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TCB-61-123-EV

REPORT OF EVALUATION

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TIRES, OVERSIZE, SPECIAL AND DESERT PHASE III: SUBARCTIC EVALUATION

UNITED STATES ARMY TRANSPORTATION BOARD

Fort Eustis, Virginia

MARCH 1963

APR 9 1963

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**TIRES, OVERSIZE, SPECIAL AND DESERT
PHASE III: SUBARCTIC EVALUATION**

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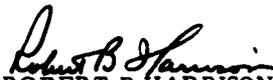
PREFACE

This paper is the final report for Phase III: Subarctic Evaluation, U S Army Transportation Board Project TCB-61-123-EV, Tires, Oversize, Special, and Desert (now USATECOM Project 7D-3118-01). The purpose of the evaluation was to obtain data for determining the capability of tires of increased size to improve wheeled vehicle mobility in subarctic terrain and environment.

Based on this evaluation, it was concluded that the Goodyear Super Terra-Grip Tires provide significant vehicle mobility improvement in winter subarctic environment. Additional evaluations with other classes of vehicles is recommended.

This report was approved for publication by the Office of the Chief of Transportation.

Fort Eustis, Virginia
March 1963


ROBERT B HARRISON
Colonel, TC
President

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**FINAL REPORT
TIRES, OVERSIZE, SPECIAL AND DESERT
PHASE III: SUBARCTIC EVALUATION**

1. AUTHORITY:

a. Directive: 1st Ind, TCCAD-SP, OCOFT, 16 August 1961, to letter, TCTCB-XP, 2 August 1961, subject: FY 62 Transportation Board Program.

b. Purpose: To obtain data for determining the capability of tires of increased size to improve wheeled vehicle mobility in subarctic terrain and environment.

2. REFERENCES:

a. Report of Evaluation, TCB-61-123-EV, Tires, Oversize, Special and Desert; Phase I, Jungle Evaluation, July 1962.

b. Plan of Evaluation for Subarctic (Alaska) 1962 Joint Evaluation of Commercial Vehicles, TCB-61-073-EO.

c. Preliminary Report of Evaluation, TCB-61-073-EO (GREAT BEAR).

d. Final Report, Exercise "GREAT BEAR"; United States Army Alaska, 8 June 1962.

e. Technical Memorandum No. 3-414, Report 4, Trafficability of Snow, Tests on Subarctic Snow; U S Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, December 1960.

f. Report of Evaluation, Kit, Off-Road Conversion, M52-127, Truck, Tractor Semitrailer Combination; U S Army Transportation Board, Fort Eustis, Virginia, October 1962.

3. DESCRIPTION OF MATERIEL:

Three types of tires were evaluated under subarctic conditions: standard military (non-directional cross-country NDCC and non-directional mud and snow NDMS) tires, Firestone Duplex tires, and Goodyear Terra-Tires. Four vehicle types, two military and two commercial with special tires, for a total of seven different vehicle tire combinations as shown in Table I were tested or observed. Table II indicates the vehicle load ratings.

Table I. Tires and Vehicles Evaluated

Item	Vehicle	Tires	Recommended Tire Infl (psi) Mud and Snow	Applicable Vehicle Wheels
1	Truck, Cargo, 3/4 Ton, 4x4, M37	9.00-16, 8 PR, Military NDMS	25	All
2	Same Vehicle	15-19.5 Firestone Duplex 10PR	12	All
3	Truck, Utility, 1/4 Ton, 4x4, Willys Jeep Universal CJ5	36x20-14R, 4PR Goodyear Terra Tires	3	All

Table I. Tires and Vehicles Evaluated (Cont'd)

Item	Vehicle	Tires	Recommended Tire Infl (psi) Mud and Snow	Applicable Vehicle Wheels
4	Same Vehicle	10-16.5 Firestone Duplex, 6PR	12	All
5	Truck, Cargo, 1-1/2 Ton, Dodge Power Wagon, WM300	46x18-16R, 4PR, <u>Goodyear Terra Tires</u> 46x24-16R, 4PR, Goodyear Terra Tires	4	<u>Front</u> Rear
6	Truck, Tractor, 5 Ton, 6x6, M52 with Semitrailer, Cargo, 12 Ton, 4 Whl, M127	46x18-20R, 8PR, <u>Goodyear Terra Tires</u> 46x24-20R, 8PR, Goodyear Terra Tires	12	<u>Front</u> Rear
7	Similar, but Separate Vehicle	14.00-20, 12PR, Military NDCC	15	All

Table II. Vehicle Load Ratings

Vehicle	Maximum Rated Payload (Lbs)	
	On Hard Surface Roads	Cross-Country
M37	2,000	1,500
CJ5	1,200	800
WM300	3,200	2,400
M52-M127	36,000	24,000

The M37 used was a standard military vehicle with no power steering. The commercial CJ5 and WM300 vehicles were equipped with Garrison power steering, although these vehicles normally are not so equipped.

4. BACKGROUND:

By use of special wheels and rims, standard military and commercial vehicles have been equipped with larger tires to provide greater mobility characteristics. These tires are characterized by wider tread, larger diameter and lower ground pressures. Effectiveness of the adaptations of such vehicles has been demonstrated in desert terrain by oil companies in Middle East exploration. Further verification was obtained by the increased performance shown by vehicles such as the Dodge Power Wagon and Willys CJ5 Jeep, equipped with oversize tires, in traversing severe rain forest terrain in the Panamanian jungle during Operation SWAMP FOX I in August and September 1961 (Reference 2a). As a result of these tests and additional information from commercial sources, plans were made for evaluation of mobility afforded vehicles by use of special tires under winter subarctic conditions. Tests covered by this report were conducted according to Reference 2b.

5. SUMMARY OF EVALUATION: (See Annexes A, B, C & D for additional data).

a. All wheeled vehicles listed in Table I were evaluated in subarctic Alaska under winter conditions during 10 January--28 February 1962. The vehicle-tire combinations, Items 2, 3 and 5, were operated and evaluated as support vehicles in Exercise GREAT BEAR by US Army Transportation Board personnel. The vehicles, Items 6 and 7, also participated in the exercise, but were operated and evaluated by US Army Alaska personnel. All of the vehicle-tire combinations in Table I, except Items 6 and 7, were evaluated during controlled operations at the Ordnance Arctic Test Facility, Fort Wainwright, Alaska. A description of the area of operations in Alaska is covered by Annex D. The total mileage and fuel and oil consumption for each vehicle is shown in paragraph 6a, Discussion.

b. The M37, equipped with 15-19.5 Duplex tires, participated in the exercise from 5-21 February 1962. The vehicle carried a maximum load of two passengers and one ton of cargo over improved roads, and three passengers and a half ton of cargo over unimproved roads and trails of the maneuver area, for a total of 840 miles and approximately 70 operating hours. The only difficulty experienced was increased steering effort due to the Duplex tires. The vehicle was also evaluated during the controlled operations at Fort Wainwright, 15 January-2 February and 23-26 February 1962. The vehicle, equipped with Duplex tires and carrying a 3/4 ton load, traversed hard packed snow on improved roads and terrain of the Red and Green courses, for a total of 593 miles, without mobility difficulty. During alternate tests with both Duplex and 9.00-16 standard tires, the vehicle failed to ascend a 20% slope covered with 2-1/2 feet of loose snow. During braking tests at 10, 20, and 30 mph on hard packed snow, the Duplex tires required 6-7 feet more stopping distance. When tested in 18 inches of snow, the vehicle advanced 183 feet with Duplex tires and 133 feet with the standard 9.00-16 tires before becoming immobilized. The vehicle traveled 47 miles during the slope, braking, and deep snow tests. There was no appreciable wear and no tire difficulties were encountered with the Duplex tires.

