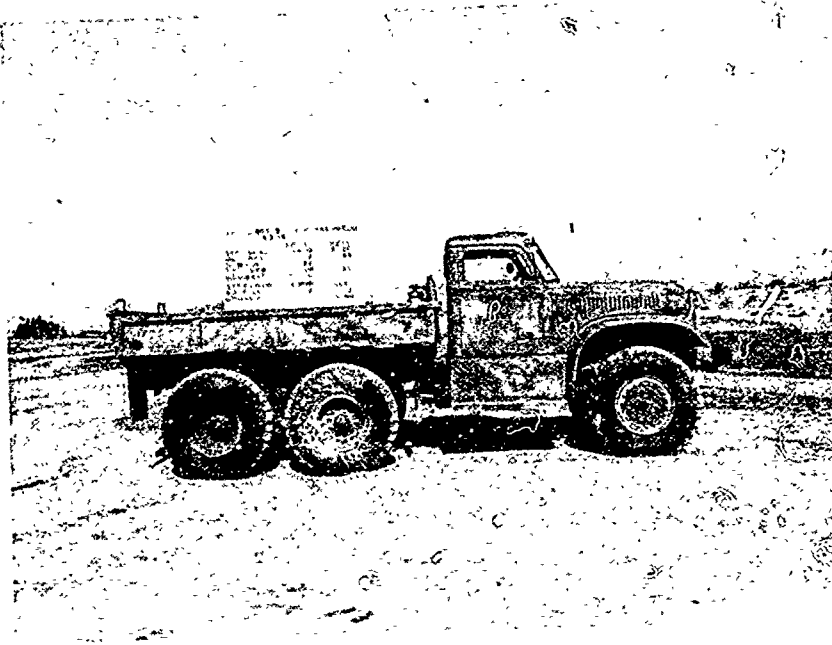
Vehicle Make Size Type	Diamond T 4 ton, 6x6 Cargo	Diamond T 4 ton, 6x6 Wrecker	Diamond T 4 ton, 6x6 Cargo	Diamond T 4 ton, 6x6 Bit. Supply
Tire Eqpt. Tread Type Tire Type	14.00-20, 12 ply with flaps Non-Directional Modified Military Low Pressure Off-Road		9.00-20, 10 ply with flaps Non-Directional Military Standard Mud and Snow	
Rim Equipment	10.00 CW with Goodyear Hinged Type D11L Beadlocks		6.00 T No Beadlocks	
Wheel Equipment	Budd No. 46140, Dish 5-3/8" 11 1/4" Bolt Circle, 10 studs No Spacers or hub adapters		Budd No. 44470, Dish 6-1/8" 11 1/4" Bolt Circle, 10 Studs No spacers or hub adapters	

b. Vehicle Loadings. In accordance with the directive SPOMD-R, dated 18 May 1943, from Ordnance Department, Tank Automotive Center, Engineering Office, Detroit, Michigan, signed by Lt. Col. Joseph M. Colby and indorsed to the Engineer Board by Office, Chief of Engineers, file GE 400.112 Tires SPEED, by Lt. Col. F. C. Kendall, the test trucks were loaded with adjustable loads as shown in the following tabulation:

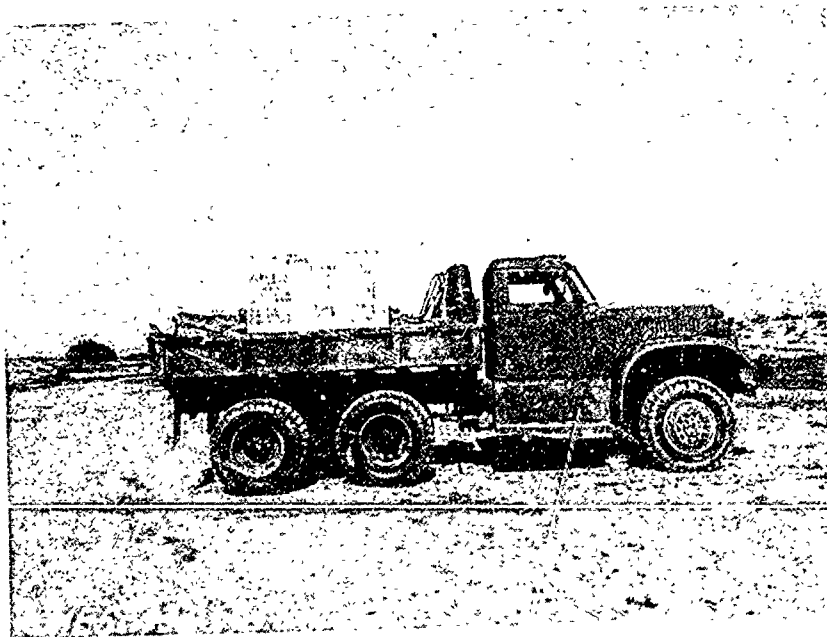
TABLE II

VEHICLE LOADS

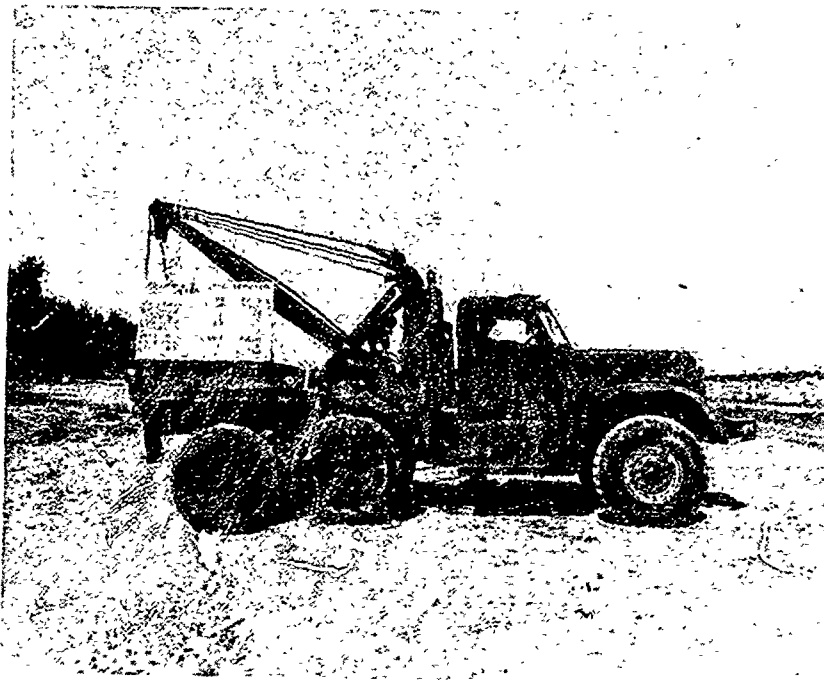
Tire Mountings	Singles All Around	Singles Front Duals Rear	Duals All Around
Tire Size	<u>14.00-20, 12 ply</u>	<u>9.00-20, 10 ply</u>	<u>9.00-20, 10 ply</u>
Axle Load			
Front	7300 lbs.	7300 lbs.	7300 lbs.
Center	9240 lbs.	9240 lbs.	9240 lbs.
Rear	9240 lbs.	9240 lbs.	9240 lbs.
Tire Load			
Front	3650 lbs.	3650 lbs.	1825 lbs.
Center	4620 lbs.	2310 lbs.	2310 lbs.
Rear	4620 lbs.	2310 lbs.	2310 lbs.
Total Vehicle Load	25780 lbs.	25780 lbs.	25780 lbs.



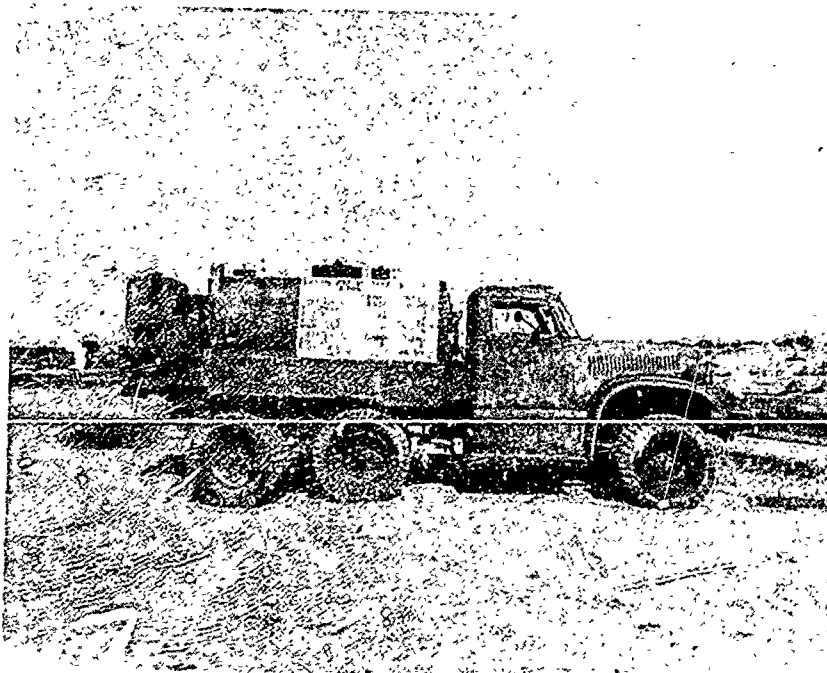
TIRE TESTS IN MUD. Diamond T 4 ton Cargo Truck as used in mud tests. This truck is equipped with 14.00-20 tires singles all around.



TIRE TESTS IN MUD. Diamond T 4 ton Cargo Truck as used in mud tests. This truck is equipped with 9.00-20 tires singles front and duals rear.



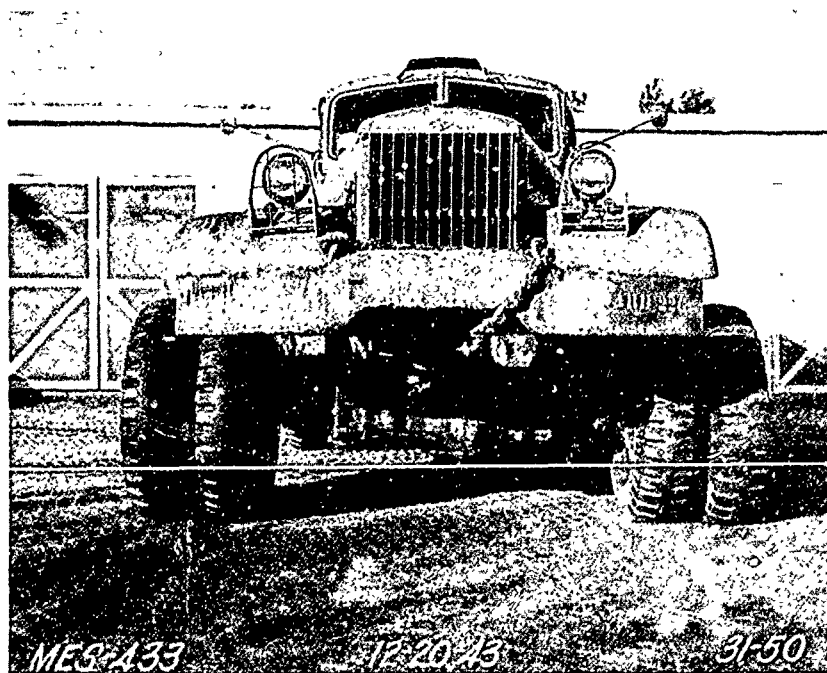
TIRE TESTS IN MUD. Diamond T 4 ton Wrecker Truck as used in mud tests. This truck is equipped with 14.00-20 tires singles all around.



TIRE TESTS IN MUD. Diamond T 4 ton Bituminous Supply as used in mud tests. This truck is equipped with 9.00-20 tires duals all around.



TIRE TESTS IN MUD. The four test trucks used in the tire tests.



TIRE TESTS IN MUD. Diamond T 4 ton Truck equipped with 9.00-20 tires duals in front, as used in mud tests.

c. Inflation Pressures. The inflation pressures used in these tests were based on values of the published load inflation tables of the Tire and Rim Association, Inc., the Ordnance Advisory Pneumatic Tire Committee, the Defense Standards Committee and the various tire manufacturers. The published load and inflation tables have been extended into low inflation ranges by the Ordnance Desert Proving Grounds and the Desert Warfare Section for the loads specified. The pressures used in the Goodrich tests are those recommended by the B. F. Goodrich Company and were taken into consideration in determining the inflation pressures used in these tests.

TABLE III

Tire Mountings	TIRE INFLATION PRESSURES		
	Singles All Around	Singles Front Duals Rear	Duals All Around
Tire Size	<u>14.00-20, 10 ply</u>	<u>9.00-20, 10 ply</u>	<u>9.00-20, 10 ply</u>
Highway Operation			
Front	22 lbs.	72 lbs.	22 lbs.
Center	34 lbs.	33 lbs.	33 lbs.
Rear	34 lbs.	33 lbs.	33 lbs.
25 mph Operation			
Front	14 lbs.	46 lbs.	14 lbs.
Center	22 lbs.	21 lbs.	21 lbs.
Rear	22 lbs.	21 lbs.	21 lbs.
Limited Operation			
Front	10 lbs.	31 lbs.	9 lbs.
Center	15 lbs.	14 lbs.	14 lbs.
Rear	15 lbs.	14 lbs.	14 lbs.
Ordnance Sand Minimum			
Front	6 lbs.	19 lbs.	6 lbs.
Center	9 lbs.	8 lbs.	8 lbs.
Rear	9 lbs.	8 lbs.	8 lbs.

d. Loaded Radius at Various Inflation. The following table presents the actual measurements of the distance from the center of the hub to the ground of the vehicles used in this test.

TABLE IV

LOADED RADIUS AT VARIOUS INFLATIONS

Inflation Wheels	Distance from Center of Hub to Ground in Inches			
	14.00-20, 12 ply Tires - Singles All Around			
	Highway	25 m.p.h.	Limited Oper.	Ord. Sand Min.
Front				
Left	21.50	21.19	20.69	19.94
Right	21.62	21.19	20.75	20.06

(continued, Table IV)

14.00-20, 12 ply Tires - Singles All Around				
<u>Inflation</u>	<u>Highway</u>	<u>25 m.p.h.</u>	<u>Limited Oper.</u>	<u>Ord. Sand Min.</u>
Wheels				
Center				
Left	22.06	21.69	20.81	20.12
Right	21.88	21.56	21.06	20.44
Rear				
Left	22.31	21.88	21.00	20.25
Right	22.12	21.62	21.12	20.38
9.00-20, 10 ply Tires - Singles Front, Duals Rear				
Wheels				
Front				
Left	18.94	18.62	18.00	17.38
Right	19.12	18.75	18.19	17.38
Center				
Left	19.00	18.50	18.00	17.81
Right	18.94	18.50	18.25	17.69
Rear				
Left	19.31	18.94	18.44	18.25
Right	18.75	18.38	18.06	17.38

e. Wheel Track Data. The following tabulation, based on the Vehicle Loads given in Table II and the Highway Tire Inflation Pressures given in Table III, summarizes the wheel track measurements for the four trucks used in the tests.

TABLE V  
WHEEL TRACK DATA  
(Measurements in Inches)

Vehicle	14.00-20, 12 ply		14.00-20, 12 ply		9.00-20, 10 ply		9.00-20, 10 ply	
Make	Diamond T		Diamond T		Diamond T		Diamond T	
Size	4 ton, 6x6		4 ton, 6x6		4 ton, 6x6		4 ton, 6x6	
Type	Cargo		Wrecker		Cargo		Bit. Supply	
Tire Size	14.00-20, 12 ply		14.00-20, 12 ply		9.00-20, 10 ply		9.00-20, 10 ply	
Gen. to Gen. of Tracks	Front	Rear	Front	Rear	Front	Rear	Front	Rear
Std Mount	75.50	82.06	75.69	82.19	74.00	72.19	74.00	72.44
Duals Frt					86.44		86.44	
Overall Track Widths								
Std Mount	90.50	97.06	90.69	97.19	83.50	94.12	82.50	94.38
Duals Frt					113.88		113.88	
Single Track Widths	15.00	15.00	15.00	15.00	9.50	24.88	9.50	24.88

f. Minimum Clearances. Minimum clearances for the front and rear end of each test truck were measured at each of the four inflation pressures used. In each case the minimum clearance was taken to be the vertical distance between the lowest point on the differential gear case and the ground. The torque rod or Equalizer is  $\frac{3}{4}$  inches lower and the brake drum is  $2\frac{1}{2}$  inches lower than the differential gear case. The test trucks were loaded as shown in Table II. Following is a tabulation of the minimum clearances.

TABLE VI

MINIMUM CLEARANCES IN INCHES

Vehicle	Diamond T		Diamond T		Diamond T		Diamond T	
Make	Diamond T		Diamond T		Diamond T		Diamond T	
Size	4 ton, 6x6		4 ton, 6x6		4 ton, 6x6		4 ton, 6x6	
Type	Cargo		Wrecker		Cargo		Bit. Supply	
Tire Size	<u>14.00-20,12 ply</u>		<u>14.00-20,12 ply</u>		<u>9.00-20,10 ply</u>		<u>9.00-20,10 ply</u>	
	<u>Front</u>	<u>Rear</u>	<u>Front</u>	<u>Rear</u>	<u>Front</u>	<u>Rear</u>	<u>Front</u>	<u>Rear</u>
Highway Infl.	14.75	15.00	14.75	15.00	11.88	11.88	11.94	12.25
25 mph Infl.	14.50	14.75	14.25	14.75	11.62	11.62	11.50	11.75
Limited Oper.	13.88	14.12	14.00	14.25	11.38	11.38	12.00	11.25
Ord.Sand Min.	13.50	13.75	13.38	13.75	10.75	11.00	10.25	11.00

9. Types of Tests. Four types of tire tests were conducted, using the four 4 ton, 6x6, test trucks. The types of tests and tire combinations used were as outlined below.

a. Dynamometer Tests were divided into phases to determine tractive efforts and rolling resistances. These tests were made with the following tire equipment combinations:

(1) Standard rear duals and front singles against low pressure singles all around.

(2) Standard duals all around against low pressure singles all around.

(3) Standard rear duals and front singles with chains all around against low pressure singles with chains all around.

b. Repeated Trip Test was made with standard rear duals and front singles against low pressure singles all around.

c. Distance Tests were run with the following tire equipment combinations.

(1) Standard rear duals and front singles against low pressure singles all around.

(2) Standard duals all around against low pressure singles all around.

(3) Standard rear duals and front singles against standard duals all around.

(4) Standard rear duals and front singles with chains all around against low pressure singles all around.

(5) Highway Inflations against reduced Inflations using standard rear duals and front singles.

(6) Highway Inflations against Ordnance Sand Minimum Inflations using standard duals all around.

(7) Highway Inflations against reduced Inflations using low pressure singles all around.

(8) Highway Inflations against Ordnance Sand Minimum Inflations using standard rear duals and front singles with chains all around.

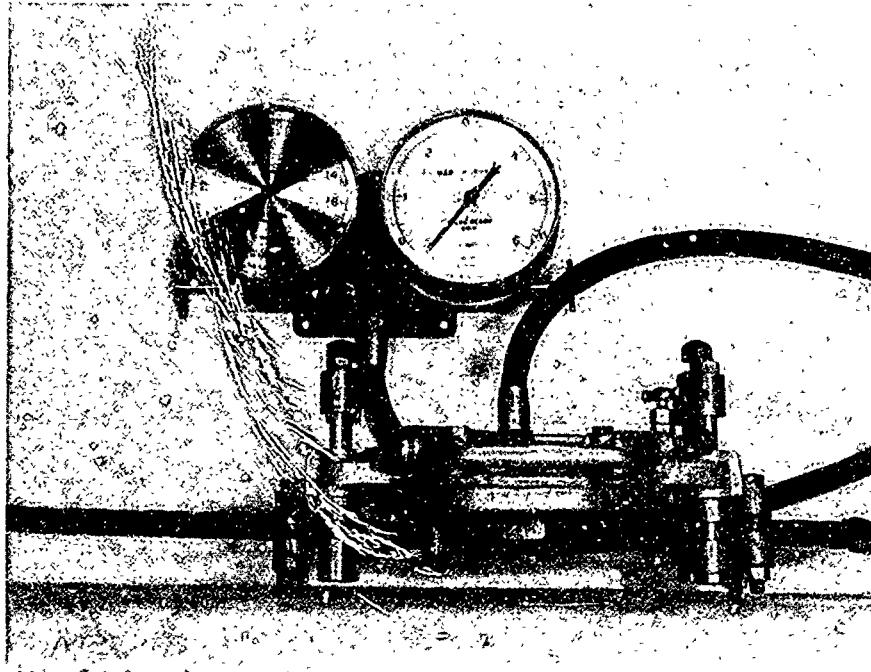
(9) Low pressure singles with chains all around against standard rear duals and front singles with chains all around.

d. Service Durability Tests were run using the same tire equipment combinations as outlined under paragraph 9 c.

