TRAFFICABILITY TESTS OF OVER-SNOW VEHICLES

By

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DEFINITION OF TERMS

Draw Bar Coefficient	Drawbar pull / Weight of Vehicle
Efficiency Coefficient	Power delivered at drawbar / Power input at drive shaft
Improvement Factor	Drawbar with grousers / Drawbar with no grousers

INTRODUCTION

This paper presents some material taken from USA SIPRE Research Paper 35, Studies on Vehicular Trafficability of Snow (Diamond, M. 1956, Part I, and Lanyon, J. 1959, Part II). It embodies sections which are thought to be of interest to users and people concerned with the trafficability of over-snow vehicles. Discussed in the paper are the development of an instrumented track pad and the forces acting on the pad for one revolution of the track. Grousers of the Kamm type are compared with a more simple 4" x 4" x ¼" angle iron grouser and the effect of the grousers on the drawbar and efficiency coefficients are shown. Some operational characteristics of the four pontoon Tucker Sno-Cat are also presented.

All tests were conducted at the U. S. Army Snow Ice and Permafrost Research Establishment, Keweenaw Field Station, located near Houghton, Michigan. The principle vehicles used in the testing were the M-7 ordnance half-track snow tractor, the Tucker Sno-Cat (Model T443) and the M29C Weasel. Specifications for these vehicles can be found in Table 1. In addition to its use in regular trials, the M-7 snow tractor was used in the testing of quick attaching grousers of different shapes and sizes.

DEVELOPMENT OF AN INSTRUMENTED TRACK PAD

Previous trafficability studies at the USA SIPRE Keweenaw Field Station revealed that an energy loss which at times may become as high as 50% of energy input does occur in some present track systems (Lanyon, J. 1959). Other tests show that this loss may not be attributed solely to the internal friction of the machine but is lost in the manner in which the track applies itself to the snow cover.

To study this loss and in order to be able to further analyze the forces acting on a track system when a vehicle encounters resistance such as in compacting and shearing of snow, and to possibly gain some insight into the nature of external rolling resistance, a track pad of the M-7 snow tractor and the M29C Weasel were instrumented to measure the forces acting normal and tangential to the pad.

Instrumentation

Instrumentation of the track pads was accomplished by removing a single pad from the tracks and fitting to it some strain bars which were in turn fitted to a back plate (see Figure 1).

The back plate for the M-7 snow tractor pad was fabricated from 1/8" sheet steel reinforced with gussets and stiffeners to eliminate as much as possible any bending that might occur in the plate. Studs were then welded into the back plate so that the assembly could be easily attached and removed from its position on the track section (see Figure 2). The back plate for the M29C Weasel pad was

1/ U. S. Army Snow Ice and Permafrost Research Establishment, Corps of Engineers, Houghton, Michigan.
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USA SIPRE Dynamometer Vehicle and M-7 Snow Tractor used in the testing of the instrumented track pad.

DISTRIBUTION OF WEIGHT AND PRESSURE OF THREE SNOW VEHICLES

Make of Vehicle	ORDNANCE	ORDNANCE	Tucker Commercial	
Model or Designation	M-7	M-29C	Model 443 (T4)	
Type of Vehicle	Half Track-Ski Front End	Full track	4 pontoons	
Total Weight of Vehicle Empty lb.	2710	4771	4000	
Weight on Tracks or Pontoons %	68	100	Front Pontoon 55	Rear Pontoon 45
Weight on Tracks or Pontoons lbs.	1843*	4771	2200	1800
Ground Contact Area on Tracks or Pontoons- 0 inch penetration sq inch	2580	3125	3000	3000
Number of Pads in Contact with Ground (per track) 0-inch penetration	12	18		
Ground Pressure on Tracks or Pontoons 0-inch penetration psi	.71	1.5	.73	.60
Weight on Skis %	32			
Weight on Skis lbs.	867			
Ground Contact Area on Skis - 0 inch penetration sq inch	770			
Ground Pressure on Skis - 0 inch penetration psi	1.13			

*NOTE: Weight of M-7 on Tracks during grouser tests was 2688 lbs.

TABLE 1.