c. The CJ5, equipped with 36x20-14R Terra-Tires, participated in the exercise, 5-20 February 1962. The vehicle carried a maximum of four passengers over improved and unimproved roads, trails, and off-road, including frozen muskeg and soft snow in the maneuver area. The left rear axle broke while enroute from Fort Wainwright to Tanacross and repairs were made by substitution of a complete military (M38A1) rear axle assembly. Subsequently, the lug bolts on the right rear wheel failed, requiring replacement of the drum. The fuel pump also required replacement. At speeds between 15-20 mph, a bouncing, erratic ride was experienced. A total of 583 miles and 38-1/2 operating hours was logged during the exercise. The vehicle was also evaluated during the controlled operations, 10 January-4 February and 23-28 February 1962. Equipped with Terra-Tires, the vehicle was used as an escort vehicle and to carry passengers. It also operated, without mobility difficulty, while carrying a 350 lb load on hard packed and loose snow over primary and secondary roads and terrain of the Red and Green courses. A total of 358 miles and 36-1/3 operating hours was logged during this period. The maximum speed attained was 25 mph. During alternate tests with both Terra-Tires and Duplex tires, the vehicle, carrying a 500 lb load, failed to ascend a 20% slope covered with 2-1/2 feet of loose snow. A 30% slope covered with 6 inches of hard packed snow was ascended with both type tires. During braking tests, the stopping distance was the same at 10 mph, but 6 and 18 feet greater, respectively, at 20 and 30 mph for the Duplex tires. When tested in 18 inches of snow, the vehicle was not immobilized with either tire. Loss of air in a Duplex tire, as a result of striking a bump, was the only tire difficulty encountered. The Duplex tire provided the smoother ride. There was no appreciable wear with either tire.

d. The WM300, equipped with 46x18-16R and 46x24-16R Terra-Tires, participated in the exercise, 6-22 February 1962. The vehicle carried a one ton load of organizational

equipment and towed a 1-1/2 ton camper trailer unit over the ice covered highway from Fort Wainwright to Tanacross at an average speed of 12 mph. The vehicle carried loads up to one ton over secondary roads and cross country in the maneuver area. A 40% slope covered with 8-10 inches of loose snow was ascended and a 65% slope descended. A 15% side slope covered with 5-6 inches of loose snow was also traversed. The total mileage operated during the exercise was 705 miles. No record was made of operating hours. Performance exceeded that of other wheeled vehicles, and in some instances, the vehicle traveled over routes which could not be traversed by tracked vehicles. Traction was considerably diminished when the vehicle was operated in unloaded condition. The vehicle was evaluated during the controlled operations at Fort Wainwright on 16-29 January and 26 February 1962. No evaluations were conducted with Duplex tires. The vehicle carried a 2400 lb load over the Green and Red courses and on paved roads. It was also used to extract the 2-ton Rolligon from 22 inches of snow. A 30% slope was ascended in forward direction and a 20% slope descended backward with vehicle loaded. The vehicle required a stopping distance of 96 feet at 20 mph and 133 feet at 27 mph during the brake tests. No mobility difficulties were encountered when operating in 2 feet of snow. While the vehicle was operating on the Red Course, the right rear axle was broken and tests were terminated. A bouncing condition was encountered when the vehicle was operated unloaded at 15-20 mph. The maximum speed attained was 50 mph. There were no tire difficulties and tires showed little wear.

e. Reference 2d indicates that the M52/M127 equipped with Terra-Tires performed well during the exercise. The Terra-Tires provided a high degree of stability on icy roads and considerably increased the vehicle's capability in off-road operation. Deep snow was negotiated without difficulty. Based on verbal information from personnel witnessing the exercise, the M52/M127 with 14.00-20 NDCC demonstrated less than moderate mobility increase over the standard 11.00-20 tires and performance was not equal to the M52/M127 equipped with Terra-Tires. Reference 2c contains a preliminary report of all vehicles evaluated.

6. DISCUSSION:

a. Speedometers were not calibrated to compensate for use of oversize tires. Annex A shows only the test mileage for each vehicle during the subarctic evaluations. The total mileage (including the distance traversed when vehicles were used for administrative purposes and for drawbar pull) and fuel and oil consumption recorded during the subarctic evaluations were as follows:

VEHICLE	TOTAL MILES	TOTAL FUEL (Gal)	TOTAL OIL (Qts)	AVERAGE MPG	AVERAGE MP QT
M37	1501	423	6	3.5	250
CJ5	1034	241	4	4.3	260
WM300	1133	236	3	4.8	377

M52/M127 Combinations - No Record

b. A direct comparison of mobility performance between the 9.00-16 standard military and 15-19.5 Duplex tires on the M37 and between the 36x20-14R Terra-Tires and 10-16.5 Duplex tires on the CJ5 is based only on results obtained from the slope, stopping distance and deep snow tests which were conducted on the Blue Course and in the hangar area on 26, 27 and 28 February 1962. Due to the relatively low mileage operated in these tests (47 for the M37 and 293 for the CJ5) together with the limited scope of the tests, the performance results obtained with each type tire is considered indicative rather than conclusive. Since 15-19.5 Duplex tires were not run on the WM300, no direct performance

comparison with 46x18-16R and 64x24-16R Terra-Tires could be made. Due to the similarity between the M37 and WM300, a correlation in performance may be expected. Within these limitations it appears that Duplex tires provide only a moderate mobility improvement over standard military tires, while Terra-Tires provide a significant improvement over both types in subarctic environment encountered. The reduced mobility performance by the Duplex tires, as compared to the Terra-Tires, may be attributable to their non-aggressive tread, stiffer (10PR) carcass construction, and smaller outside diameter and width, which results in higher ground pressure. Reference 2e indicates that snow depth in excess of 25% of the wheel diameter can cause immobilization and slipperiness at a lesser depth. The increase in diameter of the Duplex Tires over the standard tires results in increased mobility, however, since the Duplex tread is not as aggressive as the standard military mud and snow tread, the maximum increase in mobility is not attained.

c. The increased steering effort encountered on the M37, when equipped with the 15-19.5 Duplex tire, can be overcome by the installation of power steering. If this size Duplex tire could be furnished with an aggressive tread and more flexible carcass (similar to the Terra-Tire), the mobility of the M37 could be significantly improved. No additional modifications appear to be needed to adapt this tire size (and wheels). A tire of greater diameter such as the 46x18-16R and 46x24-16R Terra-Tires would require major vehicle modifications.

d. The 36x20-14R Terra-Tires provide the CJ5 with probably the maximum attainable mobility. The excess stresses imposed on the vehicle, the lack of engine power (operations in lower gears required) and extensive modification required indicate, however, that this tire size is not compatible with this type vehicle. The excessive gasoline consumption experienced can be attributed to the lower gear operation required. The 10-16.5 Duplex tire is considered more compatible in respect to size. If furnished with an aggressive tread and flexible carcass, or if a similar size Terra-Tire was available, a more optimized vehicle-tire-combination could result. (This is also considered applicable to the M151 and M38A1 since the CJ5 is representative of these vehicles in respect to size).

e. The 46x18-16R and 46x24-16R Terra-Tires installed on the WM300 provided a very significant mobility to the vehicle. This tire size is not considered incompatible even though some vehicle modifications were required. The lack of vehicle durability experienced could be improved through use of heavier duty (optional) parts. No logical explanation can be given for the erratic bouncing experienced at 15-20 mph (also on the CJ5), although it may be due to an imbalance existing in the tires and special wheels and/or distortion from low temperatures. The tires were not checked for static or dynamic imbalance.

f. The 14.00-20 cross-country military tires operated on the M52/M127 by USARAL were installed in conjunction with the Kit, Off-Road Conversion, M52-127 Truck Tractor Semitrailer Combination. While installed by USATRANSBD personnel, no record was maintained regarding the time and man-hours involved. A similar installation made at Fort Eustis, Virginia, reference 2e, required an elapsed time of 11 hours and 45 minutes and a total of 81 man-hours to complete the installation. In view of the extent of vehicle modifications involved and the less than moderate mobility increase provided over the standard 11.00-20 military cross-country tires, it appears that no further consideration should be given to the use of the 14.00-20 tires (and kit) in a subarctic environment.

g. The installation of 46x18-20R and 46x24-20R Terra-Tires on the M52/M127 involves an exchange of wheels and tires. The time required by USATRANSBD personnel was comparable to that required for the standard wheels and tires. These tires are compatible with the M52/M127 and in view of the superior mobility obtained, should be further evaluated for subarctic use. A slight overloading condition will develop if the vehicle is

loaded with an 18 ton highway load. Under this condition, the tandem wheels under the M52 will be loaded to 8,573 lbs. The maximum rated load for the 46x24-20R Terra-Tires is 8,000 lbs.

h. Based on the mobility improvement experienced with the M52/M127, it appears that an equal opportunity exists for improving the military (M series) 2-1/2 and 5 ton trucks. The 46x18-20R Terra-Tires can be installed on all the 2-1/2 ton trucks having the M44, M45, M45C, M46C and M58 chassis (Timken Model 2034 bogie) by increasing the spacing between the tandem wheels from 48 to 51 inches. This change was made on one M34 by ATAC and involved lengthening the torque rods with compensating modifications to length of propeller shafts. Power steering would also be required. The same Terra-Tire installation used with the M52/M127 can also be used with the 5 ton vehicles. No change appears to be involved other than wheels and tires.