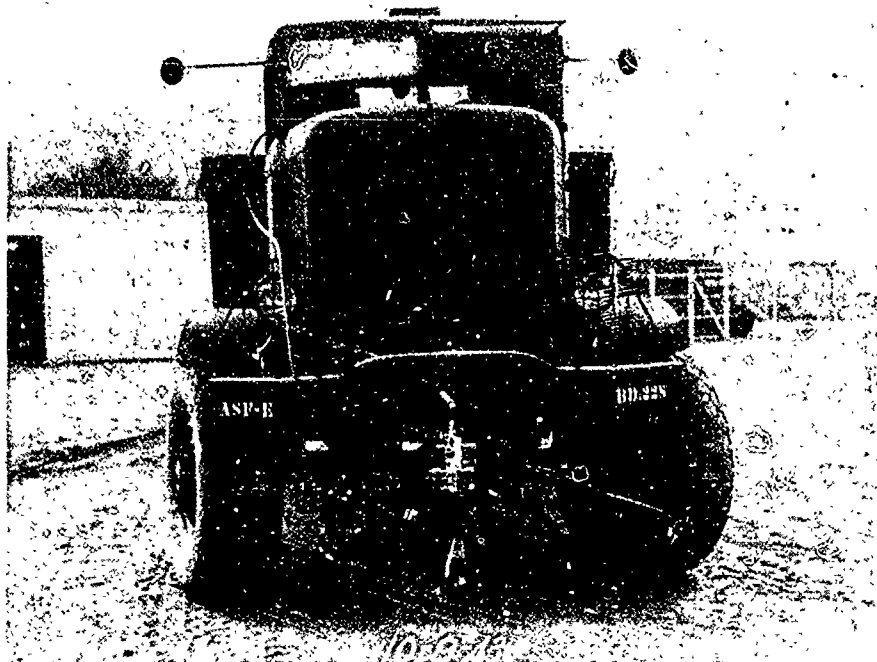
10. Test Procedure. The test procedure for each type of test is summarized in the following outline.

a. Dynamometer Tests.

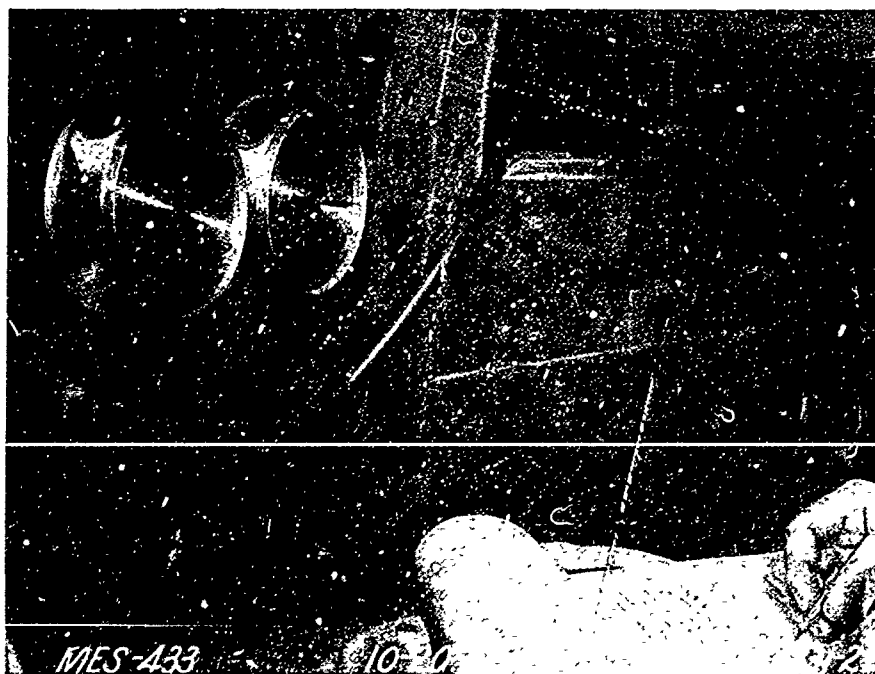
(1) Dynamometer Equipment. The dynamometer used was made by the Martin-Decker Corporation of Long Beach, California. It is a type that is clamped on a cable to measure cable tension. The capacity of the dynamometer is 20,000 pounds and it has a weight of 12 pounds. The instrument is accurate within a range of plus or minus 5 percent. The force tending to straighten the cable distorts a diaphragm on a liquid-filled case, causing pressure change. It is a force triangle, with the line loads forming two sides, and the pressure, exerted by the fluid the other. A dual gauge is used with the dials ranging from 0 to 6000 pounds and 0 to 18000 pounds. The gauge from 0 to 6000 pounds is used when the load is light because the dial increments are larger. When heavier loads are encountered, the gauge ranging from 0 to 18000 pounds is used. The gauges, which are connected to the diaphragm by non-expanding wire woven hose were mounted in the cab of the truck on which the dynamometer was mounted. The increments on the 6000 pound gauge are 50 pounds and those on the 18000 pound gauge are 200 pounds.



TIRE TESTS IN MUD. Close up of dynamometer used in tests showing offset in cable and diaphragm.



TIRE TESTS IN MUD. View showing dynamometer used in tests and method of mounting dynamometer on dynamometer truck.



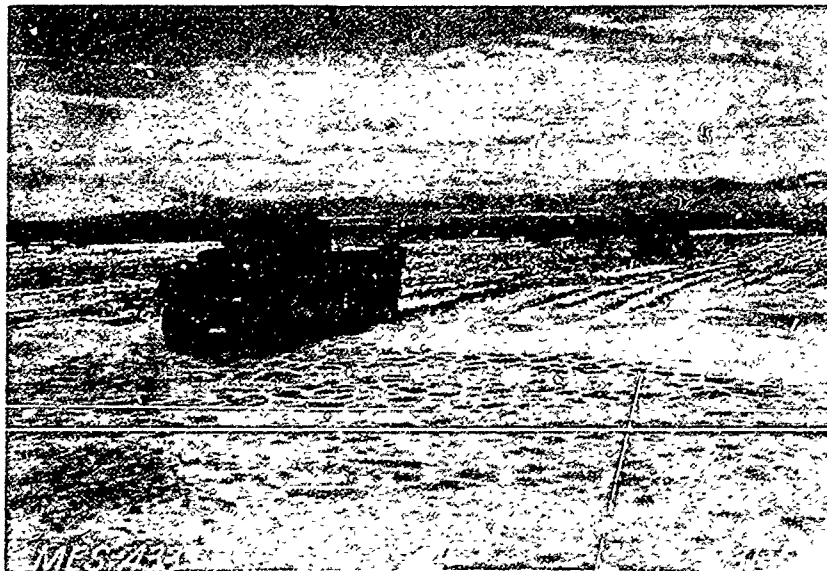
TIRE TESTS IN MUD. View showing gauges of dynamometer and where they were mounted on the dashboard in the cab of the dynamometer truck.

(2) Tractive Effort Tests. In making the tests for tractive effort, a course 100 feet in length was measured off in the muddy area and stakes were placed every 10 feet for use in recording the data. The first test truck was then lined up with the front bumper perpendicular to the line of stakes and about 2 feet distant therefrom. A steel cable, about 100 feet long, was next attached between the test truck and the truck on which the dynamometer was mounted. The dynamometer truck supplied the braking load. After the cable was connected between the two trucks, the test vehicle was run in first gear, low range, all wheel drive and the dynamometer truck was driven in an appropriate gear at a progressively slower speed, thereby allowing the compression of the engine to furnish the braking effort. Close control of braking the test vehicle could be obtained in this manner. If the brakes of the dynamometer truck were used, there was a tendency for them to grab. This grabbing invariably caused an impact on the dynamometer which resulted in an abnormally high reading. In making these tests, the trucks were driven in pairs through the measured courses, starting at one end of the stakes and continuing across the course or until the truck was unable to move with the cable slack. In each test the trucks with competing tire equipment were alternated and run so as to straddle one of the wheel tracks of the preceding vehicle. In this manner each truck made new tracks and the same time traversed mud of comparable consistency. Approximately five of the highest readings were recorded. The average of the readings on each test is attached to this report as Appendix B.

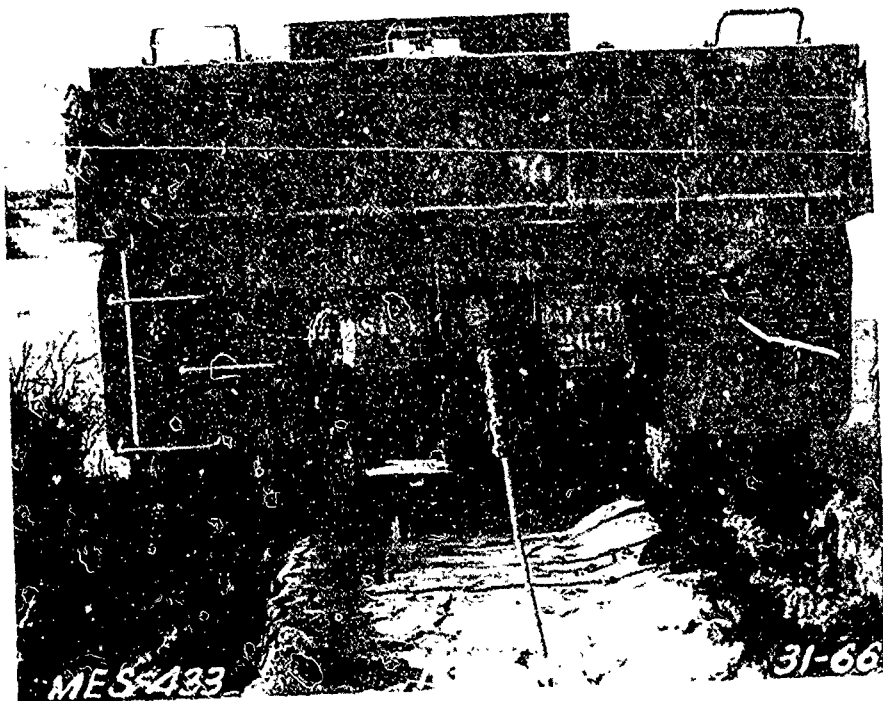
(3) Rolling Resistance Tests. The rolling resistance tests were made in areas adjacent to those used in the tractive effort tests. The test trucks were winched forward in the opposite direction from which they were run in making tractive effort tests. The winch lines on the test trucks which all were equipped with a front-mounted winch were attached to the truck on which the dynamometer was mounted. The test trucks were then used to winch themselves through the muddy area. The tachometer of the winching truck was held, as nearly as possible, at 900 rpm, thus enabling the test truck to be pulled at a constant rate of speed, approximately 25 feet per minute. Care was exercised to maintain the vehicles in proper alignment with a minimum of steering to insure operation of the winch at a constant rate of speed without stopping to respool the cable. A dynamometer gauge reading was recorded every ten feet. The test procedure was repeated for each test truck. The vehicles were paired as in the preceding described test. The trucks with competing tire equipment were pulled alternately through the mud, and astride one of the wheel tracks of the preceding vehicles. Tests were run using the tire equipment combinations outlined in paragraph 9 a and at each of the four sets of inflation pressures indicated in Table III. The average of the readings on each test is found in Appendix B.



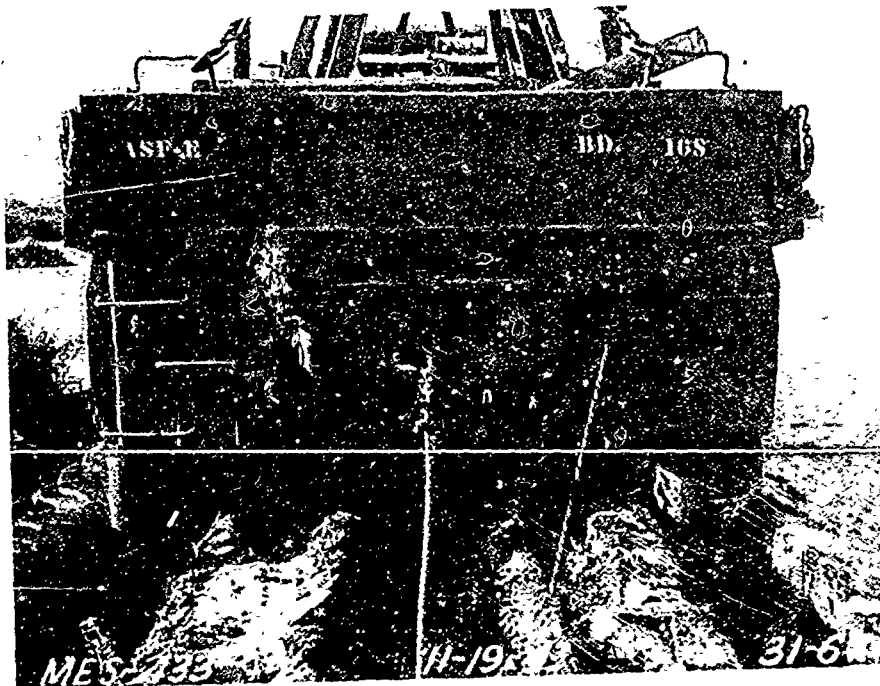
TIRE TESTS IN MUD. General view of method of determining Rolling Resistance. The test truck in the foreground winches itself through the course towards the dynamometer truck.



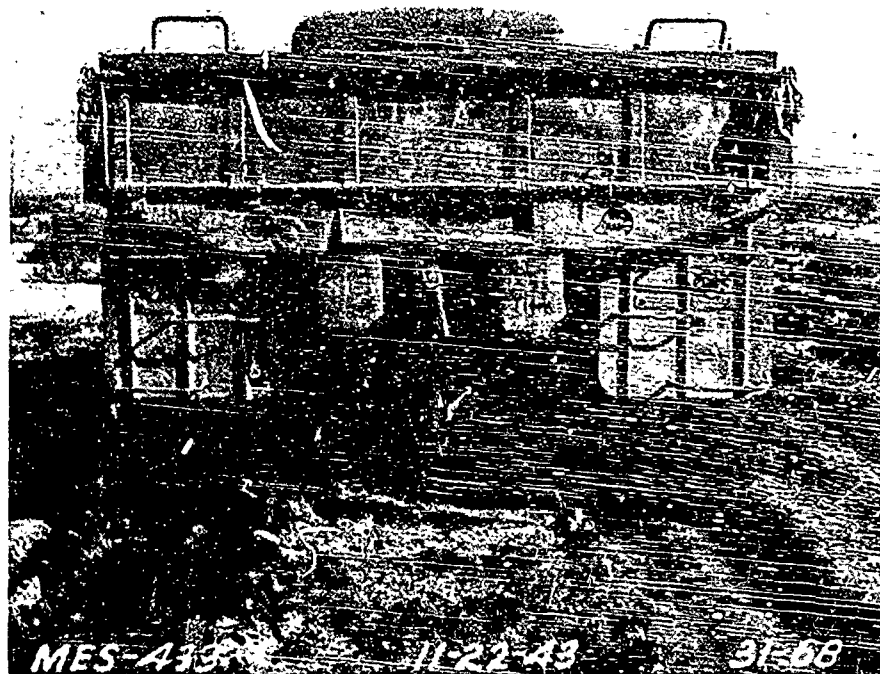
TIRE TESTS IN MUD. General view of method of determining Tractive Effort. A cable is connected between the dynamometer and the test vehicle to furnish a load for developing tractive effort. This cable is long enough to allow the dynamometer truck to stay out of the tracks made by the test vehicle.



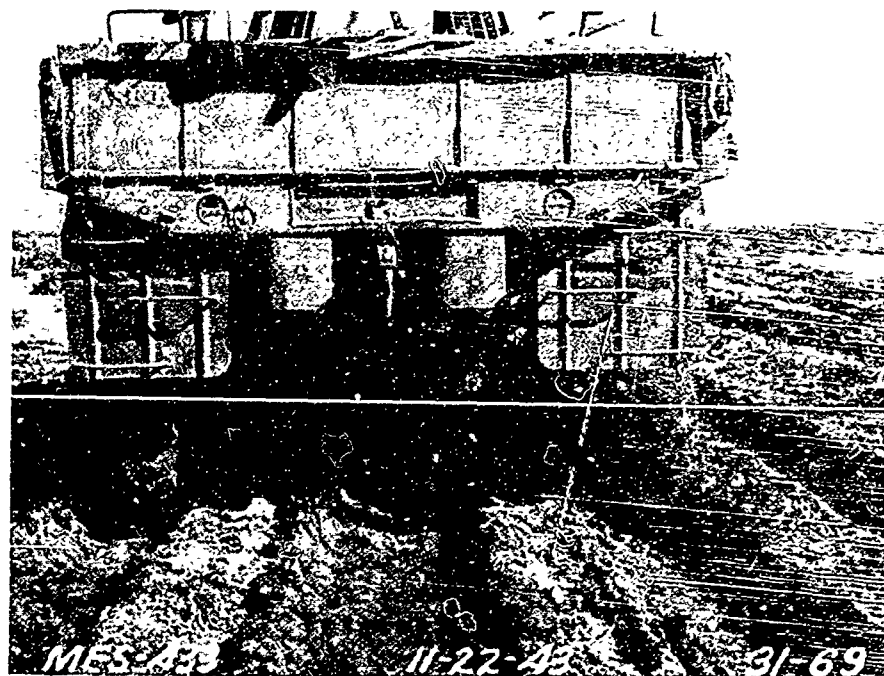
TIRE TESTS IN MUD. View of Diamond T 4 ton Cargo being driven through mud area to ascertain tractive effort. The truck is equipped with 9.00-20 duals all around at Highway Inflatons. The way the bread design fills up can be noted.



TIRE TESTS IN MUD. Diamond T 4 ton Wrecker being driven through the mud. It is equipped with 14.00-20 tires at Highway Inflatons.



TIRE TESTS IN MUD. View of test vehicle with 9.00-20 duals all around at Highway Inflatons. Note the width of tracks made by this vehicle. This truck is winching itself through the mud area.



TIRE TESTS IN MUD. Diamond T 4 ton Wrecker winching itself through the mud. This truck is equipped with 14.00-20 tires at Highway Inflatons.

b. Repeated Trip Test. In making the repeated trip test the four test vehicles were lined up abreast of each other, alternately spaced as to type of tire equipment, and about 3 feet apart. The trucks were run in the following order:

First Vehicle - 9.00-20, 10 ply tires at highway inflations.

Second Vehicle - 14.00-20, 12 ply tires at highway inflation.

Third Vehicle - 9.00-20, 10 ply tires at 25 m.p.h. inflation.

Fourth Vehicle - 14.00-20, 12 ply tires at 25 m.p.h. inflation.

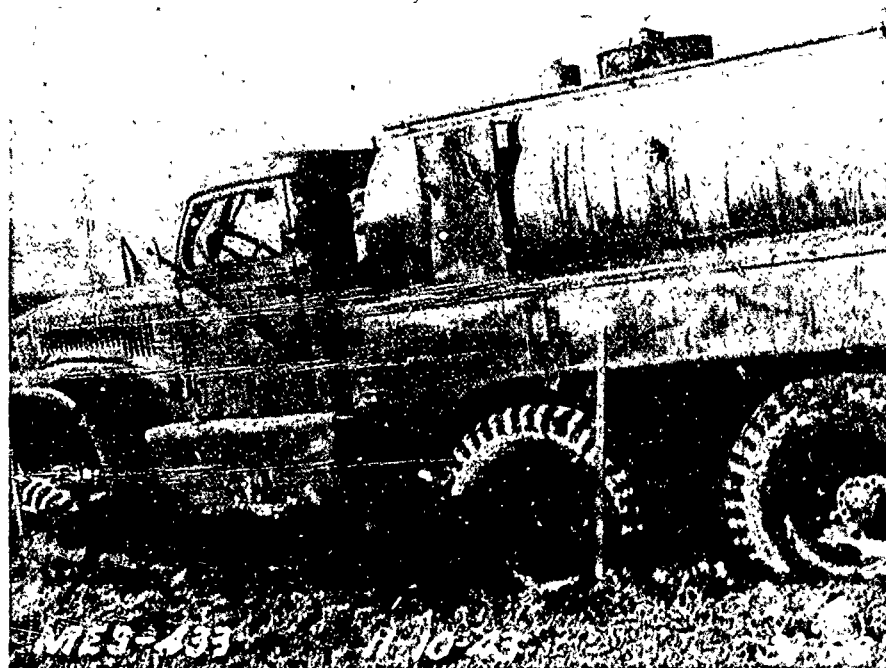
The trucks were run over a course 200 feet long in straight parallel tracks and in one direction only. The number of repeated trips each truck made in its own tracks was recorded.

c. Distance Tests. In making these tests the trucks were driven in pairs through the muddy areas, starting at a given line and continuing either across the area or until the trucks became stuck. In each test the trucks were alternated and run so as to straddle one of the wheel tracks of the preceding vehicle. The trucks were operated in second gear, low range and all wheel drive. This was done after it was found the trucks would go further in second gear than in low gear. The distance traveled by each truck, before becoming immobilized, was recorded. Tests were run using the tire equipment combinations outlined in paragraph 9 c with some of the combinations being run at each of the four sets of inflation pressures indicated in Table III.

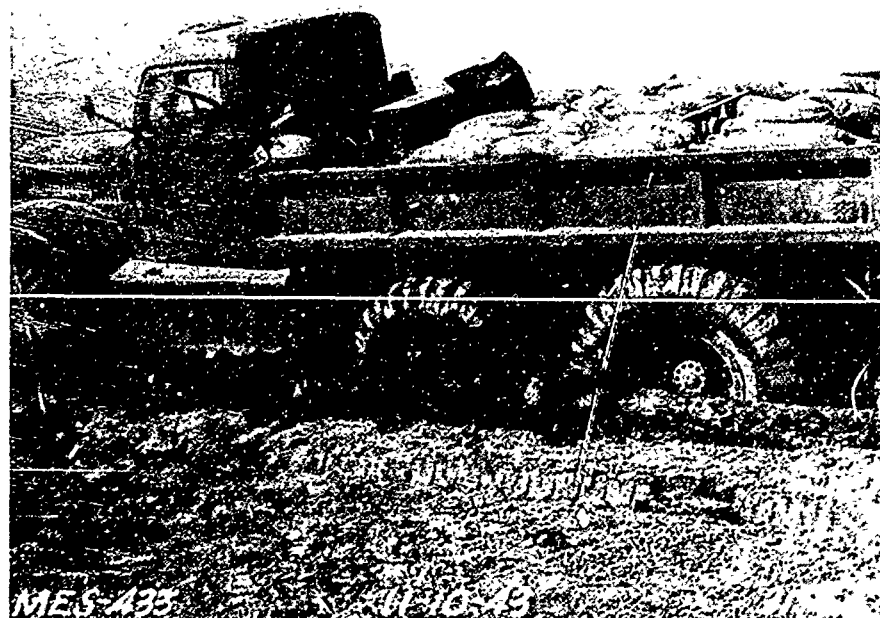
d. Service Durability Tests. The tests covered under this heading consisted of the accumulated mileage put on the test trucks during the entire testing period. They were carried on incidental to the previously described tests, being largely a result of the distances traveled between the test areas and the Desert Warfare Section headquarters. Approximately 85 percent of this travel was on paved highways, and the balance on graded desert roads and in the mud test areas. Speedometer readings, for each test vehicle, were recorded at the start of the test program and again at the conclusion of the tests. All highway travel was made using the "Highway Inflation" given in Table III. About 23 percent of the travel with the standard 9.00-20 tires was made with duals all around. The total mileage covered by all the test trucks was 4170 miles. A tabulation of the mileages for each test truck is included in Appendix B attached to this report.