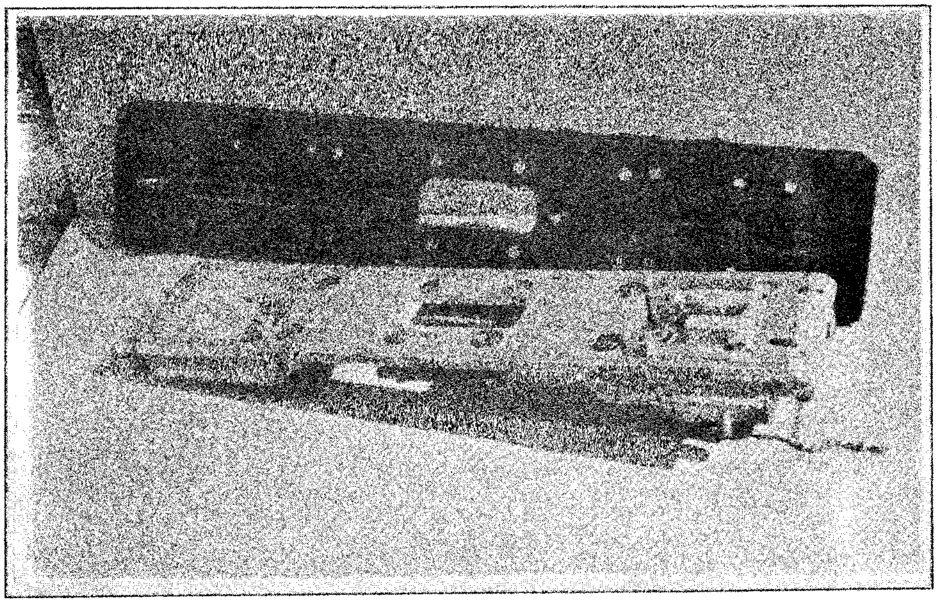


Figure 1.
Instrumented Track Pad for M29C Weasel

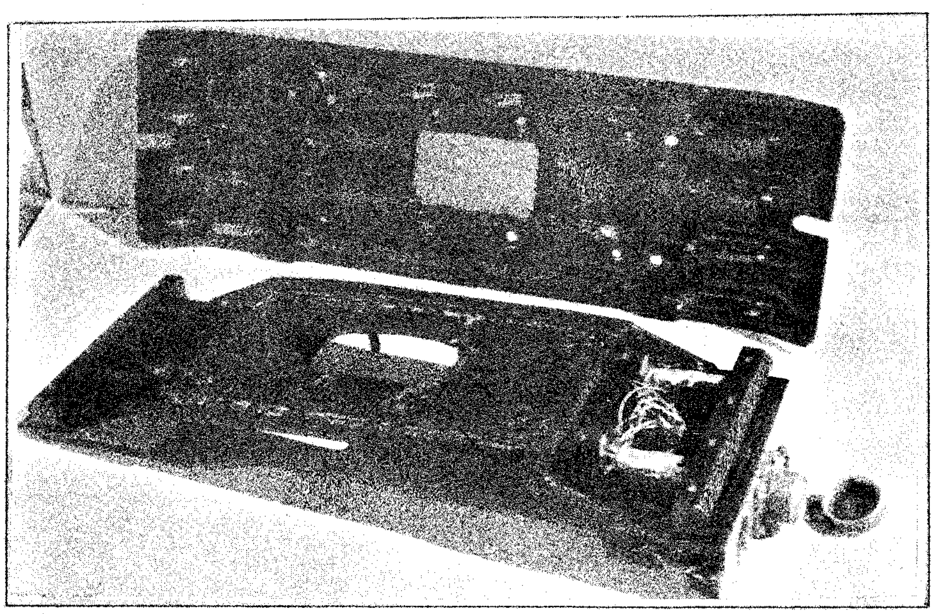


Figure 2.
Instrumented Track Pad for M-7 Snow Tractor

machined from 7075T6 high strength aluminum. Measuring elements for the instrumented pads were made up of SR4 strain gauges fastened to the bending bars and wired in the form of two electrical bridges. One bridge served to measure the strain normal to the track and the other to measure the strain parallel to the track. The signal was then brought through a four channel amplifier to a galvanometer type recording oscillograph.

