M1 Winter Tank Test
(Traction Devices)

FINAL REPORT

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SUMMARY

An Abrams M1 Tank underwent environmental testing for:

1. Snow/Ice Mobility
2. Braking
3. Slope Climbing
4. Slalom Course
5. General Operations

The vehicle was tested with the standard T156 track, T156 track with ice shoes, and T156 track with carbide tipped studs installed on each pad. To evaluate the vehicle air induction system, the vehicle was tested in light, moderate, and heavy snow, and through woods.

Test results indicate that the standard T156 track is ineffective in snow and on ice. The addition of traction aids, studs or ice shoes, showed an increase in mobility, studs performing slightly better than the ice shoes. The air induction system was not affected by the snow.

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1.0 INTRODUCTION

Performance tests were conducted on an Abrams M1 tank to determine the overall vehicle operating characteristics and the effectiveness of traction aids on iced and snowy surfaces.

The tests involved a comparison of how the M1 tank handled with an unmodified T156 track, a T156 track with ice shoes, and a T156 track with tungsten carbide tipped studs. Figure 1 shows one of the ice shoes which would later be installed on the T156 track. Figure 2 shows the tungsten carbide tipped studs installed on a track pad.

The vehicle was tested for stopping distance, slope climbing ability, and the time required to negotiate a fixed slalom course.

2.0 BRAKING TEST

The braking tests were conducted on a level 250 ft x 150 ft iced test area. The ice was cleared of all snow prior to the beginning of each test and resurfaced at the end of each test. The vehicle would accelerate to the desired speed in the acceleration lane and enter the iced area at a constant speed. The driver would apply and hold the brakes when the vehicle was completely on the ice. The test results for each track configuration are given in Table 1.

Both traction aids significantly reduced the vehicle's stopping distance. The studded pads show an 11% improvement over the ice shoes. Figure 3 shows the same test results in graph form. Figure 4 shows the sliding impression left in the ice from the ice shoes. Note the wide grooves.

Table 1. Braking Test on Ice

Distance (Feet)

Speed MPH	T156 Track	Ice Shoes	% Improvement	Studded Pads	% Improvement
5	15.26	7.40	52	4.97	69
10	50.40	26.70	47	16.90	66
15	105.40	50.80	52	44.40	58
20	212.40	92.30	57	86.50	59
25	------	122.80	--	117.50	4.3*
AVERAGE			52%		63%

* Compared with ice shoes.

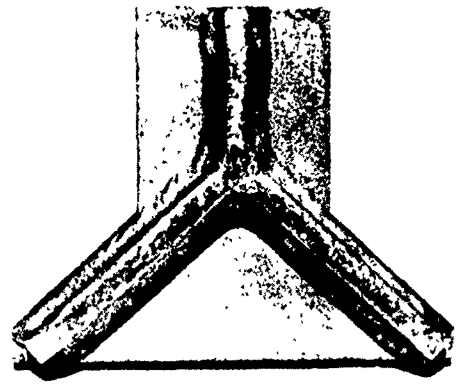


Figure 1. Ice Shoe

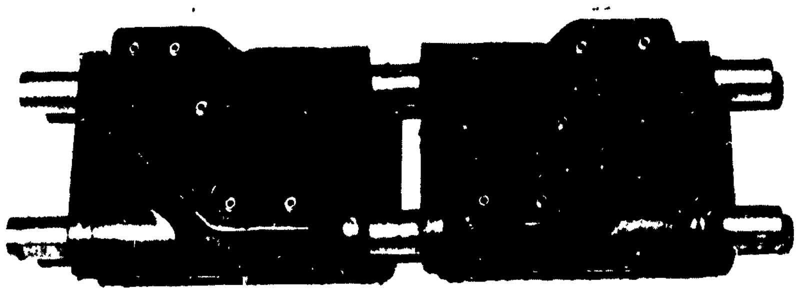


Figure 2. Tungsten carbide tipped studs installed on track pads.