## 11. Physical Characteristics of Mud.

a. Soil Analyses. Frequent mud samples were taken. All samples were submitted to the laboratories of the Los Angeles District Engineer Office for physical properties analysis of the soil. Grain sizes and grading of the materials are to be determined by mechanical analysis.



TIRE TESTS IN MUD. View of Diamond T 4 ton Bituminous Supply with the front wheels practically buried in the mud. Trucks with standard tires singles in front invariably get stuck in mud with the front wheels buried.



TIRE TESTS IN MUD. Diamond T 4 ton truck equipped with 14.00-20 tires sunk very deep in the mud.



TIRE TESTS IN MUD. View showing the way mud is piled up in front of the rear duals of a truck equipped with 9.00-20 tires duals all around. The tires are at Highway Inflatons.

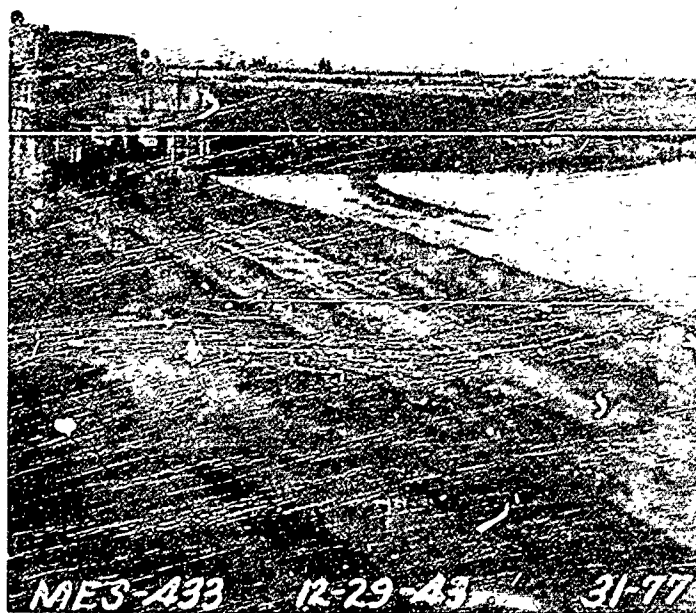


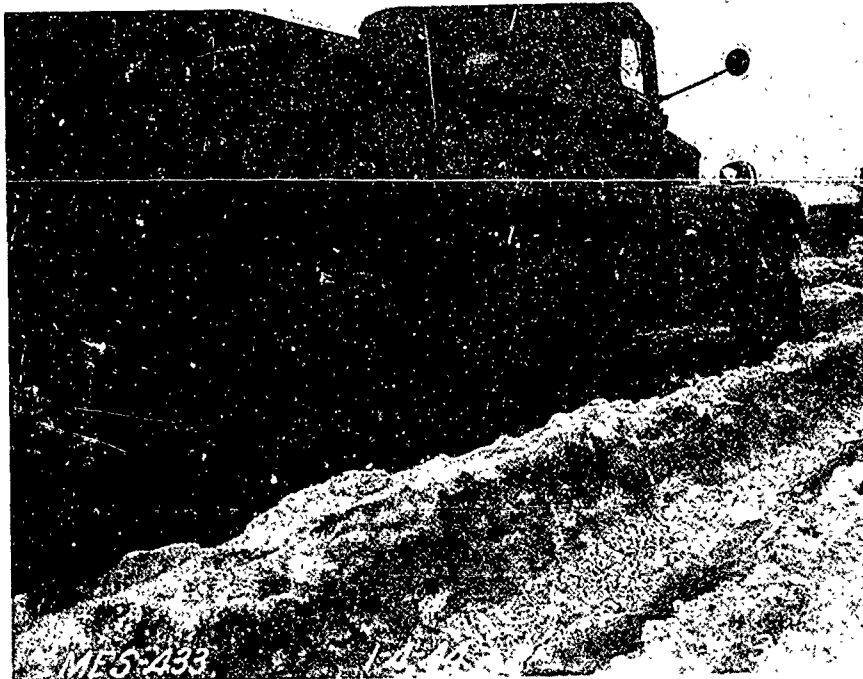
TIRE TESTS IN MUD. A test truck equipped with 9.00-20 tires. Note the way the mud balls up in front of the duals.



TIRE TESTS IN MUD.  
 Four ton Cargo truck  
 with 9.00-20 tires  
 at Ordnance Sand Min-  
 imum Inflation  
 stuck in the mud.  
 Note the depth of  
 water in this area.

TIRE TESTS IN MUD.  
 View showing the dis-  
 tance traveled by 4 ton  
 Cargo with 14.00-20  
 tires. The tracks in  
 the foreground were  
 made at Highway In-  
 flations. The dis-  
 tance the truck  
 traveled at Ord. Sand  
 Min. Inflation can  
 be seen by the posi-  
 tion of the truck in  
 the picture.

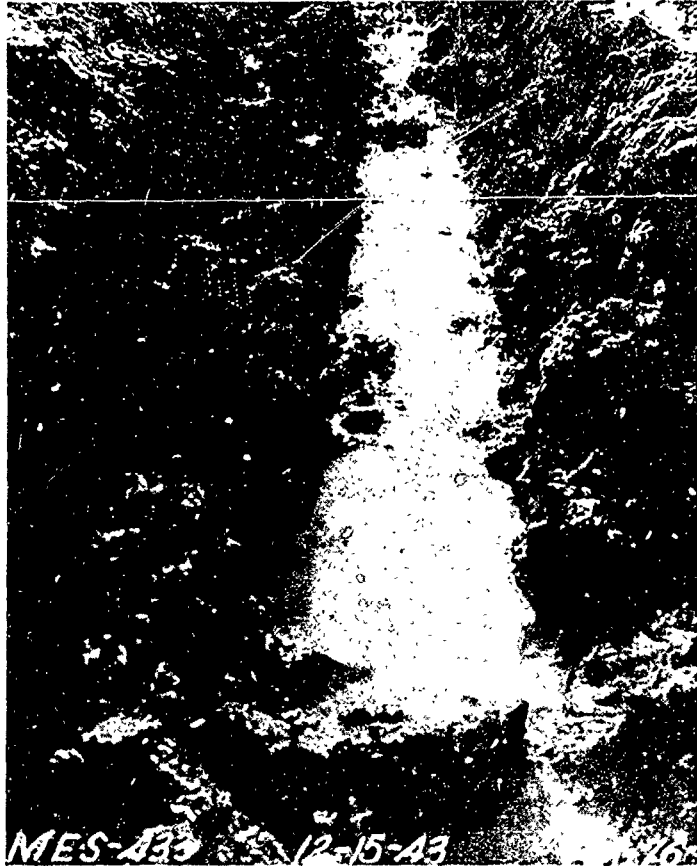




TIRE TESTS IN MUD. View showing a 4 ton Cargo truck with 14.00-20 tires at Highway Inflation stuck in the mud.



TIRE TESTS IN MUD. View of 4 ton Cargo truck with 9.00-20 tires showing the mud clinging to the wheels and piled up between the duals.



TIRE TESTS IN MUD.  
View showing the way  
the water rose in the  
deeper tire tracks  
indicating the near-  
ness of the water  
table.

TIRE TESTS IN MUD.  
A 4 ton truck with  
the front wheels  
almost covered  
with mud.

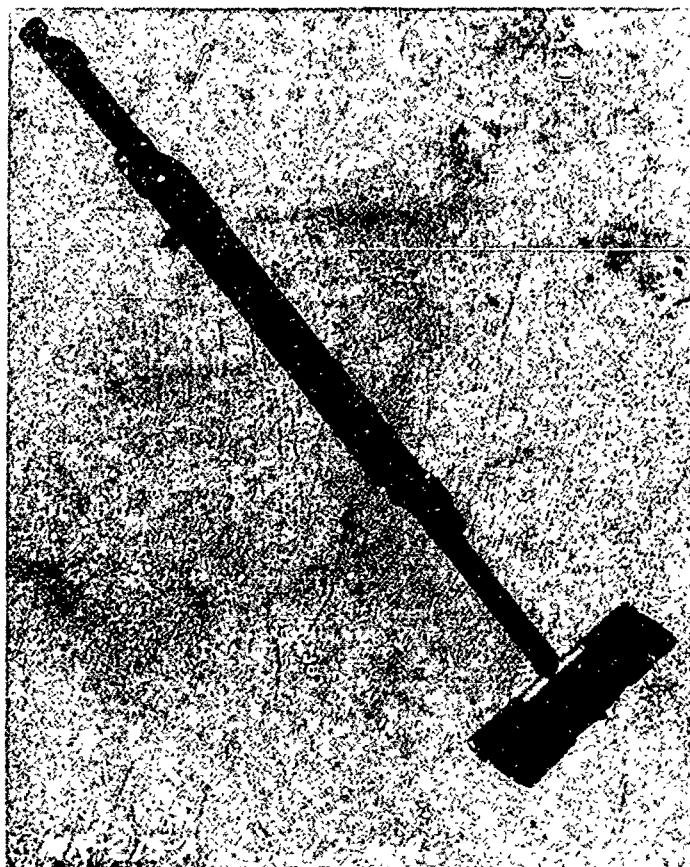




TIRE TESTS IN MUD. View showing a 4 ton cargo with 14.00-20 tires at Highway Inflation stuck in the test area. Note the depth of the tire tracks.

TIRE TESTS IN MUD.  
View of tracks made in the mud at the north end of Salton Sea. The consistency of the mud can be compared in relation to the depth of the footprints.





TIRE TESTS IN MUD.  
Penetrometer used to determine softness of mud. The penetrometer consists of two parts, the stock and the needle. In this picture a short needle is attached to the stock, while in most cases in mud a needle 12" long, with a head of  $\frac{1}{2}$ " sq.in. cross sectional area was used.

TIRE TESTS IN MUD.  
View showing method of using penetrometer. One man used penetrometer and another records the readings.



Other characteristics to be determined are plastic limit, liquid limit and plasticity index. The results of the soil tests have not been reported at this date. In Appendix B an average value for samples previously collected in this same area are presented.

b. Penetrometer Tests. Penetrometer readings were taken at frequent intervals on each dynamometer test, several of the distance tests and before and after on the repeated trip test. The readings provided an index of the relative stability of the mud. The device used was a Proctor penetrometer with a modified needle, which measures the force necessary to push a small diameter metal rod (the needle) a given depth in the mud. Readings were observed at 3, 6, 9 and 12 inch depths. Recordings of the penetrometer readings are included on the data sheets attached to this report as Appendix B.

12. Weather. Weather conditions during the test period, were quite constant. There were no high winds and although several slight rains occurred, they did not affect the tests materially.

13. Tire Gauges. Tire inflation pressures were checked frequently with small Bourdon spring-type gauges. Three of the gauges used were calibrated by the City of Los Angeles, Department of Public Works, Bureau of Standards. The results of the calibration tests are attached as Appendix C. The largest of these gauges was kept as a standard gauge in a box in the office so that it would not be subjected to injury. Two other gauges were calibrated using this standard gauge and weekly all the gauges were checked against this standard gauge.

14. Summary and Analysis of Results.

<u>DISTANCE TESTS</u>					
<u>No. of Tests</u>	<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>Distance Traveled Feet</u>	<u>Percent Difference *</u>
13	9.00-20	Standard	Highway	50.6	
12	14.00-20	Singles	Highway	87.2	72
9	9.00-20	Standard	25 m.p.h.	92.3	
9	14.00-20	Singles	25 m.p.h.	193.9	110
3	9.00-20	Standard	Limited Oper.	35.7	
3	14.00-20	Singles	Limited Oper.	54.0	51
6	9.00-20	Standard	Ord. Sand Min.	147.8	
6	14.00-20	Singles	Ord. Sand Min.	254.5	72

\* Lower figure used as basis of percentage (9.00-20's).

DISTANCE TESTS

<u>No. of Tests</u>	<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>Distance Traveled Feet</u>	<u>Percent Difference *</u>
3	9.00-20	All Duals	Highway	109.7	
3	14.00-20	Singles	Highway	244.0	122
4	9.00-20	All Duals	25 m.p.h.	101.8	
3	14.00-20	Singles	25 m.p.h.	296.0	191
3	9.00-20	All Duals	Limited Oper.	128.0	
3	14.00-20	Singles	Limited Oper.	202.3	58
4	9.00-20	All Duals	Ord. Sand Min.	113.8	
4	14.00-20	Singles	Ord. Sand Min.	206.3	81
2	9.00-20	Chains	Highway	23.5	
2	14.00-20	Chains	Highway	81.5	247
2	9.00-20	Chains	25 m.p.h.	81.5	
2	14.00-20	Chains	25 m.p.h.	131.5	161
2	9.00-20	Chains	Limited Oper.	93.0	
2	14.00-20	Chains	Limited Oper.	191.5	106
2	9.00-20	Chains	Ord. Sand Min.	92.5	
2	14.00-20	Chains	Ord. Sand Min.	205.0	122

\* Lower figure used as basis of percentage (9.00-20's)

Standard Mounting vs Duals All Around

3	9.00-20	Standard	Highway	51.3	
3	9.00-20	All Duals	Highway	74.3	45
3	9.00-20	Standard	25 m.p.h.	111.3	
3	9.00-20	All Duals	25 m.p.h.	144.0	29
3	9.00-20	Standard	Limited Oper.	109.3	
3	9.00-20	All Duals	Limited Oper.	117.7	8

\* Lower figure used as basis of percentage (Singles front, duals rear)

Standard Mounting vs Chains

1	9.00-20	Standard	Highway	25	
1	9.00-20	Chains	Highway	150	500

\* Lower figure used as basis of percentage (Singles front, duals rear)

DISTANCE TESTS

<u>No. of Tests</u>	<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>Distance Traveled Feet</u>	<u>Percent Difference *</u>
<u>Standard Mounting with Chains vs Singles without Chains</u>					
3	9.00-20	Chains	Highway	255.0	241
3	14.00-20	Singles	Highway	74.7	
3	9.00-20	Chains	25 m.p.h.	237.7	54
3	14.00-20	Singles	25 m.p.h.	154.3	
3	9.00-20	Chains	Limited Oper.	260.0	44
3	14.00-20	Singles	Limited Oper.	180.7	
4	9.00-20	Chains	Ord. Sand Min.	150.5	
4	14.00-20	Singles	Ord. Sand Min.	172.3	14

\* Lower figure used as basis of percentage

Reduction of Pressure

1	9.00-20	Standard	Highway	20.0	
1	9.00-20	Standard	25 m.p.h.	24.0	20
1	9.00-20	Standard	25 m.p.h.	24.0	
1	9.00-20	Standard	Limited Oper.	24.0	-
2	9.00-20	Standard	Limited Oper.	23.0	
2	9.00-20	Standard	Ord. Sand Min.	27.25	18
8	9.00-20	Standard	Highway	83.5	
8	9.00-20	Standard	Ord. Sand Min.	162.8	95
1	14.00-20	Singles	Highway	78.0	
1	14.00-20	Singles	25 m.p.h.	138.0	77
4	14.00-20	Singles	Highway	125.0	
4	14.00-20	Singles	Ord. Sand Min.	199.3	59

Reduction of Pressure - Duals All Around

3	9.00-20	Duals All	Highway	106.3	
3	9.00-20	Around	Ord. Sand Min.	108.0	2

Reduction of Pressure - Chains

1	9.00-20	Chains	Highway	105.0	
1	9.00-20	Chains	Ord. Sand Min.	155.0	48

\* Lower figure used as basis of percentage

DISTANCE TESTS

<u>No. of Tests</u>	<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>Distance Traveled Feet</u>	<u>Percent Difference *</u>
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Reduction of Pressure - Standard Mounting vs Singles

1	9.00-20	Standard	25 m.p.h.	50.0	
1	14.00-20	Singles	Highway	80.0	60
1	9.00-20	Standard	Limited Oper.	55.0	
1	14.00-20	Singles	Highway	150.0	173
2	9.00-20	Standard	Ord. Sand Min.	122.0	
2	14.00-20	Singles	Highway	153.0	25
1	9.00-20	Standard	Ord. Sand Min.	27.0	
1	14.00-20	Singles	25 m.p.h.	138.0	411

\* Lower figure used as basis of percentage (9.00-20's)

Reduction of Pressure - Duals All Around vs Singles

1	9.00-20	All Duals	Ord. Sand Min.	72.0	
1	14.00-20	Singles	Highway	159.0	121

\* Lower figure used as basis of percentage

Reduction of Pressure - Standard Mounting with Chains vs Singles without Chains

1	9.00-20	Chains	Highway	140.0	
1	14.00-20	Singles	Ord. Sand Min.	165.0	18

\* Lower figure used as basis of percentage

Reduction of Pressure - Standard Mounting vs Duals All Around

2	9.00-20	Standard	Highway	108.5	14
2	9.00-20	All Duals	Highway	95.0	
2	9.00-20	Standard	25 m.p.h.	54.5	
2	9.00-20	All Duals	Highway	76.5	40
1	9.00-20	Standard	Limited Oper.	54.0	
1	9.00-20	All Duals	Highway	65.0	20
1	9.00-20	Standard	Ord. Sand Min.	62.0	
1	9.00-20	All Duals	Highway	150.0	142

\* Lower figure used as basis of percentage

REPEATED TRIPS TEST

<u>No. of Tests</u>	<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>Distance Traveled Feet</u>	<u>Percent Difference *</u>
1	9.00-20	Standard	Highway	4400	
1	14.00-20	Singles	Highway	5620	28
1	9.00-20	Standard	25 m.p.h.	1600	
1	14.00-20	Singles	25 m.p.h.	3400	113

\* Lower figure used as basis of percentage (9.00-20's)

DYNAMOMETER TESTS

<u>No. of Tests</u>	<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>Tractive Effort</u>	<u>Percent Difference *</u>	<u>Rolling Resistance</u>	<u>Percent Difference *</u>
4	9.00-20	Standard	Highway	2305		3816	86
4	14.00-20	Singles	Highway	2851	24	2054	
6	9.00-20	Standard	25 m.p.h.	3825	10	5486	111
6	14.00-20	Singles	25 m.p.h.	3470		2599	
6	9.00-20	Standard	Limited Oper.	3894		3498	58
6	14.00-20	Singles	Limited Oper.	4433	14	2220	
4	9.00-20	Standard	Ord. Sand Min.	5134		3698	62
4	14.00-20	Singles	Ord. Sand Min.	5725	12	2285	
4	9.00-20	All Duals	Highway	3608	2	4174	18
4	14.00-20	Singles	Highway	3533		3523	
4	9.00-20	All Duals	25 m.p.h.	3017		4359	20
4	14.00-20	Singles	25 m.p.h.	3292	9	3639	
4	9.00-20	All Duals	Limited Oper.	3650	12	3929	22
4	14.00-20	Singles	Limited Oper.	3267		3224	
4	9.00-20	All Duals	Ord. Sand Min.	3567		3560	29
4	14.00-20	Singles	Ord. Sand Min.	4025	13	2765	
4	9.00-20	Chains	Highway	1123		5768	66
4	14.00-20	Chains	Highway	2627	134	3470	
4	9.00-20	Chains	25 m.p.h.	1779		5923	70
4	14.00-20	Chains	25 m.p.h.	2875	62	3481	

\* Lower figure used as basis of percentage

DYNAMOMETER TESTS

<u>No. of Tests</u>	<u>Tire Size</u>	<u>Type of Mounting</u>	<u>Inflation</u>	<u>Tractive Effort</u>	<u>Percent Difference *</u>	<u>Rolling Resistance</u>	<u>Percent Difference *</u>
4	9.00-20	Chains	Limited Oper.	1404		5860	81
4	14.00-20	Chains	Limited Oper.	3354	139	3236	
4	9.00-20	Chains	Ord. Sand Min.	1408		5023	110
4	14.00-20	Chains	Ord. Sand Min.	3438	144	2388	
<u>On Paved Highway</u>							
2	9.00-20	Standard	Highway	8067	7	373	18
2	14.00-20	Singles	Highway	7534		315	

\* Lower figure used as basis of percent

IV. DISCUSSION

15. Condition of Mud. It must be remembered in reviewing the data and results of these tests that mud varies from one location to another. Tests were made under only two general conditions of mud, therefore they cannot be considered as conclusive of the performance of these tires under all mud conditions. Every comparative test should be considered as complete in itself. Mud conditions differ so widely from one location to another that any other test data can only be compared with this data by considering and if possible analyzing the respective mud conditions. Some of the muddy areas at the North end of the Salton Sea are very severe and the mud at Camp Seeley is considered by the ordnance tire experts to be as severe a mud condition as can be traversed by ordinary pneumatic tired wheels. There are certain mud conditions that would be impossible to cross with any ordinary tire combination. In such cases the best way to get the equipment across would be to lay a road expedient.