The total thickness of the instrumented track pads when assembled and installed raised the height of the pad to approximately 1/4" above the regular track pads. This difference was eliminated by raising five of the regular pads on each side of the instrumented pad to the same height.

By instrumenting a track pad of both the M-7 snow tractor and the M29C Weasel, an opportunity to study the advantage or disadvantage of a spring suspension over a rigid suspension was made possible. The M-7 has its drive sprocket, bogie wheels and idlers mounted in a rigid frame and the frame is then mounted to the vehicle, as compared to the Weasel whose bogie wheels are individually mounted to the vehicle with a spring suspension.

Test Procedure and Results

In the initial testing of the M-7 instrumented track pad, the vehicle speed was held to approximately one m.p.h. Track speed at the time of testing was obtained from the chart speed of 3.2 inches/second and the known distance between the bogie wheels. The horizontal force on the pad was varied by applying a back-up load on the drawbar of the vehicle being tested. The vertical force or psi was varied by loading the vehicle with 60 lb. cement blocks in increments of 300 lbs. up to 1200 lbs. The peaks of the vertical trace indicate the position of the pad. It is assumed that the peaks occur when the pad is directly under a bogie wheel.

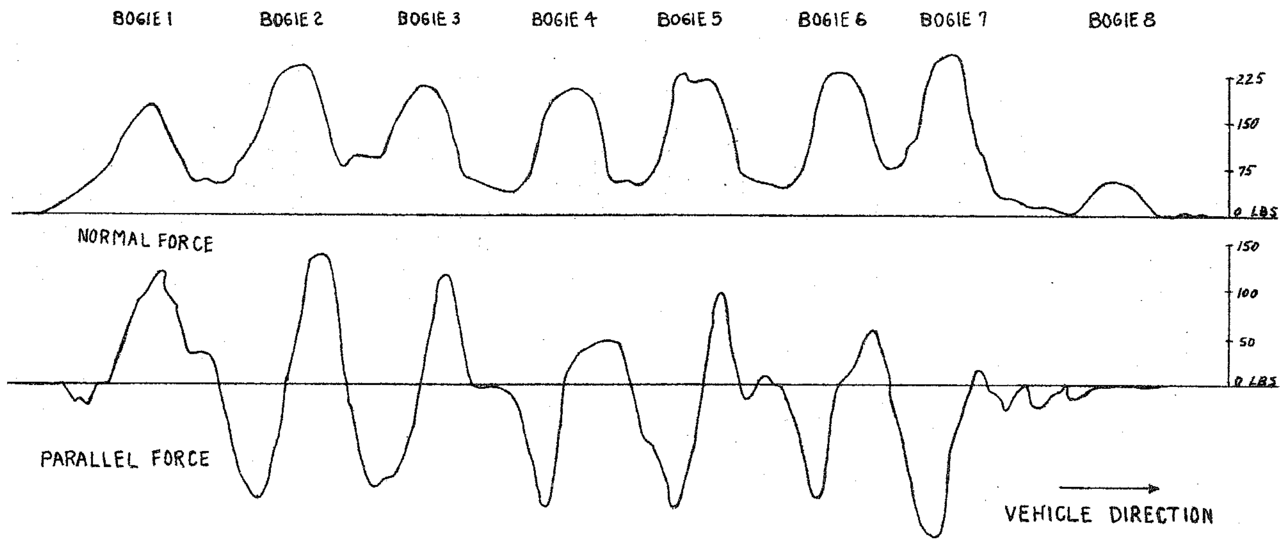
In the absence of a printed scale on the chart paper, the instrument was calibrated to read out directly in lbs/in. The scale is 150 lbs/inch for the normal trace and 100 lbs/inch for the parallel trace. The scale for the drawbar pull was 1333 lbs/inch.

A typical trace (no additional vehicle load, no drawbar load) of the normal and parallel forces acting on the strumented pad of the M29C Weasel is shown in Figure 3. The trace indicates that the maximum ground pressure occurs when the pad is immediately below a bogie wheel but that the maximum horizontal thrust occurs when the pad is slightly past the center of the bogie wheel. From the trace in Figure 3 it appears that the vertical force exerted by the bogie wheels on the instrumented pad of the M29C Weasel varies from approximately 60 lbs. to 262 lbs. or .7 psi to 3 psi. The mean ground pressure for the M29C Weasel (no-load) is calculated to be 1.5 psi, a difference of 1.5 psi between the maximum measured vertical force and the static ground pressure. Although this difference may vary as the snow conditions change and the portion of the track between the bogie wheels assumes more or less of the load, it appears that computed static ground pressure may not be the same as actual pressure under operational load.