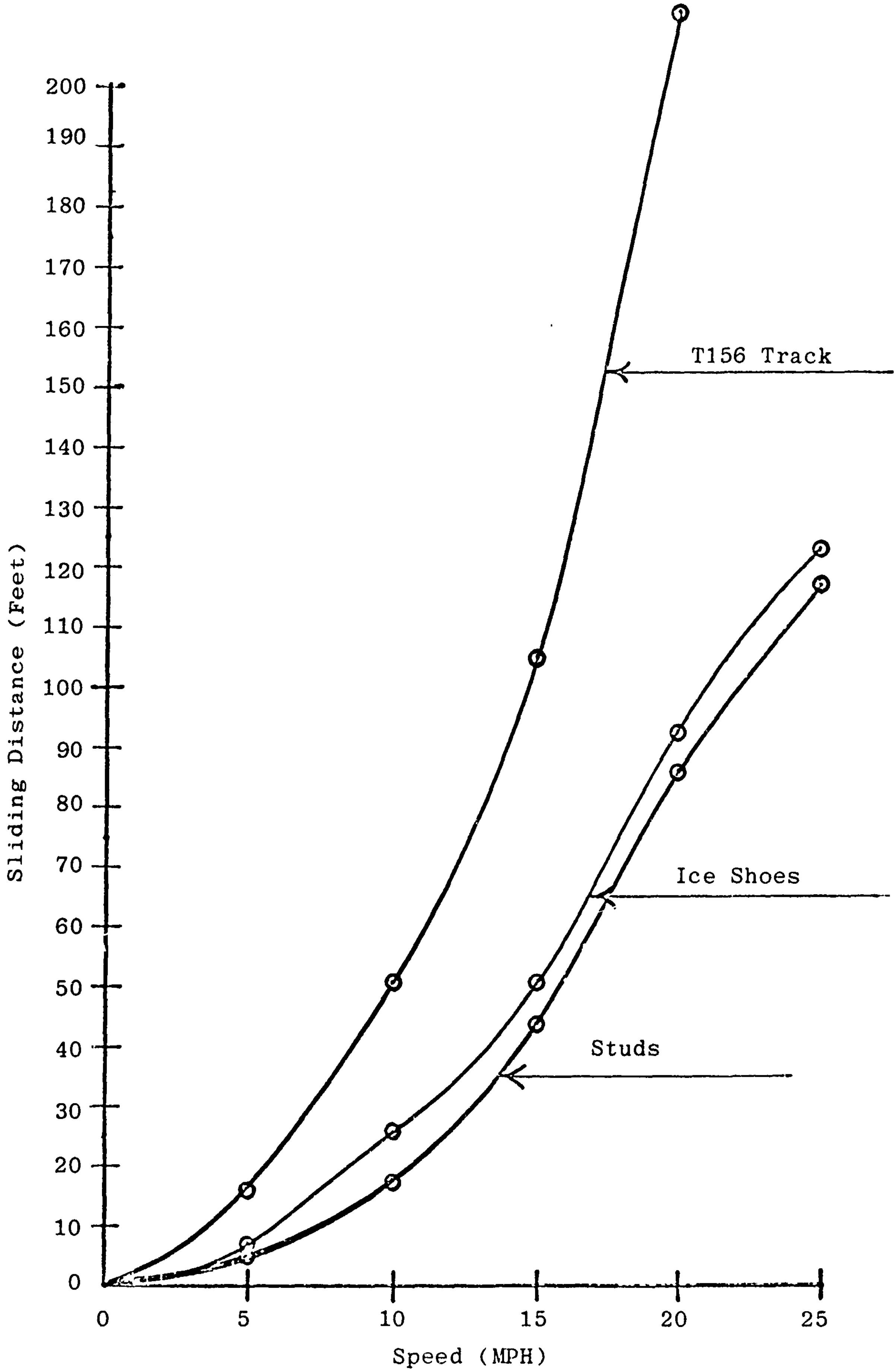


Figure 3. Sliding Distance vs Vehicle Speed

Figure 4. Ice impressions from ice shoes.