7. CONCLUSIONS: The US Army Transportation Board concludes that:

a. Goodyear Super Terra-Grip tires provide significant vehicle mobility improvement in winter subarctic environment, as compared with standard military tires or Firestone Duplex tires.

b. Duplex tires provide only limited vehicle mobility improvement over standard military tires.

c. Increased braking distance and low traction with Duplex tires on winter subarctic terrain result from the inflexible construction and tread design of these tires.

d. Power assist steering will reduce the mechanical effort and improve mobility of vehicles equipped with oversize tires.

e. Hazards can result from the bouncing, erratic ride of light-weight vehicles equipped with Terra-Tires.

f. Applications of Terra-Tires to lightweight vehicles produce undue strain on various structural and mechanical components.

8. RECOMMENDATIONS: The US Army Transportation Board recommends that:

a. Indicated mobility advantages of Terra-Tires should be further explored, particularly on representative standard military wheeled vehicles in the 2-1/2 ton and 5 ton classes.

b. Duplex tires, as well as other types of oversize tires, be further investigated if aggressive tread designs and flexible construction are available.

c. Vehicles to be fitted with Terra-Tires should be equipped with power steering and all heavy-duty optional components and structural members available.

ANNEX A
DETAILS OF EVALUATION

1. FAMILIARIZATION AND TRAINING:

a. Purpose: To determine the degree of operating and mechanical skill required to operate and maintain the equipment when fitted with oversize tires, and the time required to train personnel to adequately perform these tasks.

b. Method: Operator and maintenance personnel were trained briefly for sub-arctic operations by lecture, blackboard illustrations, and film showings. The illustrative cinema films used were: TF 17-2192, "Tracked Vehicles in Support of Winter Operations in Sub Arctic", and NSN 47-A, "Wheels to the Arctic." Approximately two hours each were devoted to the Willys CJ5 and M37 truck, and approximately four hours to the Dodge Power Wagon. Operators drove the vehicles in the Fort Wainwright area for brief familiarization. The M37 was driven on primary roads, the CJ5 on primary roads, the muskeg course (unimproved trail), and secondary dirt road, and the Dodge Power Wagon on similar terrain. The M52-127 combinations were not operated by US Army Transportation Board personnel and no familiarization and training periods were recorded.

c. Results: It was determined that the desirable familiarization and training were adequate for the operator personnel listed below:

<u>Operator Rank</u>	<u>Pertinent MOS</u>	<u>Aptitude Scores</u>	<u>Vehicle</u>	<u>Degree of skill acquired on Vehicle</u>
AFC E3	642.10	Bat II 120 Road test 93	M37	Skilled
Sgt E5	642.10	Bat II 115 Road test 97	M37	Skilled
Sgt E5	643.60	Bat II 94 Road Test 93	CJ5	Skilled
SP 4	642.10	106	Dodge WM300	Skilled
PFC E3	642.10	100	Dodge WM300	Skilled

Inasmuch as the operators had had previous experience with a wide variety of motor vehicles, they adjusted easily to the special conditions of these tests, such as uneven and slippery terrain, increased steering effort, increased stopping distances, greater vehicle width over wheels, reduced road speed, and the sometimes bumpy, erratic ride inherent in operation of certain vehicles equipped with oversize tires.

Maintenance personnel in the MOS range of 631-635 were considered qualified for the limited maintenance required for these tests.

2. PREOPERATIONAL INSPECTION:

a. Purpose: To insure that tire and vehicle combinations were in proper condition for evaluation.

b. Method: The M37, CJ5 and WM300 vehicles and tires were inspected at Fort Eustis, Virginia, and upon arrival in Alaska. In addition to normal inspection of vehicles,

tire and wheel assemblies were inspected to assure that proper combinations were installed on the applicable vehicles and that tread patterns were properly directed. Inspection was made also to determine tightness of wheel fastening and to prevent air leakage from tires. Vehicle and tire combinations were inspected again on arrival in Alaska to determine if damage or pilferage had occurred in transit, and that all units were in satisfactory operating condition for the conduct of tests. Prior to testing, any maintenance required was accomplished. The M52/M127 combinations were USARAL vehicles and only the special tires installed by USA TRANSBD personnel were inspected.

c. Results: On arrival at USATATA, Fort Wainwright, Alaska, the Willys CJ5 vehicle with Terra-Tires was found to have a broken windshield and, since the battery was covered with frost, the vehicle would not start. After the battery thawed overnight and was charged, and antifreeze added to the cooling system, the vehicle was operational. The M37 vehicles and the Dodge Power Wagon WM300 were given thorough preventive maintenance in Alaska and were found to be in satisfactory operating condition. No irregularities in tire and wheel assemblies were observed in preoperational inspection. The M52/M127 vehicles were considered satisfactory for operation after the special tires and wheels were installed.

3. OPERATION:

a. Part A - Logistical Support of Exercise GREAT BEAR:

(1) Purpose: To determine how effectively the vehicle, modified with installation of oversize tires, can perform the logistical function of cargo transporter under simulated battle conditions, and to develop maintenance data under field conditions.

(2) Method: No specific tests were performed. The vehicle tire combinations listed in Table I were used to perform missions as required by the Commander, Exercise GREAT BEAR. The vehicles were operated over frozen snow-covered trails and routes in the maneuver area (see Annex D) under prevailing subarctic weather conditions.

(3) Results:

(a) M37 with 15-19.5 Firestone Duplex Tires: The vehicle was equipped with Duplex tires for operations in the maneuver area. No operations were conducted with standard tires during the exercise. During the period 5 through 21 February 1962 the vehicle was operated over paved roads (enroute from Fort Wainwright to Tanacross and return) and over unimproved roads, trails and off-road, including muskeg and soft snow, in the maneuver area. The vehicle was also operated over paved roads to Fort Greely. The total time operated was approximately 70 operating hours; total mileage was 840 miles. The vehicle consumed approximately 212 gallons of gasoline and 3 quarts of oil during the period. Gasoline and oil consumption averaged 4 mpg and 380 mpqt, respectively. The vehicle carried a maximum load of two passengers and one ton of cargo over the improved roads and three passengers and one half ton of cargo over the unimproved roads. The maximum speed obtained on unimproved roads was 25 mph, and maximum speed on the hilly rough tank trails was limited to 3 mph. The operator indicated a need for power steering due to use of the Duplex tires.

(b) Willys CJ5 with 36x20-14R Goodyear Terra-Tires: The vehicle was equipped with Terra-Tires for operations in the maneuver area. No operations were conducted with Duplex tires during this exercise. From 5 through 20 February 1962, the vehicle, carrying up to four passengers, operated over paved roads (enroute from Fort Wainwright to Tanacross and return) and over unimproved roads, trails and off-road, including frozen muskeg and soft snow in the maneuver area. The total operating time was 38 hours, 35 minutes, and total mileage was 583 miles. The vehicle consumed approximately

70 gallons of gasoline and 1 quart of oil during the period. Gasoline and oil consumption averaged 8.3 mpg and 583 mpqt, respectively. On 6 February 1962, enroute to Tanacross, the left rear axle on the CJ5 broke. Repairs were made on 11 February 1962 by substitution of a complete military (M38A1) rear axle assembly. An attempt to use a military axle in the commercial assembly was not satisfactory. On 15 February 1962, after approximately 90 miles of operation over hilly, snow and ice covered terrain, the lug bolts snapped off the right rear wheel. Both front shock absorbers were also found broken. The vehicle remained inoperative until the right rear brake drum (including lug bolts) was replaced on 20 February 1962. The mechanical driven fuel pump was also replaced with a 12 volt electric driven pump. The operator indicated that the vehicle swayed from side to side when driven between 15 and 20 mph. Use of the vehicle in snow and mud was recommended rather than extensive operation on paved highways. The power steering installation was considered effective in overcoming the steering resistance of the Terra-Tires. Report, reference 2d, indicated the Terra-Tire installation on this vehicle to be unsatisfactory, since desired increase in cross country mobility was not provided (not equal to the Dodge WM300) and the stress placed on the vehicle was excessive.