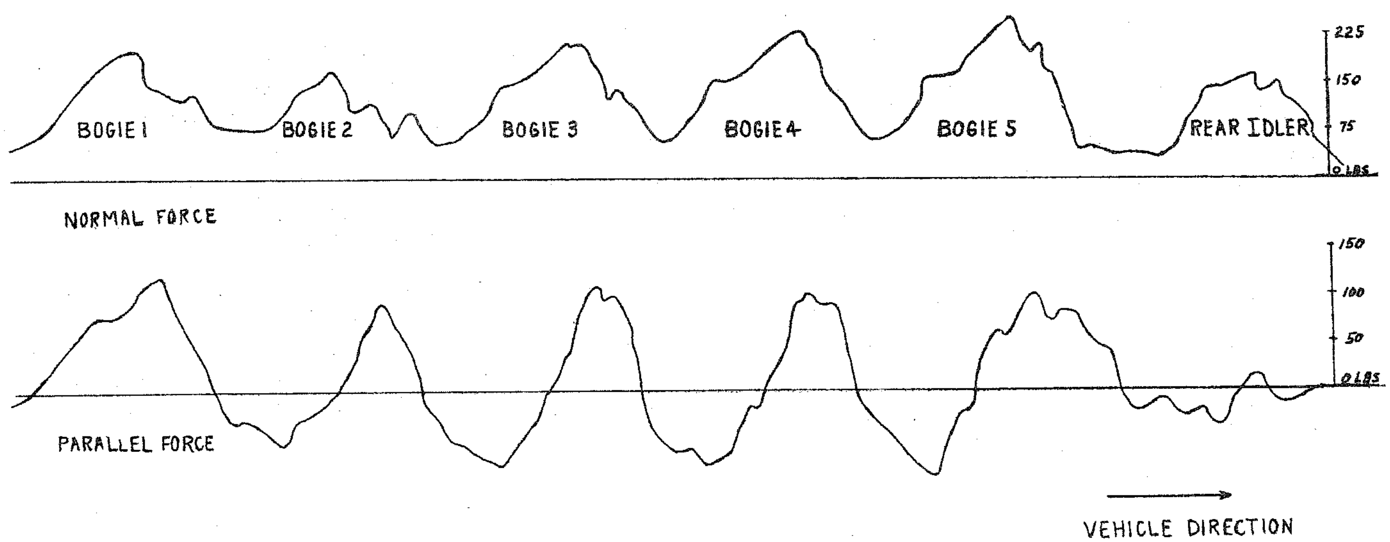
In tests with the M-7 snow tractor whose mean ground pressure is calculated as .71 psi (no vehicle load), the measured average maximum vertical force exerted on the pad was 1.1 psi. Figure 4 shows a trace of the vertical and horizontal forces acting on the pad of the M-7 tractor while operating under a vehicle load of an additional 300 lbs. and a drawbar load of 500 lbs. The trace of the normal force shows that as a drawbar load is applied to the vehicle, the vertical forces are shifted progressively to the rear bogie wheels and idler, contributing to the heel down characteristics of the track section. An increase in the vertical force on the track section of the vehicle (above the added vehicle load) is observed, indicating that part of the power input to the track section is being used to apply a moment onto the ground.

The trace of the parallel force in Figure 4 shows that the instrumented pad is registering a negative reading as it passes between the bogie wheels. One theory advanced to explain this phenomena is that as a bogie wheel approaches the instrumented pad, it has a tendency to push the pad, causing negative parallel forces. Further study will be made to determine the validity of this theory and others that may present themselves.

It is possible that with further refinement, the instrumented track pad may be used to measure external rolling resistance and the energy spent in shearing and compacting of snow. Also it should indicate the proper number, size and spacing of the bogie wheels for a particular track section. It is hoped that information received from the instrumented track pads will contribute significantly to the improvement of over snow vehicles.