2.1 Slalom Course

The slalom course was conducted on the same level 250 ft x 150 ft ice test area used for the braking test. The test procedure was to accelerate to 7.5 MPH in the acceleration lane and enter the ice area at a constant speed. After passing the first marker, the driver adjusted his speed to make the best possible time for the course and still negotiate all the turns. Time for the course started when the vehicle passed the first marker and stopped when the vehicle passed the last marker.

The slalom course was initially set up with 50-25 ft spacing. The course had to be changed however, when the unmodified vehicle could not negotiate the course without backing up or executing a controlled spin.

Another slalom course was set up with 40-40 ft spacing, but the unmodified vehicle failed that course as well. Finally, a course with 50-50 ft spacing was set up. This spacing was considered the minimum spacing the vehicle could negotiate with normal turning maneuvers. Figure 5 is a diagram of the slalom course.

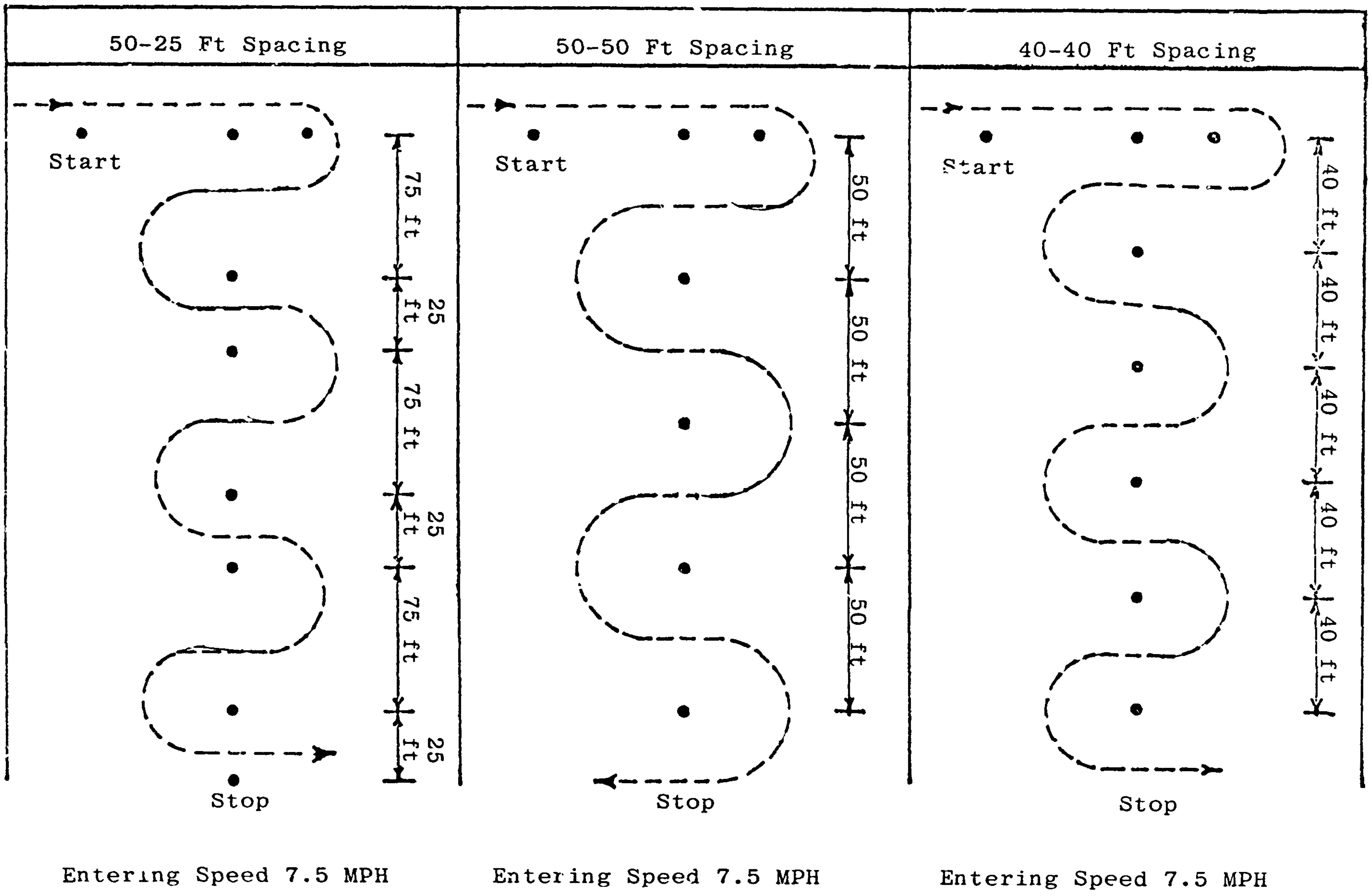
2.1.1 T156 Track

The T156 track was evaluated on the iced slalom courses to establish a base line. As expected, the unmodified track was the least effective at negotiating the terrain.

2.1.2 T156 Track with Ice Shoes

The ice shoes were evaluated on the 50-25 ft and the 50-50 ft spaced ice slalom course. There was signficiant improvement in maneuverability on the ice with the ice shoes installed.

Figure 5. Iced Slalom Courses
M1 Traction Aids



2.1.3 T156 Track with Tungsten Carbide Studs

The carbide studded track gave the best performance on the iced slalom course. Table 2 shows the results of the slalom test for each track and course configuration.

2.2 Variable Slope Climb

The slope climb test was conducted to determine the maximum slope each vehicle track configuration could negotiate. The slope was a prepared ice surface which gradually increased from 0 to 18 degrees. The slope was cleared of snow before each track configuration was tested and resurfaced at the completion of each test.

The test procedure was to start at the base of the slope and accelerate up the slope as far as possible. When the tracks began to slip, the driver would apply and hold the brakes. In all cases the vehicle would slide to the base of the slope.