16. Discussion of Tests.

a. Distance Tests. This type of test is considered as most important. This type of test is believed to give the most conclusive results of mobility. It was found that the trucks irrespectively of the size tires with which they were equipped would travel farther in mud if the front wheels were slightly and slowly oscillated from side to side. Tests of this type which are also known as "go-no-go" are the most satisfactory method of determining the relative performance in mud of various tire combinations. The ideal mud condition for making distance tests is where the mud is of progressively decreasing

firmness. In a condition like this, more value can be given to the distances the trucks travel. These distance tests made during this test were all in this ideal mud condition. It was found when a truck is stopped in muddy areas that if the truck is able to back up and take another run in the same tracks it is able to go further. It is advisable to reduce the inflation in the tires before the muddy areas are reached because after a truck becomes stuck it does not help to reduce the inflations. Single low pressure 14.00-20 tires are easier to inflate or deflate than dual standard military 9.00-20 tires because the mud balls up between the dual tires and is difficult to dig out.

(1) The "mud-mobility" of trucks equipped with 9.00-20 tires is improved by dualing the front wheels because the flotation of the front wheels is greatly increased.

(2) Reduction of tire pressures gives better "mud-mobility" because the flotation is increased and because the flexing of the tires causes a certain amount of the mud to fall off. Reducing the tire pressures increases the gross contact area and therefore increases the flotation but decreases the clearance. The increased performance of trucks in mud due to reduction of inflation pressures is not as pronounced as it is in sand where the reduction of pressures greatly increases the performance.

(3) The "mud-mobility" of trucks equipped with 9.00-20 singles in front and chains all around is better than when equipped with 14.00-20 tires, without chains, at most inflations because they have better traction. When the 9.00-20 tires are at Highway Inflation and the 14.00-20 tires are at Ordnance Sand Minimum Inflation, the 14.00-20 tires have better "mud-mobility" because the amount of flotation of the 14.00-20 tires overcomes the advantage of the better traction of the 9.00-20 tires with chains all around. Under certain conditions of mud it is feasible that trucks equipped with 9.00-20 tires will outperform trucks equipped with 14.00-20 tires. When there is a slippery slimy layer over a firm subsurface, it is believed the standard military 9.00-20 tires will cut through the slimy layer and dig into the firm subsurface while the low pressure 14.00-20 tires have more of a tendency to slip on the surface.

b. Dynamometer Tests. This type of test has been used by some organizations in addition to the Desert Warfare Section in determining the comparison of various vehicles to negotiate muddy areas. The amount of drawbar pull or tractive effort is an indication of the performance in mud of vehicles. In several of the dynamometer tests the mud condition was much less severe than encountered during the majority of the tests, hence did not provide an adequate test for the low pressure tires. These tests showed a slight percentage tractive effort in favor of the 9.00-20 tires. When an area was used in which the trucks equipped with 14.00-20 tires were able to travel 100 feet and the trucks equipped with 9.00-20 tires were able to travel only 25 feet every test showed a percentage tractive effort in favor of the 14.00-20 tires. Trailers that



TIRE TESTS IN MUD. View showing the difference in distance traveled by trucks equipped with 14.00-20 and 9.00-20 tires. All the trucks started from the same point in the same gear. The trucks equipped with 9.00-20 tires were run first and traveled 20 feet at Highway Inflation. The truck equipped with 14.00-20 tires straddling the tracks made by the 9.00-20 tires went 134 feet before it was arbitrarily stopped. Later the pressures in the trucks equipped with 9.00-20 tires were reduced to 25 m.p.h., Limited Operation and Ordnance Said Minimum Inflation and traveled 20, 24 and 30 feet respectively.



TIRE TESTS IN MUD.  
Tracks made by 4 ton  
Cargo with 14.00-20  
tires. The tracks  
in the center of the  
picture made at High-  
way Inflations are  
straddling tracks made  
at Ordnance Sand Min-  
imum Inflations.



TIRE TESTS IN MUD.  
Tracks made by 4 ton  
Cargo with 9.00-20  
tires at Highway  
Inflations. The  
Tracks in the center  
of the picture made  
without chains are  
straddling tracks  
made with chains  
all around.

are now equipped with 9.00-20 duals would have much better mud mobility and lower rolling resistance if they were equipped with 14.00-20 singles. If fender clearances will allow, it would be advisable to equip trailers with 14.00-20 tires.

c. Repeated Trip Test. This test was devised to simulate the convoy conditions of trucks following in the same tracks of preceding vehicles. It is a difficult test to run except where a mud channel with hard banks and a means of returning to the starting point is available. Repeated crossings of the channel can then be made with the trucks always being run in the same direction and in their own tracks. Difficulty was encountered in finding a condition as preferred and the trucks usually were stuck when turning and returning to the start of the course. The Distance and Repeated Trip tests were used mainly to determine the "mud-mobility".

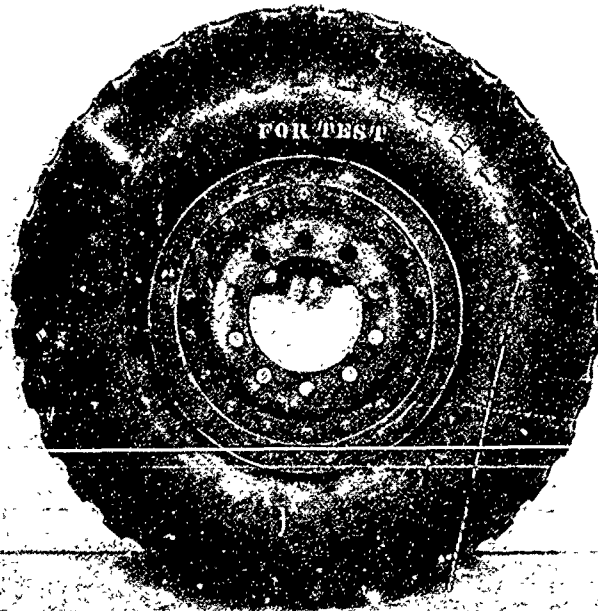
d. Service Durability Tests. In the total of 4,170 miles traveled with the test trucks not a single tire failure occurred. No premature tube failures resulted even though the tires were deflated to the Ordnance Sand Minimum Inflation during a considerable portion of the test period. No tire or tube slippage was noted during the tests, even though the 9.00-20 tires were not equipped with beadlocks or taper wedge bead rings. The mileages of the trucks equipped with the 14.00-20 tires were corrected by calibration rather than by adjustment of the speedometer. When trucks are operating in muddy areas it is especially important to keep valve caps in place because if they are left off, mud works into the valve core and stops them up making it impossible to put additional air in or let the air out of the inner tube. The load carrying capacity of a 14.00-20, 12 ply low pressure tire is nearly twice as much as a 9.00-20, 10 ply standard military tire when both are at 65 pounds per square inch inflation pressure.

17. Advantages of Chains. Standard 9.00-20 chains were used on the 9.00-20 tires, and chains that were fabricated in the local shop out of 7.50-20 chains were used on the 14.00-20 tires. It was found that a truck equipped with chains went much farther than a truck without chains. The use of chains all around affords a noticeable increase in traction because the flexing action of loosely fitted chains helps to clean the tire of mud and permits them to run with a relatively clean tread. The chains should not be too loosely fitted as they will cause damage to the body of the truck when they rotate with the wheels. Chains were only used on the trucks equipped with 9.00-20 tires when there were singles on front. The use of chains when traveling over very slippery surfaces will greatly increase tire wear, in fact more severe than when tires are run at decreased inflations.

18. Piling up of Mud. It was noted that mud had a tendency to continually pile up ahead of the duals on trucks equipped with 9.00-20 tires. This condition invariably resulted in quicker immobility of the vehicle than resulted with the 14.00-20 tired trucks when the conditions were the



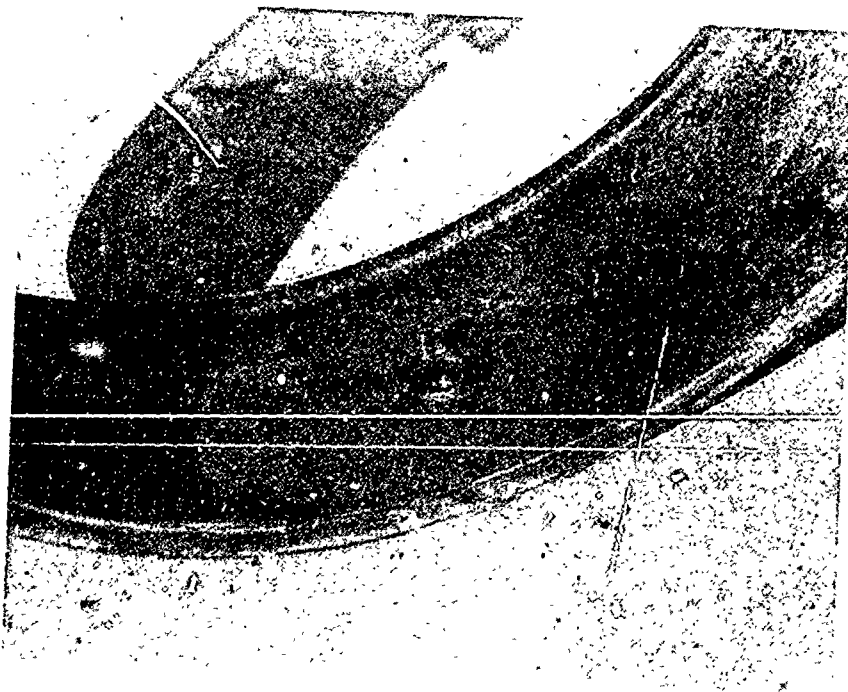
TIRE TESTS IN MUD. View showing the parts of a 1 1/4.00-20 tire and wheel that was used in the testing.



TIRE TESTS IN MUD. View showing the 1 1/4.00-20 tire and wheel all assembled that was used in the testing.



TIRE TESTS IN MUD.  
View showing the way  
the mud balls up on  
the tires. This  
truck is equipped  
with 9.00-20 tires,  
singles front and  
duals rear, chains  
all around.



TIRE TESTS IN MUD. Type of beadlock used in the 14.00-20 tires  
showing the section of the valve guide that was necessary to cut  
off so the valve stem used would lay in the proper position.

same. It is believed the fact the trucks equipped with 9.00-20 tires were dualled on the rear is the greatest reason for the poor mud-mobility of these trucks.

19. Ease of Steering. Steering on pavements or hard surfaced roads at highway inflations was found to be about the same for trucks equipped with 9.00-20 tires compared with the trucks equipped with 14.00-20 tires. When operating off-road, in mud or loose material of any sort, steering was found to be easier with the trucks equipped with 14.00-20 low pressure tires compared to those equipped with 9.00-20 tires, either singles or duals on front. Steering on pavements was found to be much easier for a truck equipped with 14.00-20 tires as compared with a truck equipped with 9.00-20 tires duals on front. When operating off-road, steering was easier with trucks equipped with 9.00-20 tires singles front as against duals front. The use of tire chains all around did not alter relationships given above. The front wheels of the trucks equipped with 14.00-20 tires were not realigned in order to assure ease of steering and so possibly if this was done the trucks with 14.00-20 tires would have been easier to steer. The front wheels should be kept in proper alignment in order to assure satisfactory tire life.

20. Wheels and Rims Used With 14.00-20 Tires. The 20 x 10.00 CW military divided rims on 5-3/8 inch dish wheels were used for the 14.00-20 tires. Eight enlisted men without any previous experience were able to mount 4 tires with tubes, flaps and beadlocks on these wheels in one hour. These wheels were mounted dish in on front and reversed in rear. The rim of these wheels rub slightly on the push rod pin connection of the brakes on the front wheels. The length of the brake push rods can be adjusted to provide satisfactory clearance.

21. Beadlocks. A slight modification of the beadlock was necessary to adapt it to the valve stems. It was found to be necessary to cut off one of the wings of the guide where the valve stem goes through so that the valve stem can lay in the proper position.

22. Cleaning Qualities. The flexing of the carcass of the 14.00-20 low pressure tire causes the mud to fall off resulting in a greater cleaning action than with the 9.00-20 standard tires. When the mud is covered completely with water, the water has a washing and cleaning effect which is a decided advantage. It is believed by the writers from previous experience that the directional mud and snow type tread cleans itself better than the non-directional military tire.

23. Comparative Weights of Tires. The weight of a 14.00-20 low pressure tire, tube and flap is 253 pounds. The weight of a 9.00-20 standard military tire, tube and flap is 117.85 pounds. Therefore the tire equipment of a standard 4 ton truck equipped with 14.00-20 tires totals 1771 pounds considering the truck has one spare. The total tire equipment of a standard 4 ton truck equipped with 9.00-20 tires weighs 1414.2 pounds taking into account the two spares.

24. Gear Ratio. In off road operation and particularly in soft soil, mud or sand operation, the large tired vehicle rolls so much easier and is so much less subject to bouncing, chattering and shocks than the smaller tired vehicle that the power transmission system is actually under less strain with the large tires than it is with the smaller tires. Furthermore, in soils and soft material, the present power transmission system is capable of spinning the large tires. When the tire spins, no increase in effective axle torque is of value. It is recognized that about 17½ percent lower effective gear reduction with heavier drive lines, differentials and axles would be desirable, particularly in highway operation, but it is believed that the present equipment is sufficiently strong to render satisfactory military off road operation and a change at this time can not be justified.

25. Clearances. It is of interest to note that the minimum road clearance of a standard 4 ton, 6x6, truck equipped with 14.00-20 tires is approximately 2-15/16 inches greater than when equipped with 9.00-20 tires. This added clearance enables a truck so equipped to negotiate certain areas of mud which would stop trucks equipped with 9.00-20 tires, and also helps in any cross country operation.

## V. CONCLUSIONS

26. Based on the results of the tests covered in this report and on tests previously conducted in sand by this Section, it is concluded that:

a. "Mud-mobility" of the standard 4 ton, 6x6, truck is better when equipped with 14.00-20 single low pressure tires than when equipped with 9.00-20 standard military tires, with either singles or duals on the front wheels.

b. "Mud-mobility" of the standard 4 ton truck with 9.00-20 tires is improved by dualing the front wheels.

c. "Mud-mobility" of the standard 4 ton truck equipped with either 9.00-20 or 14.00-20 tires is increased with reduction of tire pressures.

d. "Mud-mobility" of the standard 4 ton truck equipped with either 9.00-20 standard or 14.00-20 low pressure tires is improved by the use of tire chains.

e. "Mud-mobility" of the standard 4 ton truck is better when equipped with 9.00-20 singles in front and chains all around than when equipped with 14.00-20 tires, without chains, at most inflations. When the 14.00-20 tires are at Ordnance Sand Minimum Inflations and the 9.00-20 tires are at Highway Inflations, the 14.00-20 tires give slightly better performance.

f. The standard 4 ton truck, without modifications, is easier to steer cross country when equipped with 14.00-20 tires.

g. The ease of steering of the standard 4 ton truck, without modification is about the same on the highway, when equipped with either 9.00-20 or 14.00-20 tires.

h. The standard 4 ton truck has greater clearance when equipped with 14.00-20 tires than with 9.00-20 tires, therefore allowing better mobility for any operation other than highway.

i. The 14.00-20 low pressure tires have a greater cleaning action than 9.00-20 standard tires.

j. Mud piling up in front of the duals of the 9.00-20 tires, more than any other factor, causes trucks equipped with 9.00-20 tires to have less mobility than trucks equipped with 14.00-20 tires.

k. In severe mud a truck equipped with 14.00-20 tires has higher tractive effort than the same size truck equipped with 9.00-20 tires.

l. The rolling resistance of a truck equipped with 14.00-20 tires is always less in mud than it is for the same size truck equipped with 9.00-20 tires.

## VI. RECOMMENDATIONS

27. It is recommended that:

a. To improve the performance of 4 ton, 6x6, trucks in mud of the type in which the tests were made, 14.00-20, 12 ply low pressure single tires be used in preference to 9.00-20, 10 ply standard dual military tires.

b. If trucks are supplied with standard military non-directional 9.00-20 tires, the front wheels be dualled for increased "mud-mobility" in emergencies.

c. Chains be used on both 9.00-20 tires and 14.00-20 tires to give added "mud-mobility".

d. Reduced tire inflation pressures be used for increased "mud-mobility".

g. On trailers 14.00-20 singles be used in preference to 9.00-20 duals, if the fender clearances will allow.

*Martin R. Leidig*

Submitted by: Martin R. Leidig  
Asst. Engineer (Civil)

*C. C. Huskison*

Submitted by: C. C. Huskison  
Engineer (Civil)

*John MacClarence*  
Forwarded by: John MacClarence, Major, C. E.  
Chief, Desert Warfare Section.

APPENDIX "A"

Directive

Authorizing

Testing of 14.00-20, 12 ply

Low Pressure Tires

TECHNICAL DIVISION IV  
THE ENGINEER BOARD  
FORT BELVOIR, VIRGINIA

Date: 11 August 1943

Serial No: 36

E. B. Form No. 104.3.

Subject: Directive for (Desert Warfare ) Section.  
(~~Desert Warfare Section~~)

A (written directive signed by) Captain Glenn D. Ferguson  
(~~written directive from~~)

was received this date from Technical Division III

Authority: Letter from OCE to EB dated 5/28/43, file CE 451.92, EB 400.1  
(MES 433), subject: Service on Tires.

requesting that the following work be done under

<u>Project No:</u>	<u>File No:</u>	<u>Date</u>
MES 433	400.1 (MES 433)	2 August 1943

Directive: Desert Warfare Section to assist the Transportation Development Branch of the Engineer Board in testing of 14:00 x 20-12 ply and 11:00 x 18-10 ply low pressure tires. Schedule of test program is being prepared jointly by Transportation Development Branch and Desert Warfare Section and will be forwarded to Technical Division IV for approval when completed.

Completion Date: Funds Authorized: None other than  
MES 433

Date Received (Desert Warfare Section) : 17 August 1943  
(~~Date Received (Desert Warfare Section)~~)

Estimated Completion Date: 1 Dec 1943 Persons Assigned to Job:

Date Completed: Mr. R. C. Kerr  
Mr. C. C. Haskison  
Mr. M. R. Leidig

RETURN TO TECHNICAL DIVISION IV UPON COMPLETION OR CANCELLATION OF PROJECT

Distribution: XColonel Goerz  
Director, Technical Division I  
Director, Technical Division II  
XDirector, Technical Division III  
XDirector, Technical Division IV  
Director, Service, Admin., & Supply Division  
XChief, Desert Warfare Section (6)  
Chief, Mountain Warfare Section  
XControl and Reports Branch

C O P Y  
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APPENDIX "B"

Test Data  
Of Tire Tests in Mud  
With 14.00-20, 12 ply and  
9.00-20, 10 ply Tires

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Soil Analyses	212

DYNAMOMETER TESTS

Test No.	Date 1943	Tire Size	Inflation	Truck 4-ton Diamond T	Tractive Effort	No. of Readings	Rolling Resistance	No. of Readings	Penetrometer Readings											
									Rolling Resistance						Tractive Effort					
									Sta No.	3"	6"	9"	12"	Sta No.	3"	6"	9"	12"		
1	3	9.00-20	Hwy	Cargo	1722	10	4020	9	36	60	130	3	40	38	70	130				
1	3	9.00-20	Hwy	Bit Sup.	2030	10	4015	10	28	40	130	8	34	42	110	130				
1	3	14.00-20	Hwy	Wrecker	1850	10	2085	10	34	56	100	130	1	30	52	130				
1	3	14.00-20	Hwy	Cargo	2620	10	2170	10	30	64	130	6	40	60	110	130				
5	5	9.00-20	Hwy	Cargo	2433	10	3700	3	38	110	100	8	28	40	130					
5	5	9.00-20	Hwy	Bit Sup.	3033	10	3530	3	40	58	60	90	8	20	60	90	130			
5	5	14.00-20	Hwy	Wrecker	3467	10	1930	3	40	60	110	112	9	20	42	130				
5	5	14.00-20	Hwy	Cargo	3467	10	2030	3	50	78	110	110	7	30	36	130				
6	5	9.00-20	25 MPH	Cargo	2133	8	4963	3	30	80	130	11	30	30	130					
6	5	9.00-20	25 MPH	Bit Sup.	1800	10	5640	3	10	20	70	124	7	30	130					
6	5	14.00-20	25 MPH	Wrecker	1867	10	2395	3	20	20	90	100	8	34	130					
6	5	14.00-20	25 MPH	Cargo	1933	10	2455	3	18	92	130	10	36	100	130					
7	9	9.00-20	Ltd. Oper	Cargo	3067	10	2615	3	40	44	80	100	4	40	70	100	106			
7	9	9.00-20	Ltd. Oper	Bit Sup.	4200	10	2685	3	9	42	80	120	6	40	44	120	130			
7	9	14.00-20	Ltd. Oper	Wrecker	4333	10	1475	3	1	30	60	106	5	28	50	130				
7	9	14.00-20	Ltd. Oper	Cargo	540	10	1555	3	6	26	38	110	4	40	52	130				
8	10	9.00-20	Ltd. Oper	Cargo	3533	10	4720	3	30	26	28	34	5	40	20	22	40			
8	10	9.00-20	Ltd. Oper	Bit Sup.	2200	10	4855	3	8	26	22	32	7	20	22	30	40			
8	10	14.00-20	Ltd. Oper	Wrecker	3267	10	3615	3	7	30	20	22	5	32	25	18	18			
8	10	14.00-20	Ltd. Oper	Cargo	3067	10	2940	3	6	28	30	28	10	30	28	20	30			
9	11	9.00-20	25 MPH	Cargo	4000	10	8040	3	6	18	34	32	2	44	30	22	30			
9	11	9.00-20	25 MPH	Bit Sup.	2150	10	8220	2	3	38	26	28	4	36	30	30	32			
9	11	14.00-20	25 MPH	Wrecker	2867	10	3610	3	4	40	22	20	6	32	20	20	30			
9	11	14.00-20	25 MPH	Cargo	1950	10	3270	2	3	40	22	20	10	30	25	28	40			
10	12	9.00-20	Ord Sand	Cargo	5467	10	3460	3	4	30	28	20	6	34	42	28	30			
10	12	9.00-20	Ord Sand	Bit Sup.	4067	10	3855	3	4	50	40	20	7	30	16	22	26			
10	12	14.00-20	Ord Sand	Wrecker	5400	10	2170	3	8	30	20	22	4	52	22	20	18			
10	12	14.00-20	Ord Sand	Cargo	5560	10	2210	3	5	30	50	26	5	28	24	26	24			