(c) Dodge WM300 with 46x18-16R front and 46x24-16R rear Terra-Tires:

The vehicle was equipped with Terra-Tires for operations in the maneuver area. No operations were conducted with Duplex tires during this exercise. This vehicle also operated in the maneuver exercise from 6 through 22 February 1962. During the trip from Fort Wainwright to Tanacross on paved roads, the vehicle carried a one ton load of organizational equipment and towed a 1-1/2 ton camper trailer unit. An average speed of 12 mph was attained over the ice covered highway. Maximum test speed on highways was 15 mph. In the maneuver area the vehicle carried loads up to one ton over secondary roads and cross country. The vehicle successfully ascended a 40% slope covered with 8-10 inches of loose snow and descended a 65% slope. A 15% side slope covered with 5-6 inches of loose snow was traversed. The total mileage operated was 705 miles. No record was made of operating time. The vehicle consumed approximately 141 gallons of gasoline and 2 quarts of oil during the period. Gasoline and oil consumption averaged 5 mpg and 352 mpqt, respectively. Report, reference 2d, indicates the Terra-Tires gave the vehicle an impressive off-road capability, enabling it to traverse terrain which other wheeled vehicles could negotiate only with assistance, and in some instances, to travel routes that certain track vehicles could not manage. The only difficulty indicated by the operator was lack of traction when the vehicle was not loaded.

(d) M52/M127 with 46x18-20R front and 46x24-20R rear Terra-Tires:

This truck tractor semitrailer combination was operated by personnel assigned to USARAL. Performance of the vehicle was therefore not monitored nor evaluated by USATRANSBD personnel. Report, reference 2d, indicates that the vehicle performed well. The Terra-Tires gave a high degree of stability on icy roads and also considerably increased the capabilities of the vehicle in off-road operation. Deep snow was negotiated without difficulty.

(e) M52/M127 with off-road conversion kit using 14.00-20 military NDCC tires: While no official written report was prepared for this installation by USARAL, it is understood that the semitrailer combination was operated by personnel assigned to USARAL. The combination was not monitored nor evaluated by USATRANSBD personnel, however, verbal information from personnel witnessing the exercise indicated that the 1400-20 tires demonstrated less than moderate mobility increase over the standard 11.00-20 tires, and that the performance was not equal to M52/M127 equipped with Terra-Tires.

b. Part B - Controlled Operational Evaluation: Prior to and following completion of missions assigned in Part A under Exercise GREAT BEAR, the vehicle tire combinations listed in Table I (except the M52/M127 truck tractor semitrailer combination) were evaluated in the Fort Wainwright area (see Annex D for terrain description). The M52/M127 vehicles were not evaluated in Part B.

(1) Purpose: To determine how effectively the vehicles, modified with installation of oversize tires, can perform the logistical function of cargo transporters under controlled conditions and to develop maintenance data.

(2) Method: The vehicles, equipped with the designated tires, were operated on the test courses of the Ordnance Arctic Test Facility at Fort Wainwright over various terrains as specified in Annex D.

(3) Results:

(a) M37 with 9.00-16 standard military mud and snow tires and 15-19.5

Duplex tires:

1 The vehicle was equipped with Duplex tires, 15 January 1962, and the tires were pressurized to 40 psi. The vehicle was driven on primary roads for familiarization trials. On 16 January 1962, the tire pressure was reduced to 15 psi and from 16 through 18 January the vehicle was operated unloaded on the Red Course (level cross-country) and Green Course (hill road). On 19 January the vehicle was loaded with 3/4 ton of cargo and on 20-24 January was operated on the Red and Green Courses. Due to a frozen fuel line, the vehicle was towed from the test track area to Hangar No. 1. On 26 January, the vehicle was operated in the area around the hangar and from 27 through 29 January, was operated on the Red and Green Courses. From 31 January through 2 February and 23 through 24 February 1962, the vehicle was used as an administrative vehicle. The above operations occurred on hard packed snow. No mobility difficulties were encountered. The maximum depth the vehicle tires penetrated the snow was 2 inches. Maximum speed on the primary road was 30 mph, however, speeds generally varied between 5 and 15 mph depending on the terrain. Lowest temperature recorded was -50°F; highest, +34°F. The total hours operated was approximately 58; total mileage was 593. Two-hundred gallons of gasoline and 3 quarts of oil were consumed with an average consumption of 3 mpg and 198 mpqt, respectively. The operator reported that steering was difficult with the Duplex tires.

2 The vehicle, carrying a 3/4 ton load, was operated with both types of tires on the Blue (slope) Course, 26 February 1962. The slopes were covered with 2-1/2 feet of loose snow. The vehicle became immobilized with both types of tires and was unable to reach the base of the 20% slope. The vehicle was not operated on the Yellow Course.

3 On 27 February 1962, stopping distance tests were run with both types of tires on hard packed snow in the Speed and Braking Test area. The vehicle carried a 3/4 ton load. The results were as follows:

<u>Speed (MPH)</u>	<u>Stopping Distance (Ft)</u>	
	<u>Standard Tires</u>	<u>Duplex Tires</u>
10	10	16
20	32	39
30	77	83

4 On 27 February 1962, deep snow tests were run on level terrain with both types of tires. The vehicle was started in an area in which the snow had been packed, and was then operated at 10 mph into an area where snow depth was approximately 18 inches (top 6-inch layer was loose snow, remaining 12-inch layer was hard packed). With Duplex tires, the vehicle advanced 183 feet over the snow area before becoming immobilized. With the military mud and snow tire, the vehicle advanced 133 feet before becoming immobilized.

5 The vehicle mileage recorded on 26 and 27 February 1962 was 15 and 32, respectively, for a total of 47. Of this amount, no specific record of actual test miles traveled during the slope, stopping and deep snow test, with either type tire, was made. No fuel or oil was added on these dates.

6 There were no difficulties experienced with the tires as a result of low temperatures, and no cracks, rips or punctures were experienced in the tires during the testing period. The tires showed little wear on treads or sidewalls.

(b) Willys CJ5 with 36-20x14R Goodyear Terra-Tires and 10-16.5 Firestone Duplex tires:

1 The tests were started on 10 January 1962 with 36-20x14R Goodyear Terra-Tires pressurized to 15 psi. The vehicle was driven around the hangar for familiarization trials. On 12 January, the vehicle made a familiarization run, without load, on the Red Course (level cross-country) and on the Green Course (hill road). On this same date, the vehicle's electrical system shorted out; also, it was involved in an accident with a civilian vehicle. The left rear panel received minor damage and the tail light lens was broken. On 15 January, the tire pressure was reduced to 10 psi. As a result of driver discomfort, due to lack of a heater and metal top, the vehicle was used only to escort other vehicles and carry passengers from 15 through 19 January. The heater was installed on 20 January and the top and a windshield installed on 25 January. From 27 through 29 January, the vehicle was operated with a 350 lb load over primary and secondary roads to and from the test courses and on the Red and Green Courses. On 23 and 24 February, operation was confined to the hangar area. The above operations occurred on hard packed and loose snow. No mobility difficulties were encountered. The maximum depth that tires penetrated the loose snow was 6 inches. This occurred with vehicle unloaded. The maximum speed operated on primary roads was 25 mph, however, speeds generally varied between 5 and 15 mph depending on terrain. The lowest temperature recorded was -51°F; highest, +34°F. The total hours operated during the period was 36 hours and 20 minutes; total mileage, 358. Gasoline consumption was 112 gallons and oil consumed was one quart. Average consumption was 3.2 mpg and 358 mp qt, respectively. The operator indicated that the power steering did not perform well in extremely cold weather and the vehicle was hard to control. The Terra-Tires and wheels were considered too heavy for the vehicle due to the limited engine horsepower available.