M 29 C WEASEL TEST NO LOAD NO DRAWBAR
FIGURE 3



M 7 SNOW TRACTOR TEST 300 LBS LOAD 500 LBS DRAWBAR
FIGURE 4

COMPARISON OF GROUSERS

The trafficability trials of 1954-1955 included tests of grousers which embodied the basic ideas developed by Kamm (1947). These grousers triangular in cross section were 6" x 18" x 4" high with a forward face angle of 30° and a rear angle of 60° (see Figure 5). The grousers could be attached to the track pads of the M-7 with either face angle forward. The trials showed that an increase of 30% in drawbar pull could be obtained with these grousers but that there was little or no difference between mounting them with the 30° or the 60° face angle forward (Diamond, M. 1956).

To determine whether the depth of penetration or the configuration of the grouser was responsible for the increase in drawbar pull, angle irons (4" x 4" x ¼") were attached to the track pads (see Figure 6). This gave the same depth of penetration as the Kamm profile. Both types of grousers could be quickly mounted on or removed from the track pad of the M-7 snow tractor, permitting rapid sequential testing on the same snow cover (Lanyon, J. 1959).

In these tests the maximum drawbar pull developed by the Kamm type grouser exceeded that of the angle iron in only two out of eight pairs of tests and then only by a very small amount (see Figure 7 and Table 2). It appears that the shape and volume displacement of the Kamm type grouser may not provide higher tractive force than that to be obtained from a more simple grouser.

Kamm suggested that the ratio of grouser spacing to grouser width should be about 3:2. Tests were conducted during these studies with a different number of grousers spaced evenly around the tracks. The spacings used were one grouser on each track pad, on each third pad, on each eighth pad, and on each eleventh pad. The latter spacing made it possible to have only one grouser on each track in contact with the snow surface at a time.

In all tests the maximum drawbar pull was obtained with a grouser mounted on each track pad. Figure 8, a plot of the grouser spacing vs improvement factor $\left(\frac{\text{drawbar pull with grousers}}{\text{drawbar pull without grousers}}\right)$ shows the possible improvement in drawbar pull that can be expected from the different grouser spacings. As the number of grousers per track were reduced, the drawbar pull was also reduced. The effect of the grouser spacing on the efficiency coefficient of the vehicle is shown in Figure 9. In only one case was an improvement noted which was that of a grouser on each track pad.

These trials were not sufficient to indicate that there was an optimum grouser spacing for the particular track system used in these tests. As was shown in Figure 4, horizontal thrust on an M-7 track plate occurs when it is beneath a bogie wheel or the rear idler, hence the number, size and spacing of the bogie wheels in a track system may influence the optimum spacing of grousers, at least on some types of snow.

OPERATIONAL CHARACTERISTICS OF THE 4-PONTOON SNOW TRACTOR

In trafficability tests with the Tucker 4-pontoon Snow-Cat it was noted that the amount of torque developed in the driveshaft to the trailing pontoon was always greater than in the driveshaft to the leading pontoon (Lanyon, J. 1959). That is, if the torque in the driveshaft to the front end of the vehicle is designated T_1 and that to the rear designated T_2 then T_2 was greater than T_1 when the vehicle was driven forward and less than T_1 when driven in reverse. The relationship is shown in Figures 10 and 11. This operational characteristic was not found to be correlated with any of the snow properties measured at the test site nor with any recorded meteorological phenomena.

When trials were run on a compacted or hard surface area the same difference was found between the torque of the two driveshafts indicating that the peculiarity is inherent in the vehicle and not related to the properties of the media on which it is operating. It is probable that the force-couple in the driveshaft contributes to the apparent greater tractive ability of the trailing pontoons in spite of the fact that when operated in forward gear the unit load on the front pontoon is greater than on the rear, while when operated in reverse, the greater unit load is on the trailing pontoons.

It appears that if a track should fail on one of the rear pontoons under conditions where repairs cannot be made, improvement in performance of the crippled vehicle may be obtained by replacing the defective track on the rear with one taken from a front pontoon with the vehicle operating on only three tracks.