Penetrometer Readings at Softest Point

DYNAMOMETER TESTS

Test No.	Date 1943 Nov.	Tire Size	Inflation	Truck 4-ton Diamond T	Traction Effort	No. of Readings	Rolling Resistance	No. of Readings	Penetrometer Readings											
									Rolling Resistance						Traction Effort					
								Sta No.	3"	6"	9"	12"	Sta No.	3"	6"	9"	12"			
11	12	9.00-20	Ord Sand	Cargo	5467	10	3485	3	40	20	28	32	32	5	32	30	22	32		
11	12	9.00-20	Ord Sand	Bit Sup.	5533	10	3990	6	24	28	26	32	20	4	32	20	22	32		
11	12	14.00-20	Ord Sand	Wrecker	6000	10	2360	10	30	28	20	22	26	5	32	26	22	32		
11	12	14.00-20	Ord Sand	Cargo	6000	10	2400	8	30	20	18	18	40	9	30	40	34	40		
28A	26	9.00-20	Ltd. Oper	Cargo	5333	10	2860	2	38	36	38	42	42	9	32	50	40	42		
28A	26	9.00-20	Ltd. Oper	Bit Sup.	5033	10	3275	7	22	34	40	64	30	1	30	32	42	60		
28A	26	14.00-20	Ltd. Oper	Wrecker	5300	10	1795	5	50	30	32	50	40	6	30	40	48	48		
28A	26	14.00-20	Ltd. Oper	Cargo	5233	10	1940	9	38	40	42	60	48	1	30	48	32	50		
28B	26	9.00-20	25 MPH	Cargo	6933	10	2915	8	20	28	40	56	40	2	46	50	40	48		
28B	26	9.00-20	25 MPH	Bit Sup.	5933	10	3135	6	40	32	34	44	40	8	40	30	38	52		
28B	26	14.00-20	25 MPH	Wrecker	6667	10	1865	1	50	48	46	44	48	9	48	50	60	60		
28B	26	14.00-20	25 MPH	Cargo	5633	10	2000	5	40	30	34	42	42	2	40	30	38	40		
DUALS ON FRONT OF TRUCKS EQUIPPED WITH 9.00-20 TIRES																				
12	16	9.00-20	Ord Sand	Cargo	3167	10	3700	3	26	20	22	34	20	2	28	20	26	32		
12	16	9.00-20	Ord Sand	Bit Sup.	4100	10	4090	7	32	28	18	30	22	1	20	22	18	26		
12	16	14.00-20	Ord Sand	Wrecker	4100	10	2660	3	40	24	18	22	20	2	20	22	28	22		
12	16	14.00-20	Ord Sand	Cargo	3933	10	5270	8	22	24	20	22	22	8	22	25	30	32		
13	17	9.00-20	Ord Sand	Cargo	3333	10	3140	9	24	20	22	24	20	7	16	18	20	28		
13	17	9.00-20	Ord Sand	Bit Sup.	3667	10	3510	4	20	26	28	42	28	6	30	18	15	30		
13	17	14.00-20	Ord Sand	Wrecker	3367	10	2260	4	22	26	20	30	22	4	28	22	18	20		
13	17	14.00-20	Ord Sand	Cargo	4200	10	2870	8	44	28	18	16	24	8	24	30	20	18		
14	17	9.00-20	Ltd. Oper	Cargo	2267	10	4590	6	22	18	16	24	18	7	32	34	18	18		
14	17	9.00-20	Ltd. Oper	Bit Sup.	2400	10	5010	6	28	18	14	30	22	9	24	14	12	16		
14	17	14.00-20	Ltd. Oper	Wrecker	1867	7	4271	2	28	22	18	22	20	10	30	16	18	20		
14	17	14.00-20	Ltd. Oper	Cargo	2267	10	3390	6	32	28	16	20	20	9	40	18	10	12		
15	18	9.00-20	Ltd. Oper	Cargo	4333	10	2880	2	30	24	30	38	30	3	30	30	40	48		
15	18	9.00-20	Ltd. Oper	Bit Sup.	5600	10	3235	2	32	20	22	30	22	2	32	38	30	32		
15	18	14.00-20	Ltd. Oper	Wrecker	4400	10	2705	2	36	18	20	18	20	10	40	20	20	22		
15	18	14.00-20	Ltd. Oper	Cargo	4533	10	2530	10	40	30	20	16	16	8	30	32	36	40		

Penetrometer Readings at Softest Point

DUALS ON FRONT OF TRUCKS EQUIPPED WITH 9.00-20 TIRES

Test No.	Date 1943 Nov.	Tire Size	Inflation	Truck: 4-ton Diamond T	Tractive Effort	No. of Readings	Rolling Resistance	No. of Readings	Penetrometer Readings										
									Rolling Resistance			Tractive Effort							
									Sta. No.	3"	6"	9"	12"	Sta. No.	3"	6"	9"	12"	
16	18	9.00-20	25 MPH	Cargo	1667	10	4170	3	9	20	22	18	20	3	40	20	18	20	20
16	18	9.00-20	25 MPH	Bit Sup.	3067	10	4465	3	10	30	20	18	22	8	28	30	18	20	20
16	18	14.00-20	25 MPH	Wrecker	1833	10	3115	3	3	40	20	18	30	2	30	22	22	32	32
16	18	14.00-20	25 MPH	Cargo	3400	10	3500	3	8	28	20	18	30	2	30	26	20	24	24
17	18	9.00-20	25 MPH	Cargo	4000	10	4240	3	9	30	32	28	32	6	30	40	28	36	36
17	18	9.00-20	25 MPH	Bit Sup.	3333	10	4560	3	10	30	22	18	24	6	40	30	22	20	20
17	18	14.00-20	25 MPH	Wrecker	4267	10	3760	3	8	40	30	20	22	4	40	20	22	30	30
17	18	14.00-20	25 MPH	Cargo	3667	10	4190	3	6	32	18	20	16	10	30	40	32	30	30
18	19	9.00-20	Hwy	Cargo	2100	10	5275	6	8	20	18	18	30	2	20	22	24	30	30
18	19	9.00-20	Hwy	Bit Sup.	2683	10	5805	6	5	20	22	26	30	10	20	32	26	28	28
18	19	14.00-20	Hwy	Wrecker	2200	10	4660	6	5	28	18	20	18	9	20	18	0	40	40
18	19	14.00-20	Hwy	Cargo	2333	10	4930	6	7	20	18	20	40	8	20	12	20	30	30
19	19	9.00-20	Hwy	Cargo	4300	10	2550	6	7	30	30	34	50	10	40	40	38	64	64
19	19	9.00-20	Hwy	Bit Sup.	5350	10	3065	6	6	34	62	64	66	4	38	58	54	66	66
19	19	14.00-20	Hwy	Wrecker	4533	10	2085	6	8	32	46	46	46	2	40	40	44	66	66
19	19	14.00-20	Hwy	Cargo	5067	10	2415	6	6	30	34	54	70	7	44	30	38	40	40

ALL TRUCKS EQUIPPED WITH CHAINS

20	22	9.00-20	Hwy	Cargo	1500	10	5370	2	2	40	72	100	130	2	40	60	130	130	130
20	22	9.00-20	Hwy	Bit Sup.	1200	10	5990	1	2	60	70	130	130	1	40	50	130	130	130
20	22	14.00-20	Hwy	Wrecker	2583	10	3250	6	9	50	78	130	130	9	20	70	130	130	130
20	22	14.00-20	Hwy	Cargo	3433	10	3510	6	1	70	68	110	130	2	30	63	130	130	130
21	23	9.00-20	Hwy	Cargo	860	10	5810	4	1	40	60	70	130	1	30	70	130	130	130
21	23	9.00-20	Hwy	Bit Sup.	940	10	5900	5	3	18	70	110	130	8	20	50	130	130	130
21	23	14.00-20	Hwy	Wrecker	1660	10	3605	6	5	40	70	90	130	5	30	60	130	130	130
21	23	14.00-20	Hwy	Cargo	2833	10	3515	6	4	40	120	110	130	2	50	60	120	130	130
22	23	9.00-20	25 MPH	Cargo	1700	10	5690	6	7	30	80	110	130	10	20	50	70	130	130
22	23	9.00-20	25 MPH	Bit Sup.	2000	10	6060	3	4	70	100	130	130	4	30	90	110	120	120
22	23	14.00-20	25 MPH	Wrecker	2833	10	3215	6	6	60	80	90	130	2	30	120	110	100	100
22	23	14.00-20	25 MPH	Cargo	2800	10	3650	6	8	40	90	80	130	1	39	70	130	130	130

Penetrometer Readings at Softest Point

ALL TRUCKS EQUIPPED WITH CHAINS

Test No.	Date 1943	Tire Size	Inflation	Truck 4-ton Diamond T	Tractive Effort	No. of Readings	Rolling Resistance	No. of Readings	Penetrometer Readings									
									Rolling Resistance					Traactive Effort				
									Sta No.	3"	6"	9"	12"	Sta No.	3"	6"	9"	12"
23	23	9.00-20	25 MPH	Cargo	2017	10	5770	10	4	30	60	130	5	22	50	130	130	
23	23	9.00-20	25 MPH	Bit Sup.	1400	10	6170	10	2	30	60	54	90	22	54	120	130	
23	23	14.00-20	25 MPH	Wrecker	2767	10	3470	10	9	18	70	130	3	28	70	130	130	
23	23	14.00-20	25 MPH	Cargo	3100	10	3590	10	6	20	70	100	6	20	60	110	130	
24	24	9.00-20	Ltd. Oper	Cargo	1567	10	5190	10	8	20	36	130	2	26	30	130		
24	24	9.00-20	Ltd. Oper	Bit Sup.	1333	10	5700	10	5	40	70	60	2	20	40	130	130	
24	24	14.00-20	Ltd. Oper	Wrecker	3050	10	2845	10	8	26	40	130	2	28	46	100	130	
24	24	14.00-20	Ltd. Oper	Cargo	3600	10	3065	10	6	30	70	90	3	22	28	180		
25	24	9.00-20	Ltd. Oper	Cargo	1517	10	5990	10	7	30	50	70	130	1	20	50	60	
25	24	9.00-20	Ltd. Oper	Bit Sup.	1200	10	6560	10	10	20	50	60	110	10	32	54	70	
26	24	14.00-20	Ltd. Oper	Wrecker	3133	10	3495	10	5	22	50	100	130	10	18	30	70	
26	24	14.00-20	Ltd. Oper	Cargo	3733	10	3540	10	8	40	50	60	130	8	30	40	130	
26	25	9.00-20	Ord Sand	Cargo	1500	10	5050	10	9	36	80	130	8	30	60	130		
26	25	9.00-20	Ord Sand	Bit Sup.	950	10	5270	10	10	28	70	130	8	28	60	70	130	
26	25	14.00-20	Ord Sand	Wrecker	3033	10	2560	10	7	30	90	110	130	4	30	60	100	
26	25	14.00-20	Ord Sand	Cargo	3800	10	2020	10	5	38	70	130	2	32	60	70		
27	25	9.00-20	Ord Sand	Cargo	1433	10	4400	10	5	30	60	130	8	30	60	130		
27	25	9.00-20	Ord Sand	Bit Sup.	1750	10	5370	10	1	46	108	100	130	9	30	60	130	
27	25	14.00-20	Ord Sand	Wrecker	3517	10	2420	10	3	70	110	130	8	30	80	110	130	
27	25	14.00-20	Ord Sand	Cargo	3400	10	2560	10	10	40	100	130	6	50	70	110		
ON HIGHWAY																		
30	27	9.00-20	Hwy	Cargo	8367	10	395	10	6	395			6					
30	27	9.00-20	Hwy	Bit Sup.	7767	10	350	10	6	350			6					
30	27	14.00-20	Hwy	Wrecker	7267	10	320	10	6	320			6					
30	27	14.00-20	Hwy	Cargo	7800	10	310	10	6	310			6					

Penetrometer Readings at Softest Point

REPEATED TRIPS

Test No.	Date 1943	Tire Size	Inflation	Truck 4-ton Diamond T	Length of Course (Feet)	Number of Trips	Stuck at Feet	Total Feet Traveled	Av. Pen. Depth (Inches)	Penetrometer Readings											
										Before Test						At Bottom of Tracks					
									Sta. No.	3"	6"	9"	12"	Sta. No.	3"	6"	9"	12"			
29A	30	9.00-20	Hwy	Cargo	200	11.	00	4400	10	8*	24	18	20	26	1*	18	20	50	42		
29A	30	14.00-20	Hwy	Wrecker	200	14.	20	5620	13	1	30	36	20	60	1	50	60	64	-		
29B	30	9.00-20	25 MPH	Bit Sup.	200	4	00	1600	7.5	1*	20	30	40	34	6*	10	16	20	40		
29B	30	14.00-20	25 MPH	Cargo	200	9	200	3400	11	10	42	38	40	42	10	30	32	40	50		

Penetrometer Readings at Softest Point

DISTANCE TESTS

North End of Salton Sea

2	4	9.00-20	Hwy	Cargo				24.5		0	22	78	64	50					
2	4	9.00-20	Hwy	Bit Sup.				24.5		50	20	50	102	130					
2	4	14.00-20	Hwy	Wrecker				34.5		50	22	110	130	-					
2	4	14.00-20	Hwy	Cargo				27.5		50	30	30	30	52	48				
3	4	9.00-20	25 MPH	Bit Sup.				24.5		50	58	130							
3	4	14.00-20	25 MPH	Wrecker				28.5		50	18	72	130	130					
4	4	9.00-20	Ltd. Oper	Bit Sup.				22		50	20	48	50	130					
4	4	14.00-20	Ltd. Oper	Wrecker				22		50	20	38	40	60					
4A	4	9.00-20	Ord Sand	Bit Sup.				24.5		50	40	30	50	56					
31	6	9.00-20	25 MPH	Cargo				20											
31	6	14.00-20	25 MPH	Cargo				100											
32	6	9.00-20	Ltd. Oper	Bit Sup.				47											
32	6	14.00-20	Ltd. Oper	Cargo				100											
33	6	9.00-20	Ord Sand	Cargo				60											
33	6	14.00-20	Ord Sand	Wrecker				100											
34	6	9.00-20	Hwy	GarC				24											
34	6	9.00-20	Hwy	Bit Sup.				42											

DUALS ALL AROUND

North End of Salton Sea.

Test No.	Date 1943 Dec.	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	
34	6	14.00-20	Hwy	Wrecker	57	
35	6	9.00-20	25 MPH	Cargo	29	Standard Mounting Duals All Around
35	6	9.00-20	25 MPH	Bit Sup.	43	
35	6	14.00-20	25 MPH	Wrecker	150	
36	6	9.00-20	Hwy	Cargo	20	
36	6	14.00-20	Hwy	Cargo	134	
37A	6	9.00-20	Hwy	Cargo	20	
37B	6	9.00-20	25 MPH	Cargo	24	
37C	6	9.00-20	Ltd. Oper	Cargo	24	
37D	6	9.00-20	Ord Sand	Cargo	30	
38A	6	14.00-20	Hwy	Wrecker	78	
38B	6	14.00-20	25 MPH	Wrecker	138	
39A	6	9.00-20	Ord Sand	Cargo	27	
39B	6	14.00-20	25 MPH	Wrecker	138	
40	11	9.00-20	Highway	Cargo	88	
40	11	9.00-20	Highway	Bit Sup.	38	
40	11	14.00-20	Highway	Wrecker	92	
40	11	14.00-20	Highway	Cargo	73	
41	11	9.00-20	Highway	Cargo	109	
41	11	9.00-20	Highway	Bit Sup.	50	
41	11	14.00-20	Highway	Wrecker	113	
41	11	14.00-20	Highway	Cargo	119	
42	11	9.00-20	Highway	Cargo	111	
42	11	14.00-20	Highway	Wrecker	157	

DISTANCE TESTS

North End of Salton Sea

Test No.	Date 1943 Dec.	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled
43	18	9.00-20	25 MPH	Cargo	110
43	18	9.00-20	25 MPH	Bit Sup.	85
43	18	14.00-20	25 MPH	Wrecker	130
43	18	14.00-20	25 MPH	Cargo	187
44	18	9.00-20	25 MPH	Cargo	89
44	18	9.00-20	25 MPH	Bit Sup.	93
44	18	14.00-20	25 MPH	Wrecker	194
44	18	14.00-20	25 MPH	Cargo	322*
45	18	9.00-20	25 MPH	Cargo	185
45	18	9.00-20	25 MPH	Bit Sup.	195
45	18	14.00-20	25 MPH	Wrecker	315*
45	18	14.00-20	25 MPH	Cargo	319*
46	18	9.00-20	Ltd. Oper	Cargo	38
46	18	14.00-20	Ltd. Oper	Wrecker	40
47	18	9.00-20	Ord Sand	Cargo	165
47	18	9.00-20	Ord Sand	Bit Sup.	160
47	18	14.00-20	Ord Sand	Wrecker	217
47	18	14.00-20	Ord Sand	Cargo	264
48	18	9.00-20	Ord Sand	Cargo	162
48	18	9.00-20	Ord Sand	Bit Sup.	111
48	18	14.00-20	Ord Sand	Wrecker	177
48	18	14.00-20	Ord Sand	Cargo	307

DISTANCE TESTS

North End of Salton Sea

Test No.	Date 1943 Dec.	Time Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	
49	18	9.00-20	Ord Sand	Cargo	147	
49	18	9.00-20	Ord Sand	Bit Sup.	142	
49	18	14.00-20	Ord Sand	Wrecker	282	
49	18	14.00-20	Ord Sand	Cargo	280	
50	20	9.00-20	Highway	Bit Sup.	151	Duals all Around
50	20	14.00-20	Highway	Cargo	327	
51	20	9.00-20	Highway	Bit Sup.	146	Duals all Around
51	20	14.00-20	Highway	Cargo	285	
52	20	9.00-20	Highway	Bit Sup.	32	Duals all Around
52	20	14.00-20	Highway	Wrecker	120	
53	20	9.00-20	25 MPH	Bit Sup.	142	Duals all Around
53	20	14.00-20	25 MPH	Cargo	353	
54	20	9.00-20	25 MPH	Bit Sup.	177	Duals all Around
54	20	14.00-20	25 MPH	Cargo	365	
55	20	9.00-20	25 MPH	Bit Sup.	45	Duals all Around
55	20	14.00-20	25 MPH	Cargo	170	
56	20	9.00-20	Ltd. Oper	Bit Sup.	115	Duals all Around
56	20	14.00-20	Ltd. Oper	Cargo	260	
57	20	9.00-20	Ltd. Oper	Bit Sup.	170	Duals all Around
57	20	14.00-20	Ltd. Oper	Cargo	187	

DISTANCE TESTS

North End of Salton Sea

Test No.	Date 1943 Dec.	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	
58	20	9.00-20	Ltd. Oper	Bit Sup.	100	Duals all Around
58	20	14.00-20	Ltd. Oper	Cargo	160	
59	20	9.00-20	Ord Sand	Bit Sup.	153	Duals all Around
59	20	14.00-20	Ord Sand	Cargo	165	
60	20	9.00-20	Ord Sand	Bit Sup.	90	Duals all Around
60	20	14.00-20	Ord Sand	Cargo	277	
61	20	9.00-20	Ord Sand	Bit Sup.	152	Duals all Around
61	20	14.00-20	Ord Sand	Cargo	283	
62	21	9.00-20	Highway	Cargo	62	Standard Mounting
62	21	9.00-20	Highway	Bit Sup.	65	Duals All Around
63	21	9.00-20	Highway	Cargo	21	Standard Mounting
63	21	9.00-20	Highway	Bit Sup.	81	Duals All Around
64	21	9.00-20	Highway	Cargo	71	Standard Mounting
64	21	9.00-20	Highway	Bit Sup.	77	Duals All Around
65	21	9.00-20	25 MPH	Cargo	72	Standard Mounting
65	21	9.00-20	25 MPH	Bit Sup.	82	Duals All Around
66	21	9.00-20	25 MPH	Cargo	94	Standard Mounting
66	21	9.00-20	25 MPH	Bit Sup.	115	Duals All Around
67	21	9.00-20	25 MPH	Cargo	168	Standard Mounting
67	21	9.00-20	25 MPH	Bit Sup.	235	Duals All Around

DISTANCE TESTS

North End of Salton Sea

Test No.	Date 1945	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	
68	21	9.00-20	Ltd. Oper	Cargo	267	Standard Mounting
68	21	9.00-20	Ltd. Oper	Bit Sup.	282	Duals All Around
69	21	9.00-20	Ltd. Oper	Cargo	34	Standard Mounting
69	21	9.00-20	Ltd. Oper	Bit Sup.	38	Duals All Around
70	21	9.00-20	Ltd. Oper	Cargo	27	Standard Mounting
70	21	9.00-20	Ltd. Oper	Bit Sup.	33	Duals All Around
71	22	9.00-20	Highway	Cargo	257	With Chains
71	22	14.00-20	Highway	Cargo	99	Without
72	22	9.00-20	Highway	Cargo	243	With Chains
72	22	14.00-20	Highway	Cargo	28	Without
73	22	9.00-20	Highway	Cargo	265	With Chains
73	22	14.00-20	Highway	Cargo	97	Without
74	22	9.00-20	25 MPH	Cargo	269	With Chains
74	22	14.00-20	25 MPH	Cargo	155	Without
75	22	9.00-20	25 MPH	Cargo	217	With Chains
75	22	14.00-20	25 MPH	Cargo	201	Without
76	22	9.00-20	25 MPH	Cargo	227	With Chains
76	22	14.00-20	25 MPH	Cargo	107	Without
77	22	9.00-20	Ltd. Oper	Cargo	237	With Chains
77	22	14.00-20	Ltd. Oper	Cargo	130	Without