Once the vehicle started to slide backwards there was nothing the driver could do to stop the vehicle. The traction aids were ineffective at holding the vehicle on the slope once the vehicle started to slide. The maximum slope the vehicle negotiated was measured for each track configuration.

A second part of the slope climbing test was to determine the maximum slope on which the vehicle could hold itself without sliding backwards. This was determined for each track configuration by driving the vehicle up the slope 4 to 6 feet at a time and stopping.

The maximum slope at which the tracks would hold the vehicle on the slope without sliding backwards was recorded. This was always less than the maximum slope the vehicle could climb. Table 3 shows the results of the slope climb and the brake holding tests for each track configuration. Figure 6 is a photograph of the slope used for the tests.

Table 2. Slalom Test Results
Entrance Speed 7.5 MPH

Time to Negotiate Course in Seconds

Spacing	Run #	T156	Ice Shoes	Studs
50-25 ft	1	280	120	70
	2	195	82	65
	3	---	72	65
40-40 ft	1	150	---	--
50-50 ft	1	83	59	41
	2	---	58	39
	3	---	---	40

Table 3. M1 Traction Aids
Variable Slope and Brake Holding Test Results

	T156	Ice Shoes	Studs
Maximum Slope Climb	10°	15°	18°*
Maximum Brake Holding	5°	7°	15°

* Vehicle was able to negotiate the top of the slope.

Figure 6. Variable Iced Slope

3.0 DEEP SNOW MOBILITY

Discrete performance tests were conducted on the M1 equipped with traction aids for deep snow mobility. Turning maneuvers were conducted in deep snow with and without traction aids. Tests were conducted in undisturbed snow on a 2.3-mile closed loop course and on a 0.9-mile (hard-packed snow) plowed road.

Figure 7 is a general map of the test area used. Table 4 shows the snow density during the deep snow mobility tests.

3.1 Deep Snow Turning Mobility

A series of start, stop, forward and reverse, and turning maneuvers were used to determine vehicle characteristics and mobility in deep snow. The deep snow turning mobility test areas are identified as areas 1 and 2 on the test area map (Figure 7).