2 The vehicle, while carrying a 500 lb load, was operated with both types of tires on the Blue (slope) Course, 26 and 27 February 1962. The vehicle ascended a 30% slope covered with 6 inches of semi-packed snow with both type tires. The vehicle could not ascend a 20% slope covered with 2-1/2 feet of loose snow with either type tire. While actual distance traversed was not recorded, the greatest ascent was made with the Terra-Tires.

3 On 27 February 1962, stopping distance tests were run on the hard packed snow, with both type tires, in the Speed and Braking Test Area. The vehicle carried a 500 lb load. The results were as follows:

Speed (MPH)	Stopping Distance (Ft)	
	Standard Tires	Duplex Tires
10	19	19
20	25	31
30	40	58

4 On 20 February 1962, deep snow tests were run on level terrain with both types of tires. The vehicle was started in an area in which the snow had been packed, and was then operated at 10 mph into an area where snow depth was approximately 18 inches (top 6-inch layer was loose snow, remaining 12-inch layer was hard packed). Neither type of tire became immobilized.

5 The vehicle mileage recorded on 26, 27 and 28 February 1962 was 38, 136 and 19 respectively, for a total of 293. Of this amount, there was no specific record of actual test miles traveled during the slope, stopping and deep snow tests, with either type tire. Fifty gallons of fuel and one quart of oil were added during this period.

6 The Duplex tires provided a smoother ride than the Terra-Tires, which tended to lode on the paved highways at speeds from 15 to 20 mph. However, the Terra-Tires provided the better traction. One of the Duplex tires lost air pressure when it hit a bump. The air escaped around the rim as a result of the impact. There was no tire damage as a result of the operations and the tires showed little wear.

(c) Dodge WM300 with 46x18-16R front and 46x24-16R rear Goodyear Terra-Tires: The comparative performance with Firestone Duplex 15-19.5 tires was not conducted because the Director of Task Detachment No. 7 considered the performance of the M37 vehicle, with Duplex tires, unsatisfactory. On 16-17 January 1962, the vehicle was operated with a 2400 lb load over the Green and Red Courses and over paved roads. On 17 January, the vehicle ascended a 30% slope in forward direction and a 20% slope backward, while loaded. Tires were pressurized at 10 psi. The vehicle was also used to extract the 2-ton Rolligon, Model 1900, from 22 inches of snow. On 18 and 26 January, the vehicle was operated only on paved roads. On 25, 27, 28 and 29 January, it was again operated over the Green and Red Courses and on paved roads. On 26 February 1962, the vehicle was given stopping distance tests on hard packed snow. The average braking distance was found to be 96 feet at 20 mph and 133 feet at 27 mph. While operating on the Red Course, on the same date, the right rear axle was broken and further testing was then terminated. The above operations were conducted on hard packed and loose snow. The maximum snow depth was 2 feet. No mobility difficulties were encountered. The maximum speed operated on primary roads was 20 mph, however, 50 mph was attained on the airstrip. Speeds generally varied between 10 and 15 mph. When operating unloaded at these speeds, an uncomfortable vertical oscillation or lode was encountered especially on hard packed surfaces. Temperature ranges were similar to that listed for the other vehicles. The total hours operated during the period was not recorded. The total mileage was 308 miles. Gasoline consumption was 95 gallons and one quart of oil was added. Average consumption was 3.2 mpg and 308 mp qt, respectively. The operator reported that the transmission shift lever was difficult to engage in high-low gear and the braking system was poor in very cold weather. There was no tire damage requiring maintenance and tires showed little wear.

(d) M52/M127 with Terra-Tires and Military NDCC tires: These vehicle-tire combinations were not included in the controlled operational evaluation.

4. MAINTENANCE:

a. Purpose: To determine:

- (1) Time (man-hours) required for tire changes during operations.
- (2) Degree to which operational and organizational maintenance is affected through use of special type tire.

(3) Mechanical or structural failures due to special tires.

b. Method: Preventive maintenance checks and preoperational checks were made on a daily basis. Mechanical failures were analyzed and corrected by operators and mechanics assigned.

c. Results: Operational and organizational maintenance was accomplished readily under the subarctic conditions that prevailed. Because of the daily preventive maintenance performed, the need for extensive repairs was minimized.

The M37 vehicle was deadlined four days because of a faulty distributor, but only 2 man-hours were required for the actual replacement operation performed. The vehicle was later deadlined two hours for repairs to the personnel heater. Total repair time reported for this vehicle was 12 man-hours.

The CJ5 vehicle was deadlined a total of 6 days and 47-1/2 hours because of maintenance required. Total maintenance performed by assigned personnel was 91 man-hours.

The Dodge Power Wagon was deadlined a total of 53 hours. This does not include time the vehicle was inoperable because of a broken axle, which occurred when tests were practically completed, and was not repaired until the vehicle was returned from Alaska to Fort Eustis. Maintenance time required was 109-1/2 man-hours.

No maintenance was recorded for the M52-M127 combinations inasmuch as these vehicles were not operated as a part of this evaluation (see reference 2d).

Maintenance time required for tire changing operations was as follows:

<u>Vehicle</u>	<u>Tires Installed</u>	<u>Man-hours</u>
M37	4 Firestone Duplex 15-19.5	6
CJ5	4 Goodyear Terra-Tires 36x20-14R 4 Firestone Duplex 10-16.5	1
WM300	4 Goodyear Terra-Tires 46x18-16R (Front) 46x18-16R (Rear)	Tires not changed

5. SAFETY:

a. Purpose:

(1) To determine any adverse safety conditions which may exist during operation or maintenance.

(2) To determine the adequacy of engineered safety features.

b. Method: No special tests for safety were performed, but observations were made during operations and checks were made for any unusual hazards due to installation and use of special tires.

c. Results: The special tires presented no notable hazards, except that Terra-Tires gave the operators of lightweight vehicles a bouncing, erratic ride, and Duplex tires were found to increase braking distances on winter subarctic terrain, when compared with standard military tires and Terra-Tires. These factors have been discussed under OPERATION, above.

6. TRANSPORTABILITY:

a. Purpose: To determine transportability characteristics of the items in respect to delivering to using destinations as required by intended military mission.

b. Method: Items were prepared for shipment as recommended by the manufacturer and transported to USATATA, Alaska by various commercial and military means and returned on completion of evaluation by the same means.

c. Results: The vehicles and special tires were delivered to Fort Wainwright, Alaska without incident, except that the Willys CJ5 had a broken windshield and frost covered battery.

DEFICIENCY/SHORTCOMING

SUGGESTED CORRECTIVE ACTION

REMARKS

SECTION II

This section lists those deficiencies and shortcomings in the item which were discovered during test and satisfactorily corrected prior to completion of the test. They no longer represent a defect in the item tested. The correction must be applied to the production model of this item.

- | | | |
|---|--|---|
| 1. Firestone Duplex Tires; Tire on CJ5 went flat when vehicle hit bump in road. | Maintain proper inflation. | To improve traction of these tubeless, rigid, nonaggressive tires, air pressure was reduced to such low level that air seal in rim was destroyed. |
| 2. Goodyear Super Terra-Grip Tires: | | |
| a. Left rear spring bent on CJ5. | Investigate heavy-duty springs. | It is suspected but not proven that installation of oversize tires put extra stress on springs. The trouble may have been caused by rough terrain more than by tires. |
| b. Slipping clutch on CJ5. | Investigate alternate transmissions. | Extra strain on engines and transmissions believed to result from use of oversize tires. |
| c. Broken left rear axle on CJ5. | Where available, use heavy-duty rear end assemblies with oversize tires on lightweight vehicles. | Oversize tires change stress moments on axles of jeeps and similar lightweight vehicles. |
| d. Lug bolts broken on brake drum of CJ5. | Use of heavy duty optional equipment should help correct deficiency. | See above comment. |
| e. Broken shock absorbers on CJ5. | See above. | Added stress on shock absorbers apparently caused to some extent by use of large tires. |
| f. Broken power steering on Dodge WM300. | Redesign and strengthen. | The Garrison power steering on Dodge has been relatively trouble-free, and present deficiency observed might have been due more to excessively rough use than to installation of Terra-Tires. |

DEFICIENCY/SHORTCOMING

g. Broken bolts of wheel mountings on Dodge WM300.

h. Broken right rear axle on Dodge WM300.