REFERENCES

1. Diamond, M. (1956) Studies on Vehicular Trafficability of Snow, Part I, Snow Ice and Permafrost Research Establishment, Research Paper 35.
2. Lanyon, J. (1959) Studies on Vehicular Trafficability of Snow, Part II, Snow Ice and Permafrost Research Establishment, Research Paper 35.
3. Kamm, W. I. E. (1947) Vehicles in Snow and Bog, Air Material Command, Technical Report F-TR-2132-ND.

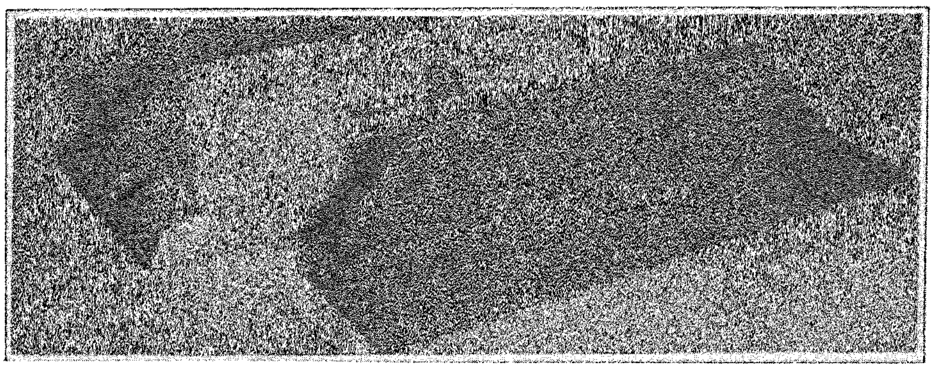


Figure 5.
Kamm Type and 4x4
Angle Iron Grousers

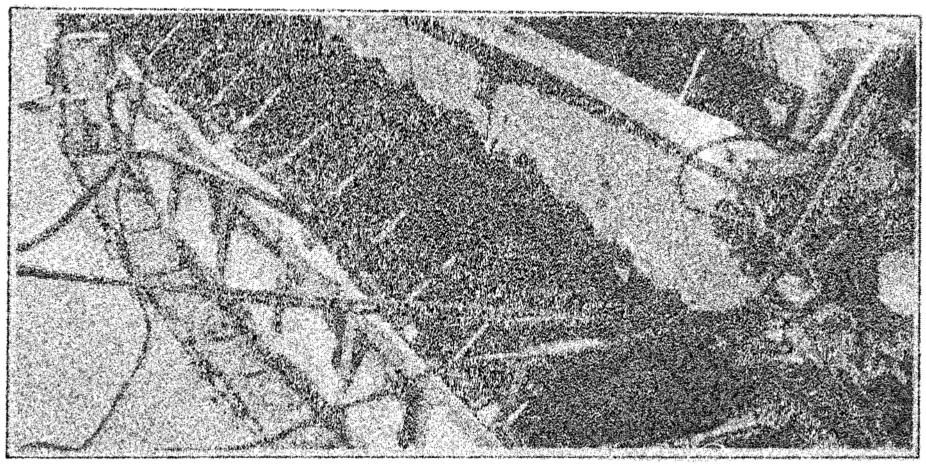


Figure 6.
4x4 Angle Iron Grousers
mounted on M-7 Track

M-7 SNO TRACTOR GROUSER TRIALS

Date 1956	Trial No.	Vehicle M-7 Type of Trial	Draw Bar lbs	Torque lb-in.	Track Depth inches
23 Feb.	1	No grousers	760	1275	3.0
23 Feb.	2	Kamm grousers every shoe (30° face forward)	1320	1850	3.0
23 Feb.	3	4x4 angle every shoe	1360	2100	6.5
23 Feb.	4	Kamm grousers every 3rd shoe	860	1550	5.5
23 Feb.	5	4x4 angle every 3rd shoe	1000	1675	4.5
23 Feb.	6	Kamm grousers every 8th shoe	880	1475	9.5
23 Feb.	7	4x4 angle every 8th shoe	820	1600	7.0
23 Feb.	8	Kamm grousers every 11th shoe (30° face forward)	800	1475	7.5
23 Feb.	9	4x4 angle every 11th shoe	840	1750	7.5
26 Mar.	10	No grousers Test #1	1000	1325	5.0
26 Mar.	11	No grousers Test #2	880	1200	5.5
26 Mar.	12	Kamm grousers every shoe	1400	1900	1.5
26 Mar.	13	4x4 angle every shoe	1360	1950	6.0
26 Mar.	14	Kamm grousers every 3rd shoe	1060	1750	10.0
26 Mar.	15	4x4 angle every 3rd shoe	1400	1850	5.0
26 Mar.	16	Kamm grousers every 8th shoe	1200	1750	7.5
26 Mar.	17	4x4 angle every 8th shoe	1140	1550	5.0
26 Mar.	18	Kamm grousers every 11th shoe	1000	1500	6.5
26 Mar.	19	4x4 angle every 11th shoe	1120	1500	3.5