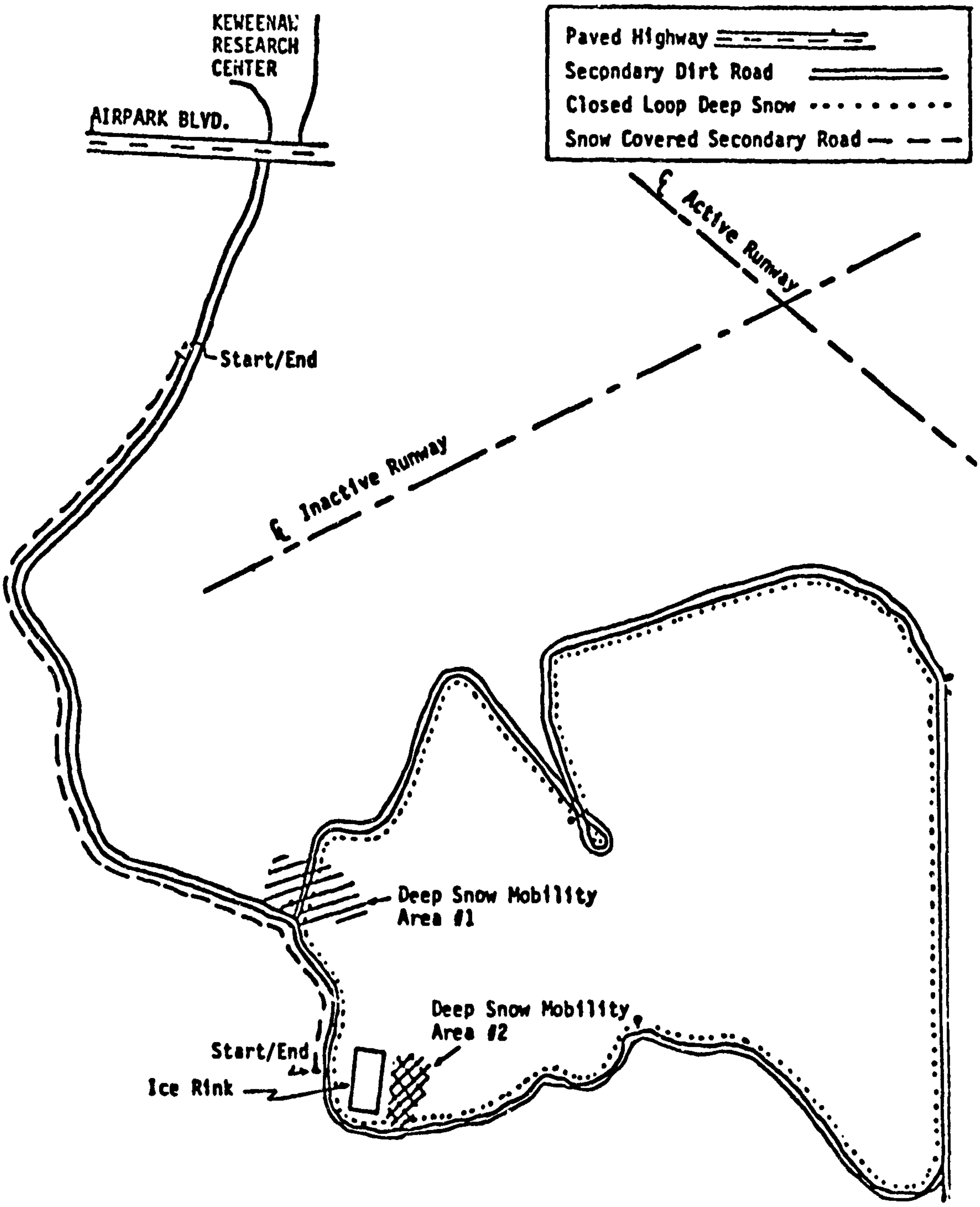
The T156 track and the ice shoes were evaluated in test area 1, and the studded track was evaluated in test area 2. In all cases, the vehicle would compress the snow 6 to 12 inches and float on the compressed snow. The snow depth was 30 to 36 inches.