SUGGESTED CORRECTIVE ACTION

Redesign and strengthen.

Where available, use heavy duty optional equipment with Terra-Tires installation.

REMARKS

Although generally satisfactory, wheel mountings for Terra-Tires on Dodge WM300 apparently were not sufficiently strong for rugged subarctic terrain.

Complete heavy duty rear end assemblies appear to be essential for off-road military use with oversize tires.

ANNEX C
PHOTOGRAPHS



Figure 1. Comparison of Tire Treads. Left to right: Standard military tire, 9.00x16, 8 ply, as used on M37; Firestone Duplex tire, 15-19.5, 10-ply, as tested on M37; Goodyear Super TERRA-GRIP TIRE, 36x20-14R, 4-ply, as tested on Willys CJ5.



Figure 2. M37 with Duplex Tires.
Front View.

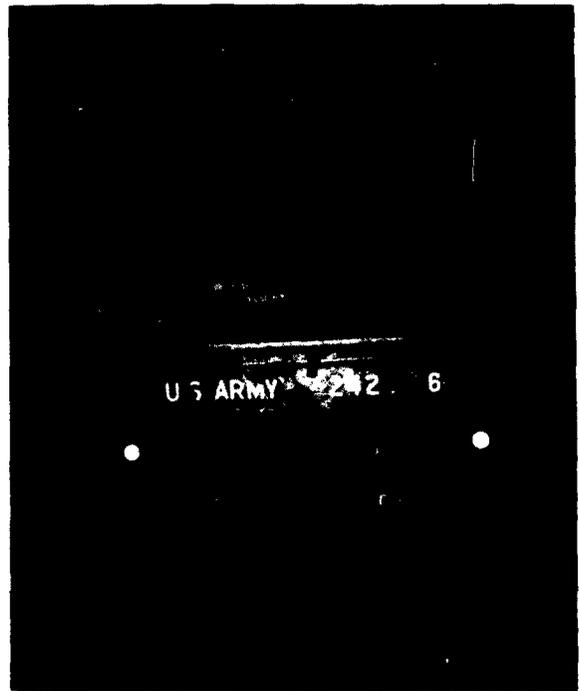


Figure 3. M37 with Duplex Tires.
Rear View of Vehicle in
Aircraft.

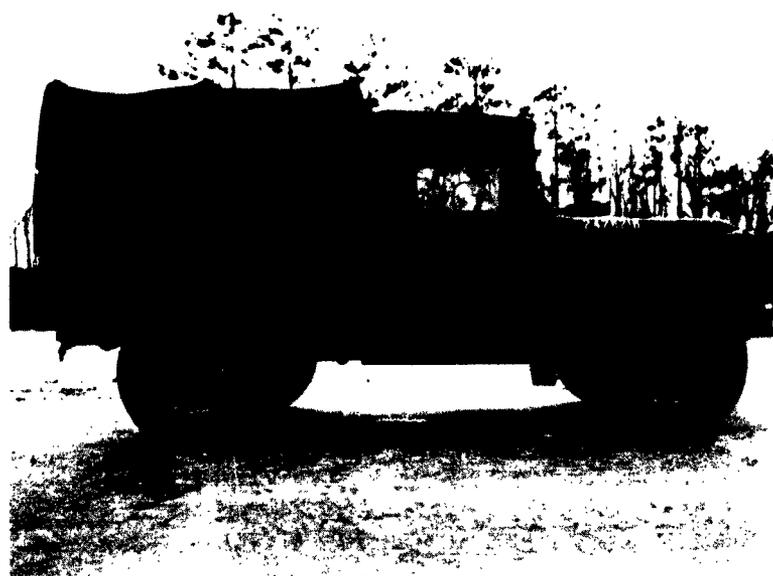


Figure 4. M37 with Duplex
Tires. Right Pro-
file.

Figure 5. M37 with Duplex
Tires. Left Pro-
file.





Figure 6. M37 with Duplex
Tires. Left Front.

Figure 7. M37 with Standard
Military Tires.
Left Front.





Figure 8. Willys CJ5 with
TERRA-TIRES.
Front View.

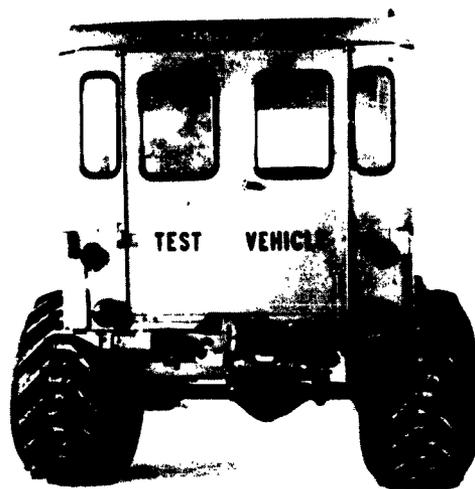


Figure 9. Willys CJ5 with
TERRA-TIRES.
Rear View.



Figure 10. Willys CJ5 with
TERRA-TIRES.
Right Profile.

Figure 11. Willys CJ5 with
TERRA-TIRES.
Left Profile.





Figure 12. Willys CJ5 with
TERRA-TIRES.
Left Front.



Figure 13. Willys CJ5 with
TERRA-TIRES.
Right Front.



Figure 14. Willys CJ5 with
TERRA-TIRES,
Left Rear.



Figure 15. Willys CJ5 with
TERRA-TIRES.
Rear axle broken
due to undue stress
upon axle assembly.



Figure 16. TERRA-TIRE Installation on CJ5. Left Front Close-up.



Figure 17. TERRA-TIRE on Left Front of CJ5. Note how body was altered to provide clearance for over-size tire.





Figure 18. Duplex Tire on Left Front of CJ5. Large fender clearance was made to accommodate larger TERRA-TIRES.

Figure 19. Garrison Power Steering and Front End Assembly of CJ5.

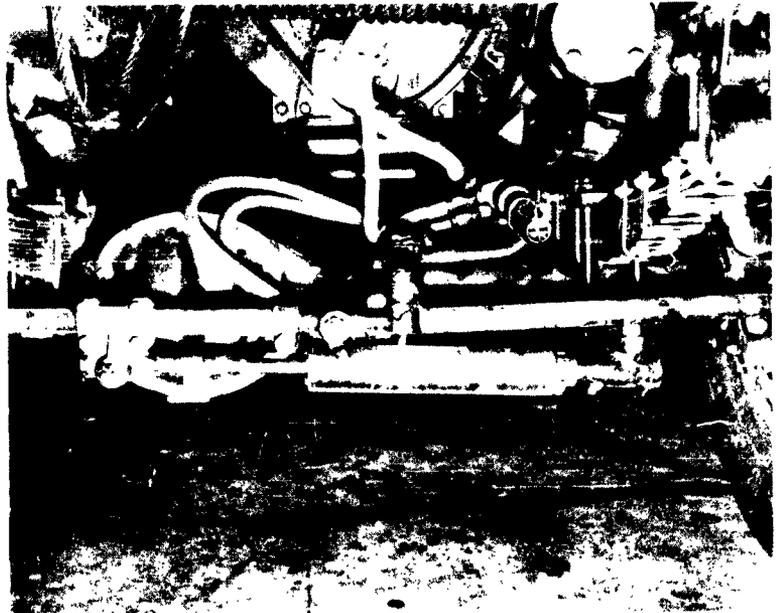




Figure 20. Dodge Power Wagon WM300 with TERRA TIRES. Front View.



Figure 21. Dodge Power Wagon WM300 with TERRA-TIRES. Rear View.



Figure 22. Dodge Power Wagon WM300 with TERRA-TIRES. Left Profile.