DISTANCE TESTS

North End of Salton Sea

Test No.	Date 1943 Dec.	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	With Chains Without
78	22	9.00-20	Ltd. Oper	Cargo	237	With Chains
78	22	14.00-20	Ltd. Oper	Cargo	232	Without
79	22	9.00-20	Ltd. Oper	Cargo	306	With Chains
79	22	14.00-20	Ltd. Oper	Cargo	180	Without
80	22	9.00-20	Ord Sand	Cargo	142	With Chains
80	22	14.00-20	Ord Sand	Cargo	200	Without
81	22	9.00-20	Ord Sand	Cargo	282	With Chains
81	22	14.00-20	Ord Sand	Cargo	247	Without
82	22	9.00-20	Ord Sand	Cargo	28	With Chains
82	22	14.00-20	Ord Sand	Cargo	194	Without
82	23	9.00-20	Highway	Cargo	20	With Chains
83	23	14.00-20	Highway	Cargo	31	With Chains
84	23	9.00-20	Highway	Cargo	27	With Chains
84	23	14.00-20	Highway	Cargo	132	With Chains
85	23	9.00-20	25 MPH	Cargo	91	With Chains
85	23	14.00-20	25 MPH	Cargo	173	With Chains
86	23	9.00-20	25 MPH	Cargo	72	With Chains
86	23	14.00-20	25 MPH	Cargo	90	With Chains
87	23	9.00-20	Ltd. Oper	Cargo	74	With Chains
87	23	14.00-20	Ltd. Oper	Cargo	177	With Chains

DISTANCE TESTS

North End of Salton Sea

Test No.	Date 1943	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	
88	23	9.00-20	Ltd. Oper	Cargo	112	With Chains
88	23	14.00-20	Ltd. Oper	Cargo	206	With Chains
89	23	9.00-20	Ord Sand	Cargo	105	With Chains
89	23	14.00-20	Ord Sand	Cargo	210	With Chains
90	23	9.00-20	Ord Sand	Cargo	80	With Chains
90	23	14.00-20	Ord Sand	Cargo	200	With Chains
91	27	14.00-20	Hwy Ord Sand	Cargo	332	
91	27	14.00-20	Ord Sand	Cargo	464	
92	27	9.00-20	Hwy Ord Sand	Cargo	132	
92	27	9.00-20	Ord Sand	Cargo	132	
93	27	9.00-20	Hwy Ord Sand	Cargo	120	
93	27	9.00-20	Ord Sand	Cargo	334	
94	27	9.00-20	Hwy Ord Sand	Cargo	117	
94	27	9.00-20	Ord Sand	Cargo	260	
95	27	9.00-20	Hwy Ord Sand	Cargo	35	
95	27	9.00-20	Ord Sand	Cargo	190	

CAMP SEELEY

Test No.	Date 1943 Dec.	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	Area
96	29	14.00-20	Hwy	Cargo	88	1
96	29	14.00-20	Ord Sand	Cargo	150	1
97	29	14.00-20	Hwy	Cargo	36	1
97	29	14.00-20	Ord Sand	Cargo	135	1
98	29	9.00-20	Hwy	Cargo	29	1
98	29	14.00-20	Hwy	Cargo	36	1
99	29	9.00-20	Hwy	Cargo	29	1
99	29	9.00-20	Ord Sand	Cargo	42	1
100	29	9.00-20	Hwy	Cargo	26	1
100	29	9.00-20	Ord Sand	Cargo	64	1
101	29	9.00-20	Hwy	Cargo	26	1
101	29	14.00-20	Hwy	Wrecker	44	1
102	29	14.00-20	Hwy	Wrecker	44	1
102	29	14.00-20	Ord Sand	Wrecker	48	1
103	29	9.00-20	Ord Sand	Bit Sup.	150	1
103	29	14.00-20	Ord Sand	Wrecker	48	1
104	29	9.00-20	Hwy	Cargo	25	1
104	29	9.00-20	Hwy	Bit Sup.	150	1
105	30	9.00-20	Hwy	Cargo	92	2
105	30	14.00-20	Hwy	Wrecker	159	2

CAMP SEELEY

Test No.	Date 1943	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	Area
106	30	9.00-20	Hwy	Cargo	92	2
106	30	9.00-20	Ord Sand	Cargo	121	2
107	30	9.00-20	Hwy	Cargo	117	2
107	30	9.00-20	Ord Sand	Cargo	159	2
108	30	9.00-20	Hwy	Cargo	60	3
108	30	9.00-20	Ord Sand	Cargo	72	3
109	30	9.00-20	Hwy	Cargo	159	2
109	30	9.00-20	Ord Sand	Cargo	87	2
110	30	14.00-20	Hwy	Cargo	159	2
110	30	9.00-20	Ord Sand	Cargo	72	2
111	30	9.00-20	Hwy	Bit Sup.	105	3
111	30	9.00-20	Hwy	Bit Sup.	155	3
112	30	9.00-20	Ord Sand	Cargo	87	2
112	30	14.00-20	Hwy	Cargo	159	2
113	31	9.00-20	Hwy	Bit Sup.	140	4
113	31	14.00-20	Ord Sand	Cargo	165	4
114	31	9.00-20	Hwy	Cargo	100	4
114	31	9.00-20	Ord Sand	Cargo	165	4
115	31	9.00-20	25 MPH	Bit Sup.	50	5
115	31	14.00-20	Hwy	Wrecker	80	5

CAMP SEELEY

Test No.	Date 1945	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	Area
96	29	14.00-20	Hwy	Cargo	88	1
96	29	14.00-20	Ord Sand	Cargo	150	1
97	29	14.00-20	Hwy	Cargo	36	1
97	29	14.00-20	Ord Sand	Cargo	135	1
98	29	9.00-20	Hwy	Cargo	29	1
98	29	14.00-20	Hwy	Cargo	36	1
99	29	9.00-20	Hwy	Cargo	29	1
99	29	9.00-20	Ord Sand	Cargo	42	1
100	29	9.00-20	Hwy	Cargo	26	1
100	29	9.00-20	Ord Sand	Cargo	64	1
101	29	9.00-20	Hwy	Cargo	20	1
101	29	14.00-20	Hwy	Wrecker	44	1
102	29	14.00-20	Hwy	Wrecker	44	1
102	29	14.00-20	Ord Sand	Wrecker	48	1
103	29	9.00-20	Ord Sand	Bit Sup.	150	1
103	29	14.00-20	Ord Sand	Wrecker	48	1
104	29	9.00-20	Hwy	Cargo	25	1
104	29	9.00-20	Hwy	Bit Sup.	150	1
105	30	9.00-20	Hwy	Cargo	92	2
105	30	14.00-20	Hwy	Wrecker	159	2

CAMP SETLEY

Test No.	Date 1943 Dec.	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	Area	
106	30	9.00-20	Hwy	Cargo	92	2	
106	30	9.00-20	Ord Sand	Cargo	121	2	
107	30	9.00-20	Hwy	Cargo	117	2	
107	30	9.00-20	Ord Sand	Cargo	159	2	
108	30	9.00-20	Hwy	Cargo	60	3	Duals All Around
108	30	9.00-20	Ord Sand	Cargo	72	3	Duals All Around
109	30	9.00-20	Hwy	Cargo	159	2	Duals All Around
109	30	9.00-20	Ord Sand	Cargo	87	2	Duals All Around
110	30	14.00-20	Hwy	Cargo	159	2	Duals All Around
110	30	9.00-20	Ord Sand	Cargo	72	2	Duals All Around
111	30	9.00-20	Hwy	Bit Sup.	105	3	With Chains
111	30	9.00-20	Hwy	Bit Sup.	155	3	With Chains
112	30	9.00-20	Ord Sand	Cargo	87	2	Duals All Around
112	30	14.00-20	Hwy	Cargo	159	2	Duals All Around
113	31	9.00-20	Hwy	Bit Sup.	140	4	With Chains
113	31	14.00-20	Ord Sand	Cargo	166	4	Without
114	31	9.00-20	Hwy	Cargo	100	4	Duals All Around
114	31	9.00-20	Ord Sand	Cargo	165	4	Duals All Around
115	31	9.00-20	25 MPH	Bit Sup.	50	5	
115	31	14.00-20	Hwy	Wrecker	80	5	

CAMP SEELEY

Test No.	Date 1943 Dec.	Tire Size	Inflation	Truck 4-ton Diamond T	No. of Feet Traveled	Area	
116	31	9.00-20	Ltd. Oper Hwy	Bit Sup. Wrecker	55	4	
116	31	14.00-20			150	4	
117	31	9.00-20	Ord Sand Hwy	Bit Sup. Wrecker	157	4	
117	31	14.00-20			147	4	
118	31	9.00-20	Hwy	Cargo Bit Sup.	150	4	Duals All Around Standard Mounting
118	31	9.00-20	Ord Sand		62	4	
119	31	9.00-20	Hwy	Cargo Bit Sup.	65	5	Duals All Around Standard Mounting
119	31	9.00-20	Ltd. Oper		54	5	
120	31	9.00-20	Hwy	Cargo Bit Sup.	88	5	Duals All Around Standard Mounting
120	31	9.00-20	25 MPH		59	5	
121	31	9.00-20	Hwy	Cargo Bit Sup.	90	5	Duals All Around Standard Mounting
121	31	9.00-20	Hwy		77	5	
122	31	9.00-20	Hwy	Cargo Bit Sup.	100	4	Duals All Around Standard Mounting
122	31	9.00-20	Hwy		140	4	
123	31	9.00-20	Hwy	Cargo Bit Sup.	65	5	Duals All Around Standard Mounting
123	31	9.00-20	25 MPH		50	5	

SERVICE DURABILITY TEST

<u>Type Truck</u>	<u>Tire Size</u>	<u>Total Miles</u>	<u>Miles on Hwy</u>	<u>Miles on Roads and Test Areas</u>	<u>Miles Duals All Around</u>
Cargo	14.00-20	1058	897	161	-
Wrecker	14.00-20	1158	980	178	-
Cargo	9.00-20	990	842	138	135
Bituminous Supply	9.00-20	964	821	143	321
Totals		<u>4170</u>	<u>3540</u>	<u>620</u>	<u>456</u>

## SOIL ANALYSES

1. North End of Salton Sea.  
Average of Numerous Samples.

Mechanical Composition					Liquid Limit	Plastic Limit	Plasticity Index
%	Having Smaller Dia. in M.M. than						
2.00	0.25	.074	.05	.005			
100	96	75	71	51	27.0	13.2	55.9

2. Camp Seeley

Mechanical Composition				
%	Having Smaller Dia. in M.M. than			
2.00	0.25	.074	.05	.005
100	95	92	91	50

APPENDIX "C"

Pressure Gauge  
Calibration

by

Bureau of Standards

City of Los Angeles

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5" Dial 0 - 60 pounds	215
2 $\frac{1}{2}$ " Dial 0- 100 pounds	216
2 $\frac{1}{2}$ " Dial 0 - 30 pounds	217

Lab. No. 64-356 City of Los Angeles  
DEPARTMENT OF PUBLIC WORKS  
Rec'd 8-16-43 Bureau of Standards  
Rep't'd 8-17-43  
To The Engineer Board 826 Yale Street

Report

Test of

PRESSURE GAUGE

A pressure gauge was tested for the Engineer Board,  
Desert Warfare Section, Thermal, California, on August 16, 1943.

Type: Five inch dial

Marked: Marshalltown Gauge

Range: 0 to 60 pounds

<u>Gauge Reading</u>	<u>Pounds Pressure</u>	<u>Correction (lbs)</u>
13 1/2	10	-3 1/2
23 1/2	20	-3 1/2
33 1/2	30	-3 1/2
43 1/4	40	-3 1/4
53 1/4	50	-3 1/4
60	57	-3

2:4

/s/ T. A. Fitch  
Director

Lab. No. 64-358  
Rec'd 8-16-43  
Rep't'd 8-17-43  
To The Engineer Board

City of Los Angeles  
DEPARTMENT OF PUBLIC WORKS  
Bureau of Standards

826 Yale Street

Report

Test of

PRESSURE GAUGE

A pressure gauge was tested for the Engineer Board,  
Desert Warfare Section, Thermal, California, on August 16, 1943.

Type: Two and one-half inch dial

Marked: Marshalltown Gauge

Range : 0 to 100 pounds

<u>Gauge Reading</u>	<u>Pounds Pressure</u>	<u>Correction (lbs)</u>
16	10	-6
26	20	-6
36	30	-6
46	40	-6
56	50	-6
66	60	-6
76	70	-6
86	80	-6
96	90	-6
100	94	-6

2:4

/s/ T. A. Fitch  
Director

City of Los Angeles  
DEPARTMENT OF PUBLIC WORKS  
Lab. No. 64-357 Bureau of Standards  
Rec'd 8-16-43  
Rep't'd 8-17-43  
To The Engineer Board 826 Yale Street

Report

Test of

PRESSURE GAUGE

A pressure gauge was tested for the Engineer Board,  
Desert Warfare Section, Thermal, California, on August 16, 1943.

Type: Two and one-half inch dial

Marked: Marshalltown Gauge

Range: 0 to 25 pounds

<u>Gauge Reading</u>	<u>Pounds Pressure</u>	<u>Correction (lbs)</u>
9	5	-4
14	10	-4
19 1/4	15	-4 1/4
24 1/4	20	-4 1/4
28 3/4	25	-3 3/4

2:4

Director

APPENDIX "D"

Quotations from Related Reports

<u>Contents</u>	<u>Page</u>
Pertinent Conclusions of B. F. Goodrich Company Report	221
Ordnance Classification of Mud	222

Pertinent Conclusions of B. F. Goodrich Company Report  
on "Ordnance Mud Flotation and Traction Tests"

(References to "types of mud" are explained  
in next section of this Appendix)

1. The results of these tests indicate that under the conditions tested, the single military desert tire equipment gives more mobility than the standard military mud and snow dual tire equipment on the 4-ton 6x6 cargo trucks.

2. Tests run using reduced inflation pressures showed a definite advantage over highway inflation for both the standard dual tire equipment and the single desert tires. However, for comparable inflation pressures, the single desert tire will perform better than the standard dual tire equipment.

3. The tests show that it is not feasible to use pressures below the recommended cross country inflation. Such practice does increase the tire flotation but is deemed inadvisable since it will result in premature tire and tube failures and requires the use of a beadlocking device.

4. Lack of mobility was encountered on the 4-ton trucks equipped with standard military non-directional mud and snow tires. The front axle on the 4-ton truck carries 21% less load and is equipped with singles instead of duals. In an effort to correct this condition, duals were applied to the front of 4-ton trucks. In Type I bottomless mud where flotation is the prime factor, this made the truck on standard military mud and snow tires equal to or slightly better in flotation than the trucks equipped with single military desert tires. However, in Type I<sup>1</sup>B, mud duals trap and push the mud ahead of the tires. In mud of this type, duals on the front increase the rolling resistance and give the truck less mobility. Use of dual tires on the front is recommended as an emergency measure under conditions in which additional flotation is needed.

5. The 14.00 x 20 military desert tires have nearly twice the load carrying capacity of the 9.00 x 20 military mud and snow tires. This added tire capacity on the front of vehicles equipped with military desert tires adds much to their flotation and mobility.

6. In addition to the mud flotation and traction tests, hill climbing trials were made. The trucks equipped with military desert tires using highway inflation climbed a twenty-one degree slope without hesitation. Trucks equipped with standard military mud and snow tires were unable to climb the hill. Use of the emergency inflation with or without chains did not improve the hill climbing ability of these tires. Single military desert tires are recommended for improved hill climbing ability.

7. It is of interest to note that the rolling radius of the 14.00 x 20 desert tire is  $2\frac{1}{2}$ " greater than the 9.00 x 20 mud and snow tire. The rolling resistance of the 4-ton truck at 10 m.p.h. on pavement using highway inflation was 535 pounds on 14.00 x 20 desert tires and 380 pounds on 9.00 x 20 standard dual tire equipment.

ORDNANCE DESERT PROVING GROUNDS  
CLASSIFICATION OF MUD

The Ordnance Desert Proving Grounds report on mud flotation classified mud into several types. Quoted here is section II A from subject report.

"Section II. A. That for the purpose of evaluating the mud mobility of military wheeled vehicles all of the various types of mud that may be encountered fall into two classifications or types.

Type I Mud: Bottomless mud where the consistency is such that the mud will not support a vehicle with standard military tire equipment at 20 pounds tire pressure. The term bottomless implies that a firm sub-surface, if existent, will be at such a depth that the vehicle undercarriage will be buried in mud, preventing forward motion of the vehicle before the driving wheels have contacted the firm sub-surface. \*\*\*\*\*

Type II Mud: A mud top-surface with a firm hard pan at a depth not to exceed the minimum vehicle ground clearance. Under this classification is also included mud where no hard pan exists but where the consistency of the mud is such that compaction will afford a sufficient bearing surface to support a vehicle with standard tire equipment at 20 pounds pressure at a depth of not to exceed the minimum vehicle ground clearance. At the depth of adequate bearing capacity, the mud must have sufficient shear resistance to permit the development of maximum vehicle tractive effort with chain equipment.

1. Type II Mud should be classified as Type IIA, when the mud has a cleaning quality such as the presence of high water content, sand, decayed vegetable matter or other non-adhesive materials which give the mud a cleaning quality. \*\*\*\*\*

2. Type IIB is mud that has no cleaning qualities and is highly adhesive such as gumbo or adobe mud."

APPENDIX C

REPORT OF SERVICE LIFE TESTS OF 14.00 X 20  
TIRES OF VARIOUS PLY

<u>Date</u>	<u>Item</u>	<u>Page</u>
1 March 43	Letter report on service life tests of 14 x 20 truck tires by Engineer Board Desert Test Section.	225

DATE: March 1, 1943

TITLE: Service Life Tests of 14.00 - 20 Truck Tires in Various Plies

PROJECT NO: ST 136

SUBMITTED BY: Burl Heileman,  
Assistant Engineer

### I SUBJECT

This report covers controlled tests made to determine the comparative service life of 14.00 - 20 truck tires in various ply-constructions under conditions of actual operation on the highway and across rocky desert terrain.

### II AUTHORITY

Oral request of Major W. W. Milner, C.E., to make service life tests as recommended in First Interim Report of the Desert Test Branch on "The Performance Tests of 14.00 - 20 Tires in Sand", Dated January 2, 1943. Testing was terminated in compliance with letter the Engineer Board, file 400.112 (EB 136), dated February 10, 1943.

### III FACTUAL DATA

1. From previous tests, it has been learned that the mobility of a vehicle in very soft sand can be improved greatly by decreasing the tire inflation pressure, and that for tires of any given size, the most flexible tire, which is usually the one with the smallest number of plies, gives maximum performance. An objection was raised that while thin, flexible tires are superior in very soft sand, they would not be practicable for use on hard-surfaced roads or for off-road conditions where rocks may be encountered.

2. Tests were made to determine the expected length of service on highways of 14.00 - 20 truck tires in various plies.

a. A Diamond T, 4-ton, 6 x 6, cargo truck, with rated load, was operated exclusively on hard-surfaced highways with the following tires which had not been previously used: (See Fig. 1)

- (1) Two U. S. 14.00 - 20, Six-ply, sand type
- (2) Two Goodyear 14.00 - 20, Eight-ply, earthmover
- (3) Two Firestone 14.00 - 20, Ten-ply, earthmover

b. A speed of 35 miles per hour was maintained as much as possible, and all tires were inflated to 20 pounds per square inch.

c. It was noted that the inflation pressures increased as the tires heated in operation, and that the six-ply tires gained less pressure than the ten-ply tires.

d. The position of each tire was changed at intervals to eliminate any unusual condition of wear due to poor wheel alignment or other factors.

e. The following table shows the load on each tire, and the distances traveled in each wheel position on the truck.

Distances in Miles Traveled by Tires on Highway

Tire	Wheel Position and Load						Total 24,800#
	Front		Rear				
	Left 3300#	Right 3300#	Left For. 4550#	Right For. 4550#	Left Rear 4550#	Right Rear 4550#	
U. S. Six-ply	306	1500	---	281	---	962	3049
U. S. Six-ply	962	---	281	---	1500	306	3049
Goodyear Eight-Ply	281	962	1500	---	306	---	3049
Goodyear Eight-Ply	---	---	962	306	281	1500	3049
Firestone ten-ply	1500	281	306	962	---	---	3049
Firestone ten-ply	---	306	---	1500	962	281	3049

f. No tire failed during this test.