NOTE: 23 Feb. Snow Density .282 $\frac{gm}{cm^3}$ Drop Cone Hardness 46.5

26 Mar. Snow Density .394 $\frac{gm}{cm^3}$ Drop Cone Hardness 1.27

TABLE 2

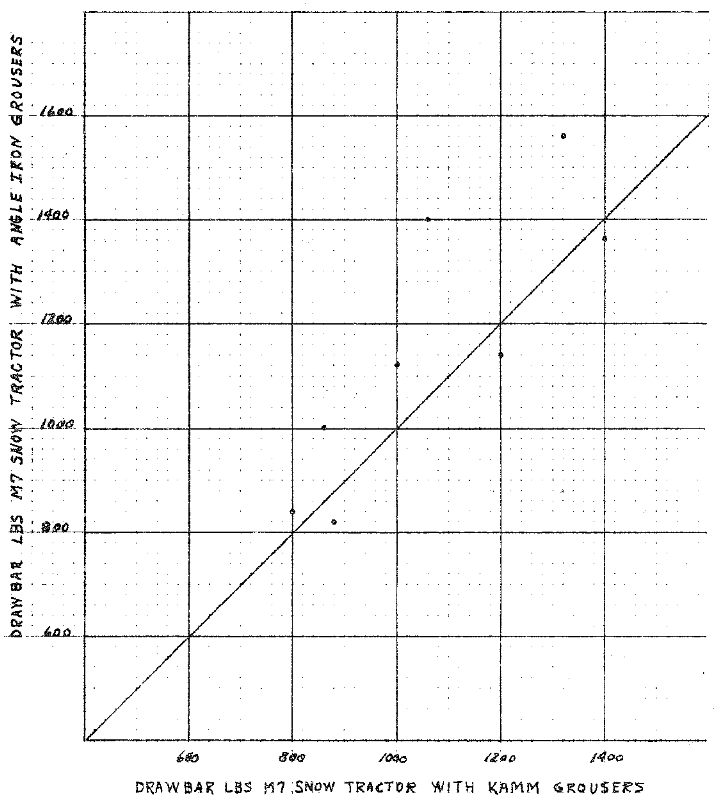


FIGURE 7

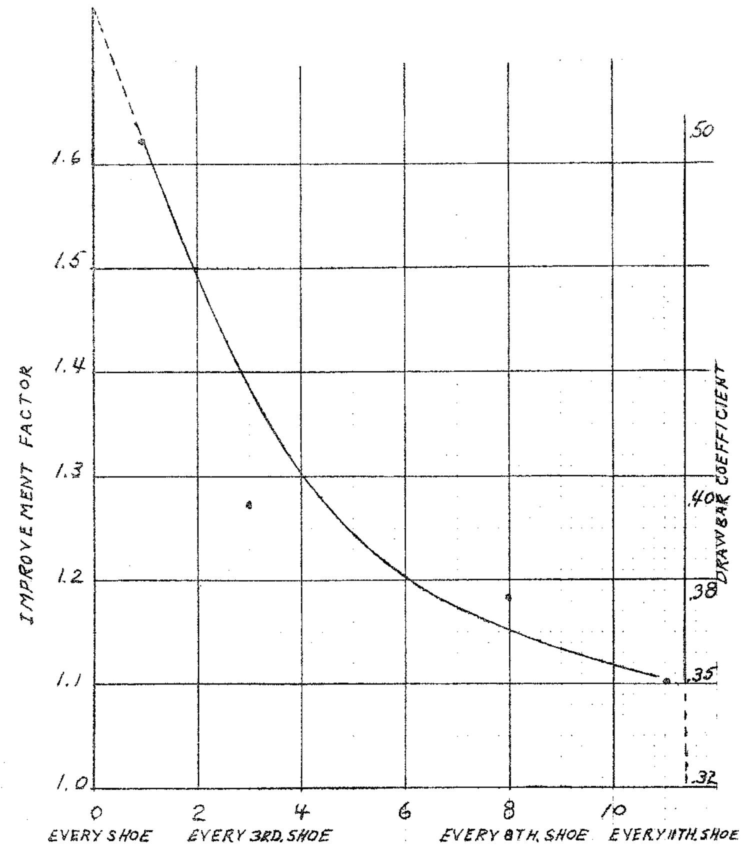