Figure 23. Dodge Power Wagon WM300 with TERRA-TIRES. Right Profile.

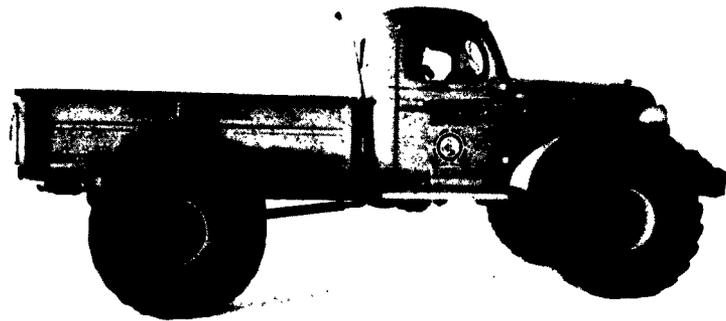
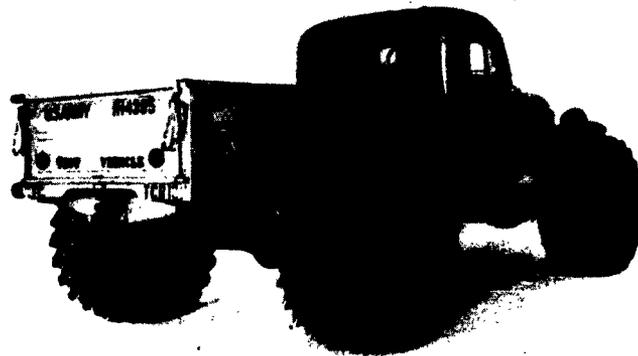




Figure 24. Dodge Power
Wagon WM300 with
TERRA-TIRES.
Left Front.

Figure 25. Dodge Power
Wagon WM300 with TERRA-
TIRES. Right
Rear.



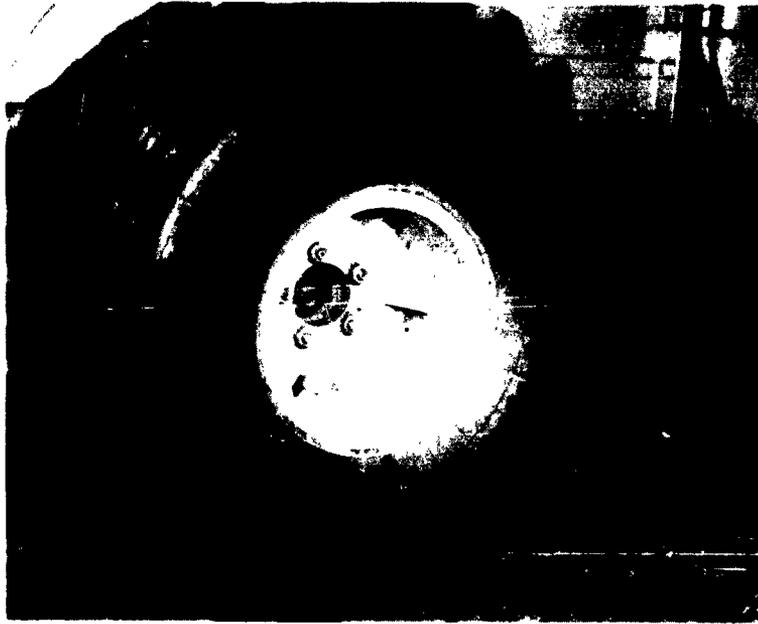


Figure 26. TERRA-TIRE Installation on Dodge Power Wagon. Right Rear Close-up.

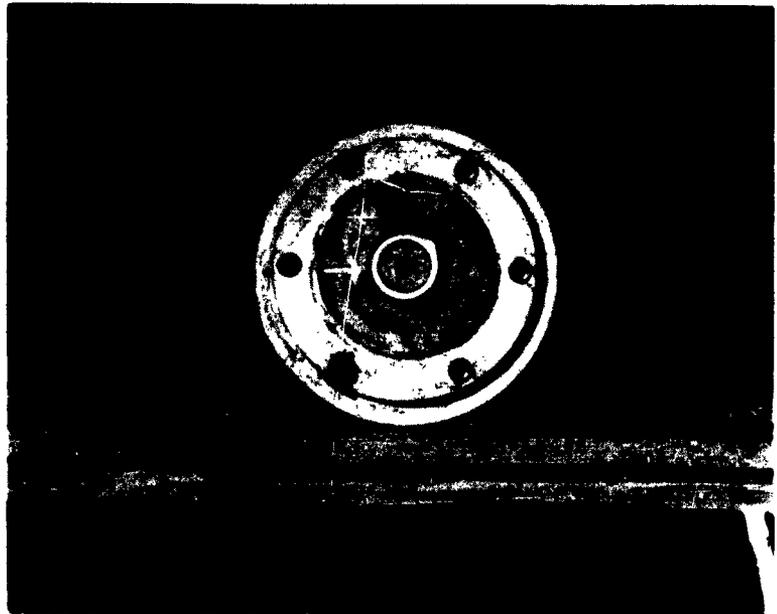


Figure 27. Broken Axle of CJ5.

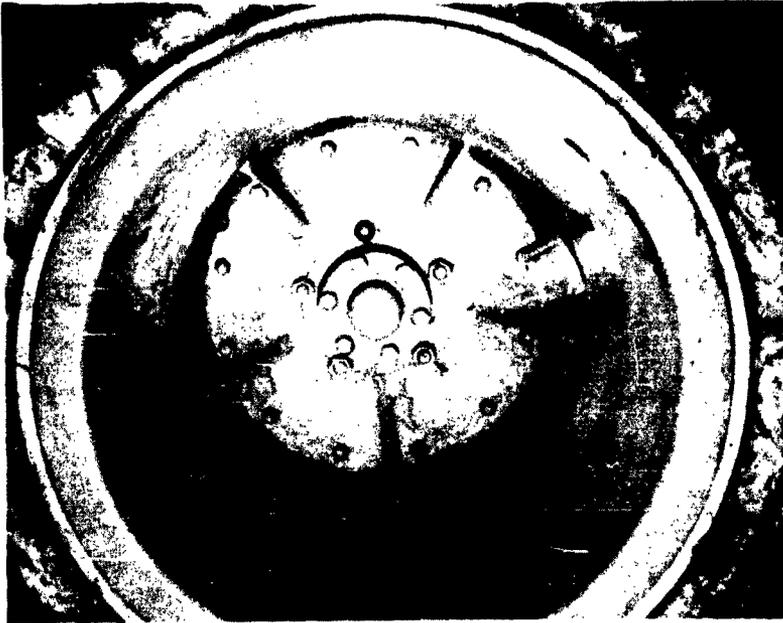
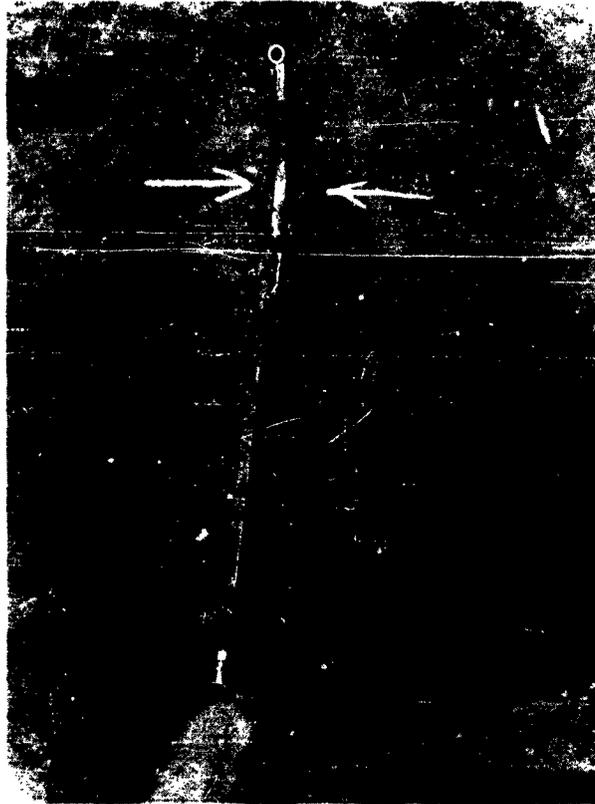


Figure 28. Broken Bolt on
Wheel Mounting of
Dodge Power Wagon
with TERRA-TIRES.