3. Tests were also made to determine the resistance to damage of the tires in various plies when operated over very rocky terrain.

a. A Diamond T, 4-ton, 6 x 6, cargo truck, with rated load, was operated over extremely rocky terrain with the following tires which had not been previously used: (See Fig. 1)

- (1) Two U. S. 14.00 - 20, six-ply, sand type
- (2) Two Firestone 14.00 - 20, ten-ply, earthmover
- (3) Two Firestone 14.00 - 20, twelve-ply, earthmover shallow design

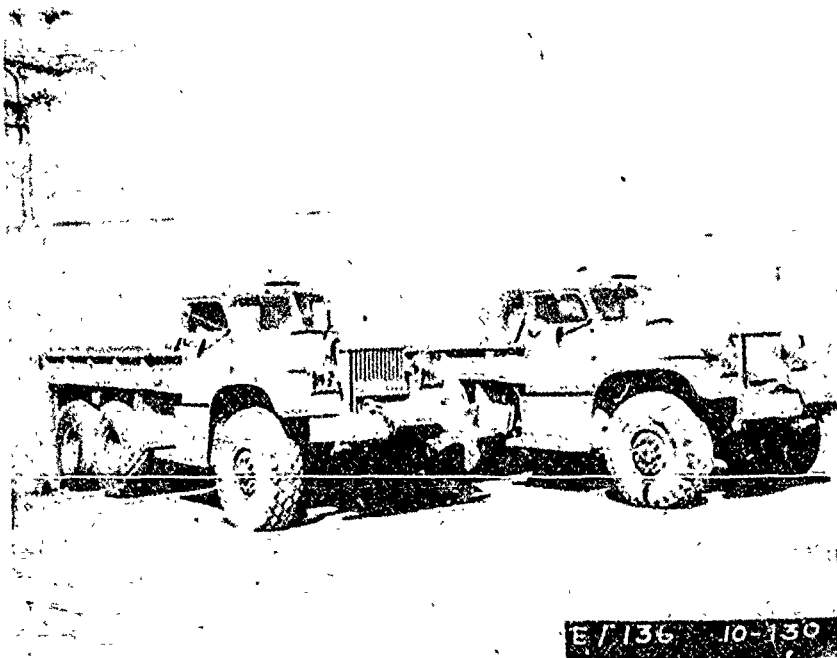


Figure 1. The two Diamond T 4-ton 6 x 6 cargo trucks which were used in these tests.



Figure 2. Terrain selected for testing tires for service life on rocks.



Figure 3. United States 14.00 - 20 6-ply tire striking large rock.



Figure 4. Firestone 14.00 - 20 12-ply tire striking large rock.

b. As failures occurred, the tires were replaced with identical new ones.

c. A course 0.7 of a mile long through rocks was selected so that it was not possible to drive without striking rocks with all wheels at all times. The rocks were the maximum size that could be driven over without striking and damaging the differential cases of the truck. (See Figs. 2 to 4.)

d. The truck was driven as fast as possible, the limiting factor being control, as the driver was bounced around a great deal. It was possible to drive in second gear, high range, or third gear, low range, with the engine at maximum governed speed. Actual speeds varied from six to ten miles per hour. Tire inflation pressures were maintained at 20 pounds per square inch.

e. The position of each tire was changed at intervals to eliminate any unusual condition of wear due to poor wheel alignment or other factors, and all-wheel drive was used to further equalize wear on all tires.

f. The following table shows the load on each tire, and the distances traveled over the rock course in each wheel position on the truck. In addition to the distances shown, each tire was driven an approximately equal distance at a very slow speed over a smooth gravel road in getting to and from the test area.

Distances in Miles Traveled by Tires over Rocky Terrain

Tire	Wheel Position and Load						Total
	Front		Rear				
	Left 3300#	Right 3300#	Left For. 4300#	Right For. 4300#	Left Rear 4300#	Right Rear 4300#	
*U. S. Six-ply	--	--	--	--	--	37	37
Firestone Ten-ply	--	--	74	--	--	--	74
*U. S. Six-ply	--	--	--	66	--	29	95
U. S. Six-ply	86	28	--	--	--	--	114
*Firestone Ten-ply	28	66	12	29	--	--	135
*U. S. Six-ply	29	--	66	--	28	35	158
*Firestone Twelve-ply	66	29	28	--	54	--	177
Firestone Ten-ply	--	86	--	28	29	66	209
Firestone Twelve-ply	--	--	29	86	66	28	209

g. Tires marked with an asterick (\*) in the above table failed due to interior breaks in the carcass caused by striking rocks, except the Firestone twelve-ply. This tire went flat while the truck was on the rock course, but upon inspection, no damage to the carcass was discovered. A cut was found in the tube, caused by small pieces of gravel which had entered through the valve-hole in the rim.

h. The tread pattern of all tires used in the test was cut and worn off from contact with the rocks. (See figs. 12 to 17) In addition to this damage, on the U. S. tires the side-wall rubber separated from the fabric, and a joint between the tread and side-wall opened up. (See Figs. 10 and 11) This bond-failure at the shoulder of the tread has been observed on all of the tires of this make which have been used, regardless of type of service, and is apparently due to the method of applying the tread-rubber and failure to develop proper bond with the side-wall covering. It can not be classed as a defect of six-ply tires.

#### IV DISCUSSION

1. Information was desired on the relative life of tires of various ply-constructions in actual service. A military truck tire in desert service would be operated at times on roads, on sand, and over rocks. It had been previously determined that satisfactory mobility in soft sand could be obtained by using an inflation pressure of 20 pounds per square inch. This pressure was adopted for the service tests because in actual service there would be occasions when rocks would be encountered or highway operation becomes necessary immediately after traversing soft sand without an opportunity to re-inflate the tires.

2. The tires which were tested for highway operation showed nothing significant at the conclusion of the test.

a. It had been intended to run the tires to destruction, but the test was terminated at the end of 3049 miles in accordance with instructions received in a letter previously referred to from the Engineer Board.

b. The ultimate life of these tires is not known, but some of the original tires should have lasted more than 10,000 miles.

c. The tread design on the earthmover type tires showed definite signs of wear, as was to be expected because this design is not intended to have good wearing qualities on highways. This is not regarded as significant because this test was only to determine the effect of number of plies, and any tread pattern can be molded on a tire of any number of plies.



Figure 5. Break on inside of United States 14.00 - 20 6-ply tire which occurred after driving 98 miles over rocky terrain.



Figure 6. Chafed place in tube caused by break in carcass shown above.



Figure 7. Typical interior break in United States 6-ply tire.

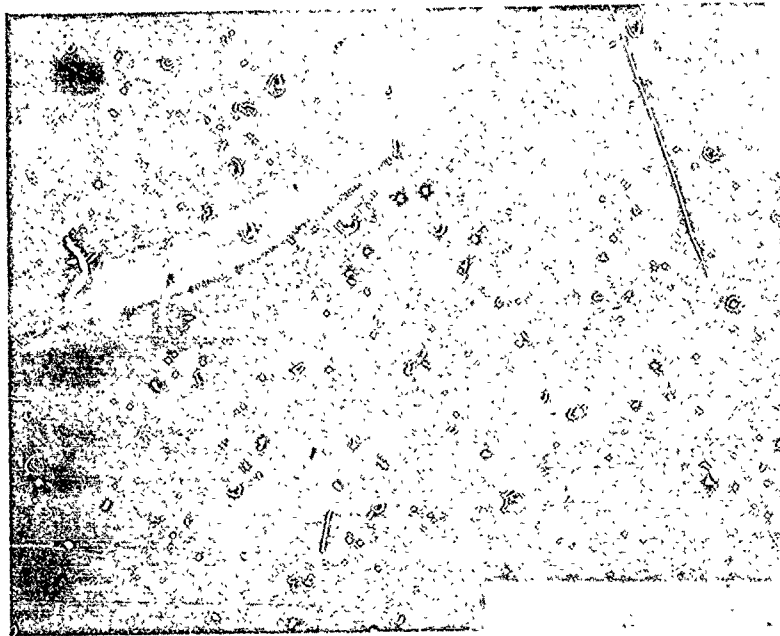


Figure 8. Interior break in Firestone 14.00 - 20 10-ply tire.



Figure 9. Typical pinched place in tube.



Figure 10. Separation of sidewall from tread rubber on United States 6-ply tire. This is apparently a fault in construction methods and has no relation to number of plies.

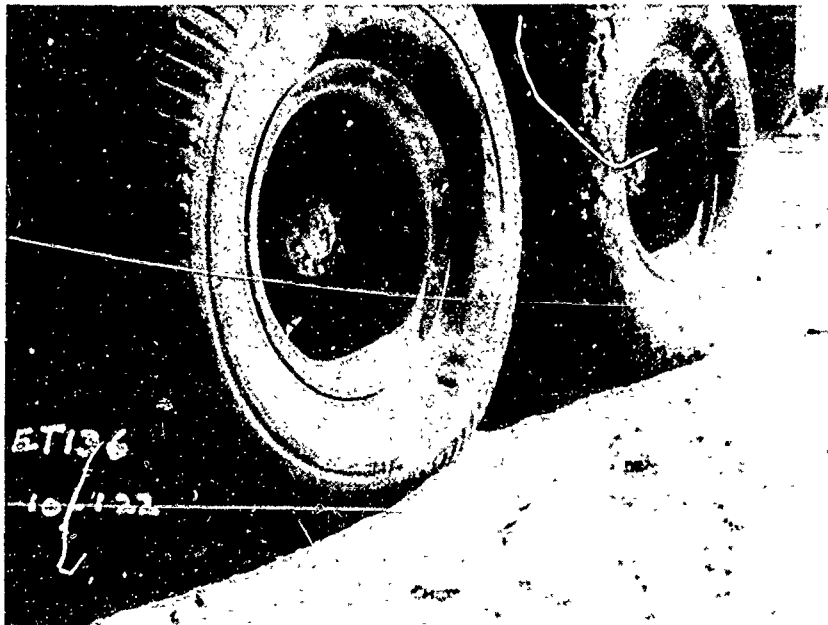


Figure 11. Separation of sidewall rubber from fabric on United States 6-ply tire.

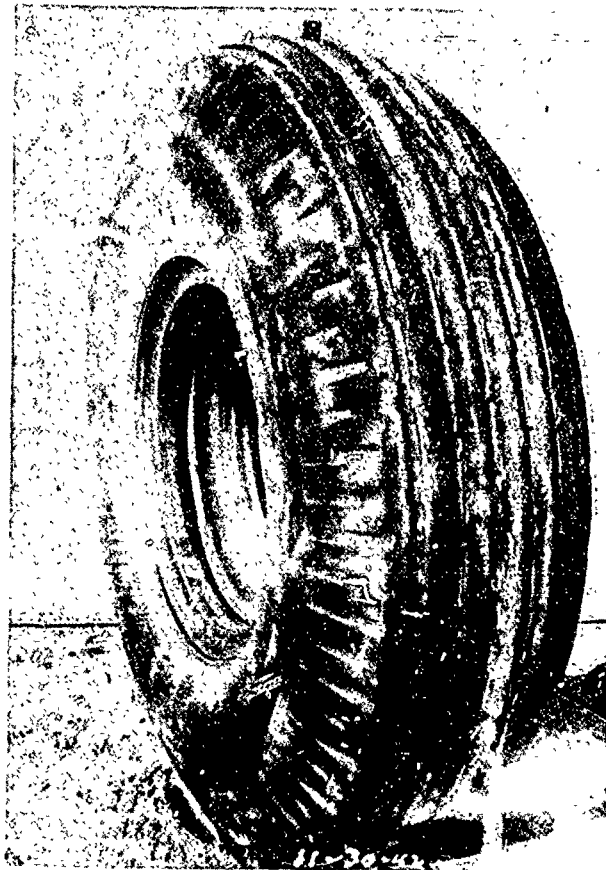


Figure 12. New United States 14.00 - 20 six-ply tire.

Figure 13. United States 14.00 - 20 six-ply tire after 150 miles of operation in rocky terrain.

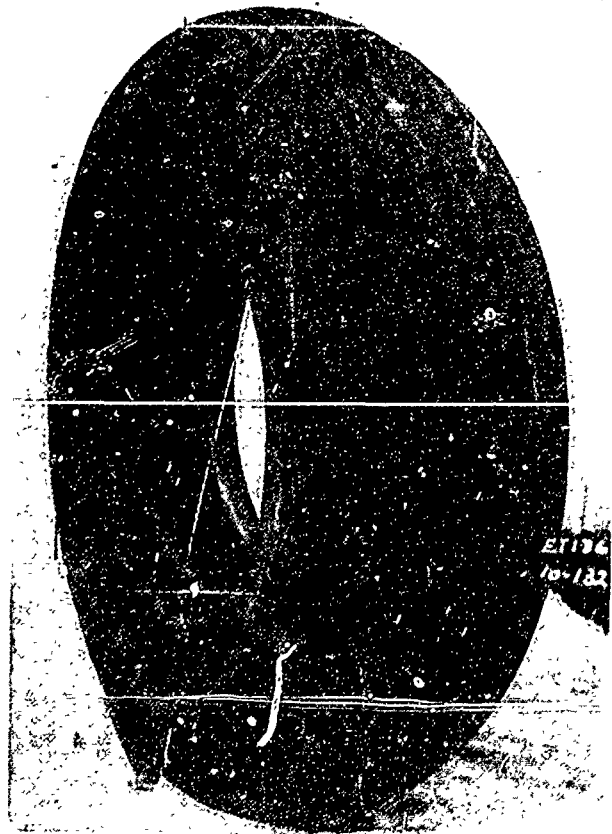




Figure 14. New  
Firestone 14.00 - 20  
10-ply tire.

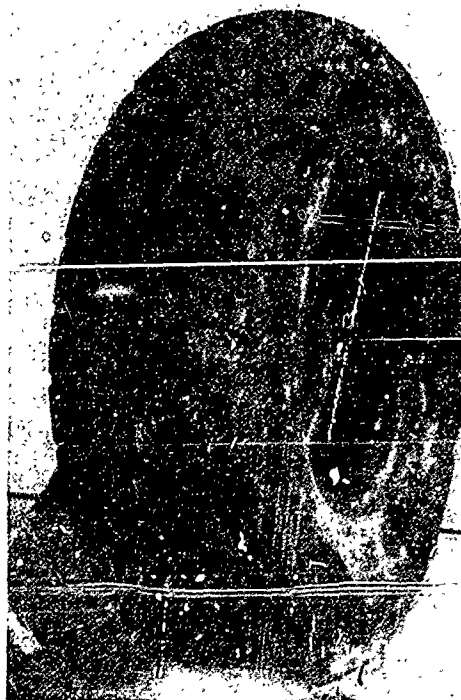


Figure 15. Firestone  
14.00 - 20 ten-ply  
earthmover tire after  
209 miles of operation  
on rocky terrain.



Figure 16. New  
Firestone 14.00 - 20  
12-ply earthmover  
tire, shallow design.

Figure 17. Firestone  
14.00 - 20 12-ply tire  
after 209 miles of  
operation over rocky  
terrain.



d. The fact that the six-ply tires operated without failure would indicate that they are satisfactory for operation in highway service.

3. From the record of tire failures on rocky terrain, it can be seen that resistance to impact damage increases with the number of plies.

a. Three six-ply tires failed, but these tires had a much longer life in rocky terrain than had been expected.

b. One ten-ply tire failed.

c. No twelve-ply tire failed as a result of striking rocks.

4. The test on the rocky terrain was extremely severe; in most cases of actual service, slower speeds would be used in crossing such areas. However, in any off-road going, a tire is apt to strike an isolated rock at high speed. It is noted that this test was more critical of the truck than of the tires and the fact that the tires held up as well as they did is evidence that any of them could be considered very durable. The following damage to the truck was incurred:

a. Gas tank badly dented and hole punched in tank.

b. Gas tank developed leak due to vibration.

c. Brake airline broke repeatedly.

d. Radiator shell support bolt broke twice.

e. Hood hinge became separated.

f. Brake drum broken on edge by rocks.

g. Steering column support bolts came out.

h. Bolts holding cab loosened.

5. Tire failures in all cases, except the twelve-ply tire, were due to the fabric rupturing on the interior of the tire, which pinched the tube. (See Figs. 5 to 9.) The tires did not blow out violently, as would have been the case if higher pressures had been used, but went flat over a period of three to five minutes.

6. It was previously determined that twelve-ply tires with a smooth, shallow tread pattern will give reasonably satisfactory mobility in very soft sand, though not equal in performance to the

Project No. St 136

March 1, 1943

six-ply tire. In this test, it has been shown that the twelve-ply tire is as satisfactory as other plies for highway service, and has a longer life-expectancy when subjected to severe abuse on rocky terrain. The six-ply tire is unsatisfactory for use in rocky terrain.

7. This Branch does not have sufficient information as a result of this limited service life test to draw conclusions as to the difference in merit of the ten and twelve ply tires or to estimate mileage per pound of rubber for the various ply tires.

#### VI RECOMMENDATIONS

For general desert terrain, a compromise is necessary between the tire giving the maximum sand performance and the tire giving the best all-around desert service.

a. The ten-ply or twelve-ply tires, with shallow tread design, are recommended as satisfactory.

b. The six-ply tire is not recommended.

SUBMITTED BY

Burl Heileman  
Burl Heileman,  
Assistant Engineer.

APPROVED BY

W. W. Milner  
Major W. W. Milner,  
Chief, Desert Test Branch.

APPENDIX D

DIRECTIVES TO CONDUCT TIRE TESTS

<u>Date</u>	<u>Item</u>	<u>Page</u>
21 April 43	Letter from Chief of Ordnance requesting that the Engineer Board conduct tire tests.	253
28 May 43	Letter from Chief of Engineers directing tire tests be conducted.	257
28 June 43	Letter from Engineer Board requesting approval of project MES 433, Service of Tires for Engineer Equipment.	258
30 June 43	1st Indorsement from Chief of Engineers approving project MES 433.	261

WAR DEPARTMENT  
Tank-Automotive Center

Detroit, Michigan

Robson/ck

April 21, 1943

Subject: Special Traction and Flotation Tire Test

To: Office of the Chief of Engineers  
New War Department Building  
Washington, D. C.  
ATT: Lt. Col. F. S. Besson  
Engineering and Development Branch

THRU: Office of the Chief of Ordnance  
Pentagon Building  
Washington, D. C.  
ATTN: Chief, Technical Division

1. The Ordnance Department is providing one set each of 11.00-18 and 14.00-20 desert type tires to the following Service Boards:

Field Artillery  
Infantry  
Armored Force  
Tank Destroyer

2. These will be given tests for traction, flotation and general service durability. They have not been shipped to Engineer Board because it is understood considerable experimentation has been conducted on these tires both at the Yuma Desert Test Branch and at Fort Story. It is believed these tires are available for traction and flotation testing at your Command.

3. Steps are being taken to obtain results from these various Boards and also from test organizations under the direct control of the Office of the Chief of Ordnance on the mud, traction and flotation ability of these desert type tires. It is believed they may provide considerably improved performance over present type dual tires, and one of the principal objectives of this test will be to establish or disprove this belief.

4. It is requested that the Engineer Board submit any information available on this subject, and conduct any necessary tests to add conclusive evidence to this subject.

For the Deputy Chief of Ordnance:

/s/ B. J.  
JOSEPH M. COLBY  
Lt. Col., Ord. Dept.  
Assistant

EXHIBIT "A"

DIAMOND T- 4-TON, 6x6, CONVERSION. (For one truck.)

7 Wheels.

20 x 10:00 CW  
5-3/8" Dish  
10 Stud                    11-1/4" Stud Circle  
Bull Type No. 46160-D-1  
Wheel Ordnance No. 40890  
Ring Ordnance No. C 91161  
Nut Ordnance No. A 233035

Complete Wheel, Ring, Nut Assembly

7 Bead Locks    Continuous Band

Hinged Type. Similar to Goodyear D-6-L Type.  
Width 5.288". To fit 20 x 10:00 CW and 14:00 x 20-12  
Ply Desert Tire.

7 Flaps for Above Tires

Note: No flaps required for bead locks, but flaps will  
be required if flat base rims are used.

2 Right Hand Hub Adapters

4 Inch  
10 Stud                    11-1/4" Stud Circle  
Complete with studs and cap nuts

2 Right Hand Hub Adapters

3 Inch  
Same Comments

2 Left Hand Hub Adapters

4 Inch  
Same Comments

2 Right Hand Hub Adapters

3 Inch  
Same Comments

(EXHIBIT "A" - cont.)

8 Tires

14:00 x 20 - 12 Ply  
Desert Type Modified  
Shallow N. D. tread

8 Tubes for Same

EXHIBIT "B"

G.M.C. - 2-1/2-Ton, 6x6, CONVERSION. (For one Truck.)

7 Wheels, Ordnance Standard Divided Rim

18 x 8:00 CV  
3-1/2" Dish  
6 Stud 8-3/4" Stud Circle  
Budd, Type

Complete Wheel, Ring and Nut Assembly

7 Bead locks. Continuous Hinged Band

Similar to Goodyear D-10-L Type  
Hinged Low Type Bead Lock  
5.468" Width  
See Tire and Rim Assoc. 1942 Handbook, Page C-12  
Military Supplement  
To fit 18 x 8:00 CV Rim and 11:00 x 18 - 10 Ply  
Desert Tire

6 Flaps for above tires

Note: Flaps not needed with bead locks but desired for  
use with flat base rims that may be used in test.

2 Right Hand Hub Adapters

1-1/2 Inches  
6 Stud 8-3/4" Stud Circle  
Complete with studs and Cap Nuts

2 Left Hand Hub Adapters

Same

8 Tires

11:00 x 18 - 10 Ply  
Desert type modified shallow,  
Non Directional, Mud and Snow

8 Tubes

For above tires.

O.O.451.92/3257  
Attn: SPOTT  
TAC 451.92/1578

1st Ind.

Perrine/mcc  
Exten. 4480

War Department, Ordnance Office, ASF, Washington, D. C., April 28,  
1943.

To: Office of the Chief of Engineers, New War Department Building,  
Washington, D. C. Attn: Lt. Col. F. S. Besson, Engr. & Dev.  
Branch.

1. Forwarded for compliance with request made in basic com-  
munication.

For the Chief of Ordnance:

/s/ W. Fred Jordan  
Major, Ord. Dept.  
for G. M. BARNES,  
Major General, Ord. Dept.,  
Chief, Technical Division.