FIGURE 8

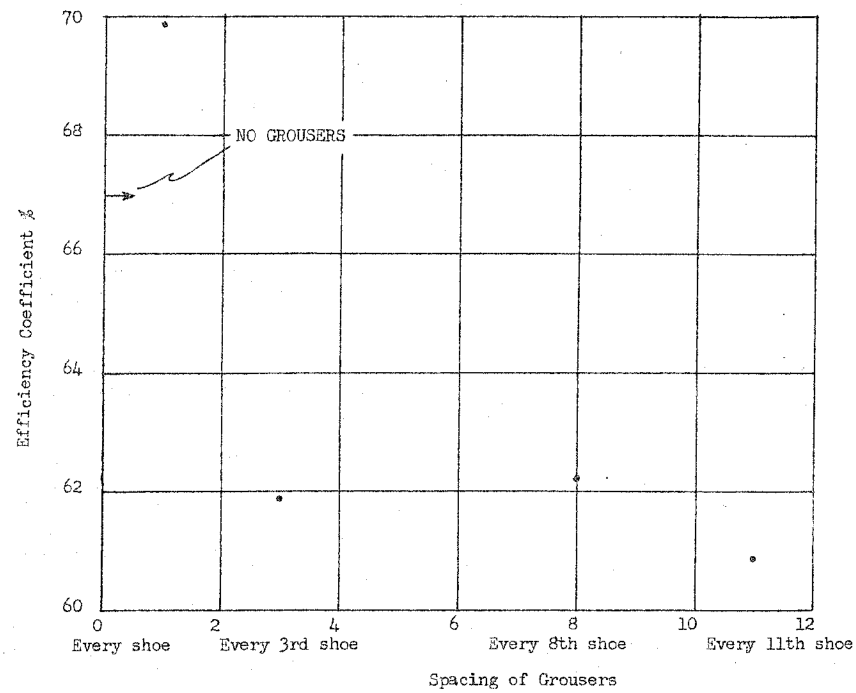


Fig 9

1957

Torque 1 & 2 vs Drawbar Pull on T-443 Sno-Cat

Trial No. 13

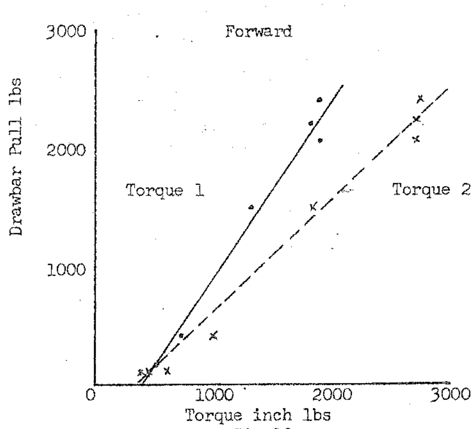


Fig 10

Trial No. 16

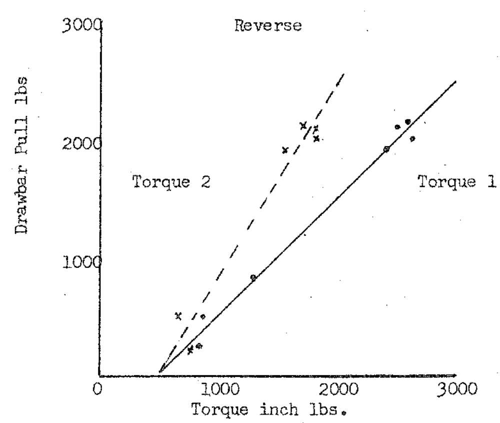


Fig 11