Figure 29. Damaged Wheel
Mounting of Dodge
Power Wagon with
TERRA-TIRES.





**Figure 30. Damaged Power Steering
Rod on Dodge Power Wagon
WM300.**

ANNEX D
AREAS OF OPERATIONS

1. TEST AREA. Vehicle evaluation at Fort Wainwright took place at the Ordnance Arctic Test Facility. The courses are located approximately 2 miles north of Hangar No. 1. Driving distance to the test courses is 6 miles, 2 miles over paved road and 4 miles over secondary all-weather road. The airstrip just outside of Hangar No. 1 was used as a speed and braking test area. There are four different test courses and the speed and braking test area. The roads vary from unimproved surfaces to paved surfaces.

a. Red Course (Level cross-country). During the winter, when the ground is frozen, the course is representative of an unimproved road. During the summer, the area is thawed muskeg and is impassable for vehicles except those of special design. The course is extremely bumpy and has many turns, some approaching right angles. The only slopes in the course occur where the trail crosses a creek. The grade of the creekbanks is approximately 10 percent. The entire Red Course is 5 miles long and requires 25 to 30 minutes to traverse. During the winter, the course is open to all vehicles, wheeled or tracked.

b. Green Course (Hill road). This course represents an improved road with varying slopes and curves. The maximum slope is approximately 10 percent. The curves in the course are relatively gentle, except for one right turn and one left turn which are practically 90°. The course is 4 miles long.

c. Yellow Course (Hill cross-country). This course is intended primarily for the evaluation of tracked vehicles. It consists of side slopes; various curves, both hairpin and gentle; and vertical slopes approaching 40 percent. Only vehicles with an exceptionally aggressive track system have been able to negotiate this course unassisted. The course is classified as dangerous, and not to be attempted by inexperienced drivers. It is 3 miles long.

d. Blue Course (Sage Hill slopes). This course is not yet completed. The 5-, 10-, and 20-percent slopes are completed, however, and vehicle evaluations can be made on these slopes. The 40-percent slope is presently roughed in, but slopes on it vary from 20 to 60 percent. The course is approximately 1/2 mile long.

e. Speed and Braking Test Area. The surface is concrete and was covered by approximately 3 to 4 inches of hard-packed snow.

2. MANEUVER AREA.

a. Topography

The GREAT Bear maneuver area extends approximately 160 miles in a north-west-southeast direction and covers approximately 3,200 square miles. It is bordered on the south by the Alaska and Richardson Highways and on the north by an unnamed range of mountains. Eielson Air Force Base lies at the northwestern end and Tanacross at the southeastern end. This area is a part of the Tanana River drainage system.

All trails and routes of movement throughout the maneuver area were prepared for the maneuver and were, thus, semipermanent winter trails. These routes were prepared with bulldozers, and were extremely rough.

Snow depth throughout the maneuver area averaged from 2 to 5 feet, with the deeper snow accumulation in the draws and ravines.

The maneuver area can be divided into two sectors: the first is a lowland parallel to the Tanana River; the second is an upland area which extends in a northwest-southeast direction generally to the north of the lowlands.

(1) Lowlands. The Tanana River flows the entire length of the maneuver area, but its lowlands extend only about 130 miles from Shaw Creek Lodge to the Robertson River and vary in width from 6 to 18 miles within the boundaries of the maneuver area. These flat plains are virtually free of ridges or cliffs but are heavily forested in many areas with spruce, aspen, or birch from 10 to 50 feet high. There are also numerous regions where vegetation is extremely light and where swampy ground predominates. This area includes, in addition to the Tanana River, Lake George (approximately 2 miles by 5 miles) and Healy Lake (approximately 2 miles by 4 miles).

(2) Highlands. This region includes most of both the upper and lower quarters of the maneuver area. It rises in a series of rugged foothills which vary between 2,000 and 3,000 feet in elevation in the northwest and rise as high as 4,000 feet at the southeastern end. Although these foothills, overridden by glacial ice during the Ice Age, have relatively subdued relief when compared to the forbidding peaks of the Alaska Range to the south, they do pose a number of formidable obstacles. Approximately nine-tenths of this region contains ridges about 2,500 to 3,000 feet above the plains. Only the valleys formed by the numerous creeks and rivers are less than 1,400 feet high. Slopes vary from 15 to 60 percent. Some of these valleys and draws are moderate and broad enough to accommodate vehicular traffic.

b. Drainage. The Tanana River, flowing northwest, drains the entire maneuver area. Into it flow the majority of the streams in the area, running in a north-south direction. Two exceptions to this are the Gerstle and Johnson Rivers which drain into the Tanana River from the Alaska Range to the south of the Tanana River. The Tanana River runs for the most part in a meandering course, only locally interrupted by short stretches of swifter flow. Generally, its flow averages about 3.0 knots. Upstream from the mouth of the Delta River, the width is reported as 775 feet. At other locations, its width has been given as between 600 and 900 feet. No detailed data are available.

c. Vegetation. Vegetation in the maneuver area varies from forest, consisting of spruce, aspen, or birch, ranging in height from 10 to 50 feet, to tundra vegetation, consisting of dense growth of mosses and lichens and dwarf cespitose herbs and shrubs. Tundras mark the limit of arborescent vegetation. Muskeg areas occurring along flat-bottomed depressions and drainage ways have brush 2 to 5 feet high and a thick layer of spongy moss and sedges.

d. Roads and Trails. Except for the Alaska and Richardson Highways, roads within the maneuver area are limited and of little use. There are two unimproved gravel roads only 2 or 3 miles long near Big Delta and Delta Junction. There are also some trails, most of which are 6- to 10-foot clearings through brush and trees, suitable only for tracked vehicles.

e. Cross-country Movement.

(1) Lowlands. Cross-country movement is possible throughout most of the lowlands in February because frost depths have reached a minimum of 2 feet. The major obstacles to movement at this time are the dense forests, some steep bluffs along the Tanana River, and open water in some of the streams. In most cases, however, obstacles

can be bypassed with careful reconnaissance and maximum engineer assistance. Ice crossings on the Tanana River are relatively simple. Snow in the lowlands does not normally restrict movement; during the winter, snow depths average about 2 feet and drifting is negligible.

(2) Highlands. In the upland area, cross-country movement for tracked vehicles is possible, although extremely difficult. Avenues of approach are few and must be carefully chosen since this area contains some virtually impassable barriers. Also, drifting snow is more extensive and presents a considerably greater problem than it does in the lowlands. In addition, there are numerous sharp draws, defiles, and ridge lines which form cross-compartments perpendicular to the axis of advance and which, to be negotiated successfully, require careful preliminary reconnaissance and preparation.

(3) Lakes, Streams, and Springs. Most of the lakes and streams in the maneuver area are frozen to a depth of from 20 to 36 inches in February. On a reconnaissance of the area in March 1961, ice thicknesses averaged 36 inches, although there was open water in some places, particularly at the inlets and outlets of the larger lakes. One fairly common hazard is that some lakes and streams are subject to periods of overflow which results in water or slush either standing or flowing over a layer of ice. This condition is not always readily apparent, since a thin coating of ice or snow can easily conceal it. Marshes and bogs adjacent to some of the lakes must also be approached with caution. Generally, however, ice thickness is sufficient to support all wheeled and tracked vehicles, particularly if proper route reconnaissance has been conducted.

There were numerous hot springs throughout the maneuver area. Many of these springs were located on the various supply routes, often hampering and delaying movement along the routes.

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of tires under subarctic conditions: standard military (non-directional cross-country NDCC and non-directional mud and snow NDMS tires, Firestone Duplex tires, and Goodyear terra-tires. Seven different vehicle-tire combinations, military and commercial, were evaluated or observed. The Goodyear Super terra grip tires provided significant vehicle mobility improvement in winter sub-arctic environment. Additional evaluations with other classes of vehicles are recommended.

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