WAR DEPARTMENT  
Office of the Chief of Engineers  
Washington

400.112(Tires)SPEED

May 28, 1943

Subject: Special Traction and Flotation Tire Test.

To: The President,  
The Engineer Board,  
FORT BELVOIR, VIRGINIA.

1. Inclosed, for your information, is a letter from the Tank-Automotive Center, dated April 21, 1943, on special traction and flotation tire tests to be conducted by the Service Boards mentioned in the first paragraph.

2. It is directed that the Engineer Board conduct comparative tests on 2-1/2-ton, 6x6, G.M.C. cargo dump trucks and 4-ton, 6x6, Diamond-T dump trucks equipped with 11:00 x 18-10 ply and 14:00 x 20-12 ply desert type tires respectively, as compared with corresponding vehicles equipped with standard tires. Inasmuch as the directive of May 10, 1943 on testing low pressure tires on 4-ton, dump trucks covers similar but less comprehensive tests, the directive is rescinded.

3. Tests are to include traction, flotation, and general service durability, with special emphasis on performance in mud.

4. The inclosed exhibits A and B are submitted as an aid in procuring equipment necessary for conducting the tests.

By order of the Chief of Engineers:

/s/ E. L. Knutson  
E. L. KNUTSON,  
Captain, Corps of Engineers,  
Assistant, Equipment Development Branch,  
Engineering Division.

3 Incls.

Incl. 1 - Ltr frm TAC, dtd 4/21/43 to OCE w/1st Ind, File 400.112  
Incl. 2 - Exhibit "A". (Tires)  
Incl. 3 - Exhibit "B".

WAR DEPARTMENT  
THE ENGINEER BOARD  
CORPS OF ENGINEERS, U. S. ARMY  
FORT BELVOIR, VIRGINIA

Refer to File No. 451,92

28 Jun 1943

Subject: Service Project for Tires.

To: Chief of Engineers, U. S. Army.

1. Office, Chief of Engineers letter to the Engineer Board, dated May 28, 1943, file 4CO.112(Tires) SPEED, 451.92, contained a directive 'to conduct traction, flotation and general service durability tests on 14:00 x 20 12-ply, and 11:00 x 18 10-ply desert tires with special emphasis on performance in mud. The 2 $\frac{1}{2}$ -ton cargo-dump and the 4-ton dump trucks, also under test at the Board, to be utilized in testing the tires'.

2. The testing of desert tires as directed, will necessarily require a considerable amount of work and equipment, and may extend over a long period of time. It is believed that this can best be handled by setting up a Service Project to cover this activity, and other problems relating to tires.

3. It is requested that Service Project No. MES 433, Service on Tires for Engineer Equipment, be authorized.

For the Board:

/s/ Peter P. Goerz  
Peter P. Goerz,  
Colonel, Corps of Engineers,  
Executive Officer.

2 Incls.  
Incl "A" & "B"

INCLOSURE "A"

Project No. MES 433

Service on Tires for  
Engineer Equipment

Authority: Office, Chief of Engineers letter to the Engineer Board, dated May 28, 1943, file 400.112(Tires) SPEED, 451.92.

Purpose: The project being requested is required for the purpose of conducting tests and studies on low-pressure pneumatic tires for Engineer equipment, as directed by the Chief of Engineers.

Military Characteristics:

Not applicable.

INCLOSURE "B"

Project No. MES 433

Service on Tires for  
Engineer Equipment

Plan of Service

1. The Engineer Board has under test at this time, two 4-ton dump trucks and eight  $2\frac{1}{2}$ -ton cargo-dump trucks. One-half of these trucks (including the 4-ton) will be equipped with low-pressure (desert) tires. Dump trucks will be operated in pairs as much as is practicable; one truck of each pair will be equipped with standard tires, the other with low-pressure (desert) tires. Records will be kept of the mileage, loads, inflation, and the type of roads over which the trucks are operated.

2. In addition to the tests outlined in Paragraph 1, such traction, flotation and rolling resistance tests will be conducted in mud as the available facilities at the Engineer Board and the immediate vicinity permit. The tests will be started on or about July 10, 1943, depending on the delivery of the tires and wheels from the manufacturer. The actual test work will be done by the Transportation Test Section.

3. An interim report will be submitted to the Chief of Engineers at the end of the first 45 days of test. Due to the short duration of the test, from which any conclusions may be drawn, it may be impracticable to submit data in this report. A more conclusive report will be submitted at the end of a 6-month test period, and at such other times in between as appears desirable.

Approval by the Board 25 June 1943

CE 400.112 (Tires) SPEED Subject: Service Project for Tires  
1st Ind.

Office, C. of E., 30 June 1943.

To: The President, The Engineer Board, FORT BELVOIR, VIRGINIA.

Service Project No. MES 433 for service testing tires  
for Engineer equipment, in accordance with inclosures "A" and  
"B", is authorized.

By order of the Chief of Engineers:

/s/ James H. Stratton,  
JAMES H. STRATTON,  
Colorel, Corps of Engineers,  
Chief, Engineering Division.

2 Incls.  
n/c

APPENDIX E

DIRECTIVE TO DISCONTINUE TIRE TESTS

<u>Date</u>	<u>Item</u>	<u>Page</u>
8 Nov. 43	Letter from Chief of Engineers requesting relocation of low pressure tire test area with 1st indorsement by Engineer Board.	265
14 Dec. 43	Letter from Engineer Board recommending discontinuance of mud tests.	267
29 Dec. 43	First indorsement from Chief of Engineers directing discontinuance of mud tests.	269

WAR DEPARTMENT  
OFFICE OF THE CHIEF OF ENGINEERS  
WASHINGTON

CE SPENG

8 November 1943.

Subject: Relocation of Tests on Low Pressure Tires in Mud.  
(Work Order No. DME 3119).

To: The President  
The Engineer Board  
FORT BELVOIR, VIRGINIA.

It is requested that the equipment for low pressure tire tests in mud, now being conducted at Salten Sea, be moved to the Engineer Test Laboratory for Soils at Vicksburg, as soon as practicable, and that the tests be conducted at that location.

By order of the Chief of Engineers,

/s/ E. L. Knutson

for

WILLIAM J. NEW,  
Major, Corps of Engineers,  
Executive Officer, Equipment Development Branch,  
Engineering Division.

Subject: Relocation of Tests on Low  
Pressure Tires in Mud.  
(Work Order No. DME 3119)

CE SPENG  
EB 400.1 (MES 433) 1st Ind.

Engineer Board, Fort Belvoir, Virginia, 13 Nov 1943

To: Chief of Engineers, U. S. Army.

1. Tests of 11.00 x 18 and 14.00 x 20 low pressure tires now being conducted by the Engineer Board, Desert Warfare Section, at the Salton Sea, are approximately 75% complete. It is estimated that all tests in this area will be completed on or before 1 December 1943.

2. A reconnaissance has been made of the facilities for testing tires in mud at the Waterways Experimental Station, Vicksburg, Mississippi, and it is believed that adequate facilities for testing are available there. Tentative arrangements have also been made with the staff of the Waterways Test Laboratory for conducting tests, there, should the tests at the Salton Sea be considered inconclusive.

3. After the tests are completed at the Salton Sea and the data have been summarized, it may be found that no further mud testing will be required. The Engineer Board will be in a better position to furnish definite information as to what action should be taken after this has been done.

For and in the absence of the President:

/s/ W. J. Matteson  
W. J. Matteson,  
Colonel, Corps of Engineers,  
Asst. Executive Officer.

400.1 (MES 433)

14 December 1943

Subject: Low Pressure Tire Mud Tests.  
(Work Order No. DME 3119).

To: Chief of Engineers, U. S. Army.

1. Reference is made to a letter from your office dated 8 November 1943 requesting transfer of low pressure tire mud tests from the Salton Sea Area to The Engineer Test Laboratory for Soils at Vicksburg, and to the 1st Indorsement thereto, dated 13 November 1943, which stated that this office would "furnish definite information" as to the need for further mud tests about "1 December 1943".

2. There are two basic problems inherently associated with the question of conversion to low pressure tires,

a. The procurement of sufficient data to indicate the advisability of conversion, and to indicate the specific conversion in the case of all vehicles of present design.

b. The procurement of sufficient engineering data (tractive effort, rolling resistance, carcass strength, etc.) to enable the proper application of low pressure tires to vehicles of new design.

These two problems are fundamentally different since, in the second case, no restrictions exist, whereas in the first case any conversion made is governed by such factors as bogie axle spacing dimension, load line displacements feasibility of field kits, etc. As an example, the present 2-1/2-ton, 6x6, vehicle equipped with 7.50x20 high pressure tires duals rear, is best converted to 11.00x18 low pressure tires singles all around, yet the tires for this vehicle (if bogie axle spacing did not govern as it does in this case) appear to be 11.00x20 low pressure. These, however, cannot be used on a conversion basis, but new designs should take this into account.

3. Enough data now exists to make specific recommendations as to the conversion of all present standard vehicles to low pressure tires. Sufficient data does not exist to prepare traction effort and rolling resistance curves (mud) for use in new vehicle design. Approximately six months would be required to obtain comprehensive and adequate mud data for future design use.

Ltr to OCE  
File 400.1 (MES 433)  
cont.

4. While it is acknowledged that the procurement of this engineering data would be entirely worthwhile and would be a substantial contribution to the question of the design of future army vehicles, it is seriously doubted that the low pressure tire question as a whole will pass through any more than phase one (conversion) during the process of the present war, and accordingly, the value to the present war effort of further mud tests is in serious doubt.

5. On the other hand, the mobility of U. S. Army vehicles is of prime importance. If sufficient data, upon which to base new designs (phase two), is not now obtained, the chances are that it will not be obtained for several years which may conceivably jeopardize the required mobility of future vehicles of our army. One of the greatest disadvantages which could be given our army would be the use of low pressure tires by the enemy forces, prior to their use by our own forces.

6. The recommendations of this office are that no further mud tests be conducted at this time. It is requested that the above factors be considered, and this office be advised of the decision made.

/s/ John W. N. Schulz,  
John W. N. Schulz,  
Brigadier General, U. S. Army,  
President.

CE SPENG

Subject: Low Pressure Tire Mud Tests.  
(Work Order No. DME 3119).

1st Ind.

Office, C. of E., 29 December 1943.

To: The President, The Engineer Board, FORT BELVOIR, VIRGINIA.

It is directed that further mud testing of tires be discontinued and that the assembling of all information obtained to date be expedited and forwarded to this office, in order that the information may be furnished to Army Service Forces and the Ordnance Department for their use in decisions affecting low pressure tires.

By order of the Chief of Engineers:

/s/ William J. New

WILLIAM J. NEW,  
Major, Corps of Engineers,  
Chief, Equipment Development Branch,  
Engineering & Development Division.

BASIC: EB to OCE dated 14 Dec. 1943

APPENDIX F

LETTER REPORT SUMMARIZING TIRE TEST RESULTS

<u>Date</u>	<u>Item</u>	<u>Page</u>
21 Dec. 43	Letter from Engineer Board summarizing test results, submitted prior to preparation of test report.	273

21 December 1943

Subject: Special Traction and Flotation Tire Test.

To: Chief of Engineers, U. S. Army.

1. Reference is made to letter your office, subject above, dated 28 May 1943, file 400.112 (Tires) SPEED, which directed comparative tests of  $2\frac{1}{2}$ -Ton and 4-Ton vehicles equipped with low pressure tires as compared with the same vehicles with standard tires. The tests conducted in compliance with that directive have been concluded, but due to their comprehensive nature, the final report is still in preparation.

2. It is the purpose of this letter to give advance information as to the major conclusions reached as a result of the tests conducted. During all tests special emphasis was placed on relative performance in mud of the two types of tire equipment under identical loading conditions. The following major conclusions have been reached.

a. That the mud performance of the 4-ton, 6 x 6 truck, equipped with 14.00 x 20-12 ply "desert" type tires, singles all around, is definitely and under all conditions tested superior to the mud performance of the same vehicle when equipped with standard 7.50 x 20-8 ply non-directional mud and snow type tires, duals rear, under all inflation conditions, i.e., under highway inflation, 25 miles per hour off-road inflation, limited operations inflation, or Ordnance sand minimum inflation. The same relative performance extends also to these vehicles with tires equipped with chains. In each case, the rolling resistance of the 14.00 x 20 tire (singles) was less and the tractive effort greater, than with the 9.00 x 20 tire duals rear.

b. That the mud performance of the  $2\frac{1}{2}$ -Ton, 6x6 truck, equipped with 11.00 x 18-10 ply "desert" type tires, singles all around, is superior in general to the mud performance of the same vehicle when equipped with 7.50 x 20-8 ply non-directional mud and snow type tires, duals rear. In all cases and under all inflations, the rolling resistance of the 11.00 x 18, both with and without chains, is less than the 7.50 x 20, whereas comparative tractive effort is indefinite, depending upon mud conditions, but in favor of the 11.00 x 18 tires a majority of the time.

c. That the mud performance of the  $2\frac{1}{2}$ -Ton, 6 x 6, could be made comparable with the mud performance of the 4-Ton, 6 x 6 (14.00 x 20 singles), if 12.00 x 20 tires could be used on the

vehicle. This conclusion is based on load-performance studies which indicate that best performance results when wheel loads comparable to those of the  $2\frac{1}{2}$ -ton, 6x6, are supported by tires of about 12.00 x 20 size.

d. That the general service durability of the 11.00 x 18 and 14.00 x 20 "desert" type tire, when applied to the  $2\frac{1}{2}$ -ton and 4-ton vehicles, is satisfactory.

e. That, in view of the results of these tests and of performance comparison tests previously conducted in soft sand and other difficult terrain with these same tires, it is concluded that these tires should be standard equipment on all  $2\frac{1}{2}$  and 4-Ton, 6x6 vehicles in tactical units.

2. The following recommendations are made, based on the mud tests and all previously conducted tests in difficult terrain.

a. That the 11.00 x 18-10 ply "desert" type tire be declared standard equipment for all  $2\frac{1}{2}$ -Ton, 6x6 tactical vehicles.

b. That the 14.00 x 20-12 ply "desert" type tire be declared standard equipment for all 4-Ton, 6x6 tactical vehicles.

c. That conversion kits, based on Inclosures 1 and 2 hereto, be issued to troops as soon as may be practicable to effect this recommended conversion.

d. That, in the event that a redesign of the present  $2\frac{1}{2}$ -Ton, 6x6 truck is ever contemplated, consideration be given to performance tests of the new vehicle when equipped with 11.00 x 20 or 12.00 x 20 "desert" type tires.

e. That a copy of this letter report be made available to Major James H. Allen, ASF Requirements, Room 4E619, the Pentagon, as he is compiling results of the tests by various technical branches.

For and in the absence of the President:

/s/ W. J. Matteson,  
W. J. Matteson,  
Colonel, Corps of Engineers,  
Executive Officer.

2 Incls.

Incl. 1 - Suggested Conversion  
Kit for  $2\frac{1}{2}$ -Ton Truck (in dup)

Incl. 2 - Suggested Conversion  
Kit for 4-Ton Truck (in dup)

cc w/incls: The Engineer Board  
Desert Warfare Section  
Thermal, California

APPENDIX G

CORRESPONDENCE RELATIVE LOAD AND INFLATION DATA

<u>Date</u>	<u>Item</u>	<u>Page</u>
18 May 43	Letter from Chief of Ordnance covering specific load and inflation data, with 1st and 2nd indorsements to the Engineer Board	277
3 July 43	Letter from Engineer Board requesting confirmation of specific load and inflation data and 3rd indorsement with revised inflation data.	280

WAR DEPARTMENT  
ORDNANCE DEPARTMENT  
Tank Automotive Center

W. H. Campbell/sb

May 18, 1943

Subject: Test of 11.00-18 10-Ply and 14.00-20 12-Ply Desert Type  
Tires for General Service Durability and Flotation in  
Mud or Sand.

To: Office of the Chief of Engineers  
New War Department Building  
Washington, D. C.  
ATTN: Lt. Col. F. S. Besson  
Engineering and Development Branch

THRU: Office of the Chief of Ordnance  
Pentagon Building  
Washington, D. C.  
ATTN: Chief, Technical Division

1. This acknowledges your request by telephone to this office  
May 15, 1943, for instructions on conducting the above tests.

2. The following instructions were issued to various Service  
Boards that are conducting similar tests:

<u>Tire Size</u>	<u>Load</u>		<u>Inflation</u>	
	<u>Front</u>	<u>Rear</u>	<u>General Service</u>	<u>Mud or Sand</u>
11.00-18 10-Ply	2650#		35# )	To be determined
14.00-20 12-Ply	3650#		65# )	by test.

3. It will also be necessary to obtain the following change-  
over equipment to conduct this test:

2½-Ton 6x6 Truck

7 Wheels, complete with 8.00 CV divided rims, side rings,  
and flange nuts #L82497

2 Spacers, right hand #E2491

2 Spacers, left hand #82492

The manufacturer's numbers are those of the Motor Wheel  
Corporation, Lansing, Michigan.

4-Ton 6x6 Truck

7 10.00-20 CW Wheels with 4-3/4" dish, #47280-D1

The manufacturer's number is that of the Budd Wheel Company, Detroit, Michigan.

A speedometer adapter will be required for both vehicles, and unless other means are available for inflating the tires on the 2 $\frac{1}{2}$ -Ton 6x6 Truck, and air compressor should be applied to the vehicle. Information on the speedometer adapter and air compressor may be obtained from Major F. R. Hail, Engineering and Manufacturing Branch, Trucks and Trailers Unit, Tank-Automotive Center, Fisher Building, Detroit, Michigan.

For the Chief of Ordnance:

/s/ Joseph M. Colby

JOSEPH M. COLBY  
Lt. Col., Ord. Dept.  
Assistant

O.O 400.112/3695

Attn: SPOTT

TAC 400.112/1836

Merton/mb

1st Ind.

4481

War Department, Ordnance Office, ASF, Washington, D. C., June 4, 1943.

To: Office of the Chief of Engineers, Attn: Engineering & Development Branch, Lt. Col. F. S. Besson.

1. Forwarded is basic communication listing Service Board test information for Desert Type Tires, 11.00-18 and 14.00-20.

For the Chief, Technical Divisions:

/s/ W. F. Beasley

W. F. BEASLEY  
Chief Engr., Tank & Motor  
Transport Development  
Liaison.

2nd Ind.

Office, C. of E., June 9, 1943.

To: The President, The Engineer Board, FORT BELVOIR, VIRGINIA.

1. Forwarded.

2. Your attention is invited to the directive to the Engineer Board, dated May 28, 1943, from this office, on Special Traction and Flotation Tire Test, in which it was directed that the Engineer Board conduct comparative tests on cargo dump and dump trucks equipped with the subject tires.

By order of the Chief of Engineers:

/s/ F. C. Kendall

F. C. KENDALL,  
Lt. Col., Corps of Engineers,  
Exec. Officer, Equipment Development Br.  
Engineering Division.

451.92

3 July 1943

Subject: Tests of 11:00 x 18-10 ply and 14:00 x 20-12 ply Desert Type Tires for General Service Durability and Flotation in Mud or Sand.

Through: Chief of Engineers, U. S. Army.

To: Ordnance Department, Tank Automotive Center,  
Engineering Offices, Fisher Building,  
Detroit, Michigan.

Attn: Lt. Col. Joseph M. Colby  
Ordnance Department.

1. With reference to your letter of 18 May 1943, file TAC 400.112/1836 SPCMD-R.

2. Paragraph 2 of your letter lists the general service inflation pressure of the 14:00 x 20-12 ply tire as 65 pounds for a load of 4,620 pounds. The inflation pressure given is for a load of 6,780 pounds as listed in the military supplement of the Tire and Rim Association, Inc., Page M-1-A. For a load of 4,620 pounds, the general service inflation pressure should be 34 pounds.

3. The various Service Boards conducting tests should probably be informed of this correction.

For the Board:

/s/ Peter P. Goerz

Peter P. Goerz,  
Colonel, Corps of Engineers,  
Executive Officer.

BASIC:

Ltr. frm Lt. Col. Colby,  
Ord. Dept. thru Office,  
Ch. of Ord. to OCE, dtd  
5/18/43

TAC 451.92/2162

Attn: SPQMD-R

O.O.M. 451.92/3718

C.E.400.112(Tires)SPENG 3rd Ind.

Robson/lt

War Department, Tank-Automotive Center, Development Branch Detroit,  
Michigan, 28 July 1943.

To: Office of the Chief of Ordnance, Technical Division, Pentagon  
Building, Washington, D. C.  
ATTENTION: Mr. W. F. Boasley

1. Comment of the Engineer Board is entirely correct, and this  
office reissued all Service Board test forms on 9 July, revising this  
to use the following inflations:

Normal	40#
Cross Country	25#
Emergency	15#

2. For normal operations 40# is recommended in order to realize  
maximum wear and resistance to wiping, although it is acknowledged  
that 34# will carry the load imposed these tires.

/s/ B. J. Lemon

B. J. LEMON  
Lt. Col., Ord. Dept.  
Chief, Rubber Section  
Development Branch

# UNCLASSIFIED

(UNPUBLISHED CARD)

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U.S. ARMY CORPS OF ENGINEERS, ENGINEER RESEARCH AND  
DEVELOPMENT LABS., FORT BELVOIR, VA. (REPORT NO. 796)

LOW PRESSURE TIRES IN MUD - AND APPENDIXES A-G

C.C. HUSKISON; MARTIN R. LEIDIG; JOHN MACCLARENCE; AND  
OTHERS 1 MARCH 44 281PP. PHOTOS, TABLES

ARMY MATERIEL (27) 60 VEHICLES, CARGO  
NON-COMBAT VEHICLES (3) 0 TIRES - SERVICE TESTS

11, 11 / 22

2 / 3, 12

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Cancelled

Date

10/2/59

By authority of

OT

JME

5/5/58

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