Turning ability was limited with the T156 track, because of sluggish steering and vehicle drifting. Linear motion including starting and stopping, was no problem. With the installation of the ice shoes or studs, the turning mobility and steering response was improved. Figure 8 shows the vehicle in deep snow. Note the snow compacted by the hull.

During the deep snow turning maneuvers, snow pressure on the number 7 skirt pushed the skirt into the drive sprocket. Both number 7 skirts, right and left, were removed for the rest of the testing. Figure 9 shows the damaged track skirt.

Figure 7

Test Area Map



Track Configuration	Ambient Temp. (°F)	Average Snow Depth (in)	Sample Location*	Sample No. **	Depth of Sample (in)	Temp. of Sample (°C)	Density of Sample (gms/cc)	Average Density (gms/cc)
T156	19	42	1	1	6	-9.0	.302	.303
				2	12	-4.5	.276	
				3	18	-1.0	.332	
T156	18	42	1	1	6	-12.0	.176	.286
				2	12	-10.0	.336	
				3	18	-8.0	.276	
				4	24	-4.0	.296	
				5	30	-2.0	.346	
Ice Shoes	10	44	1	1	6	-8.0	.262	.325
				2	12	-5.0	.328	
				3	18	-4.0	.360	
				4	24	-2.0	.350	
Studs	30	38	2	1	6	-5.0	.255	.328
				2	12	-4.0	.302	
				3	18	-3.0	.318	
				4	24	-3.0	.363	
				5	30	-3.0	.401	

*Sample location refers to the deep snow mobility areas shown on the general area map.

** Several samples were taken after each of the first deep snow mobility tests of each track type. the samples were taken at the indicated depth randomly next to the track path taken by the tank.

Table 4. Snow Density During Deep Snow Mobility

Figure 8. Deep Snow Mobility Test. Snow compacted by tank hull.

Figure 9. Deep Snow Mobility Test. Damaged track skirt.

3.2 Closed Loop Test

A deep snow mobility test was performed to evaluate the effectiveness of the traction aids. The course was 2.3 miles long with gentle curves and level terrain.

The closed loop course was not attempted with the standard T156 track because of the limited mobility exhibited in the deep snow mobility test area. The ice shoes and studded track improved the vehicle mobility and steering response. Table 5 shows the results of the closed loop, deep snow mobility test.

Figure 10 is a map of the test course. The snow depth is indicated at random points along the course. Figure 11 shows the test vehicle negotiating deep snow on the 2.3-mile closed loop course.

3.3 Hard-Packed Snow (Secondary Road)

A snow-covered secondary road was used to evaluate the traction devices on hard-packed snow. The test course was 0.9 mile long.

The test procedure was to start from a stop and complete the course in the best time possible while remaining on the road. Table 6 shows the results of the speed runs for all track configurations.

Traction devices improved the vehicle's time to negotiate the course. Traction devices also improved mobility in snow. However, the test results are inconclusive as to what type of traction aid is best for snow mobility.

4.0 GENERAL OPERATIONS

Comments on general operations are subjective evaluations from observations of the vehicle performing in deep snow, on ice, and on hard-packed snow.

Table 5. Closed Loop Deep Snow Mobility Test Results

	Time (min/sec)	
Run #	Ice Shoes	Studs*
1	10:41	9:50
2	9:52	8:55
3	-----	8:40
Average	10:18	9:06

Table 6. Snow-covered Road Test Results

Time in minutes/seconds

Run #	T156	Ice Shoes	Studs
1	2:45*	2:02	2:01*
2	2:33*	2:05	2:04
3	2:57*	2:19*	2 01
4	2:16	2:04	1:57
5	2:12	1:53	2:22*
6	2:12	2:04	2:01
7	----	----	2:13
8	----	----	2:04
AVERAGE	2:29	2:05	2:05

* Vehicle left the roadway during the run.

NOTE: 2:00 min = 27 MPH for this course.

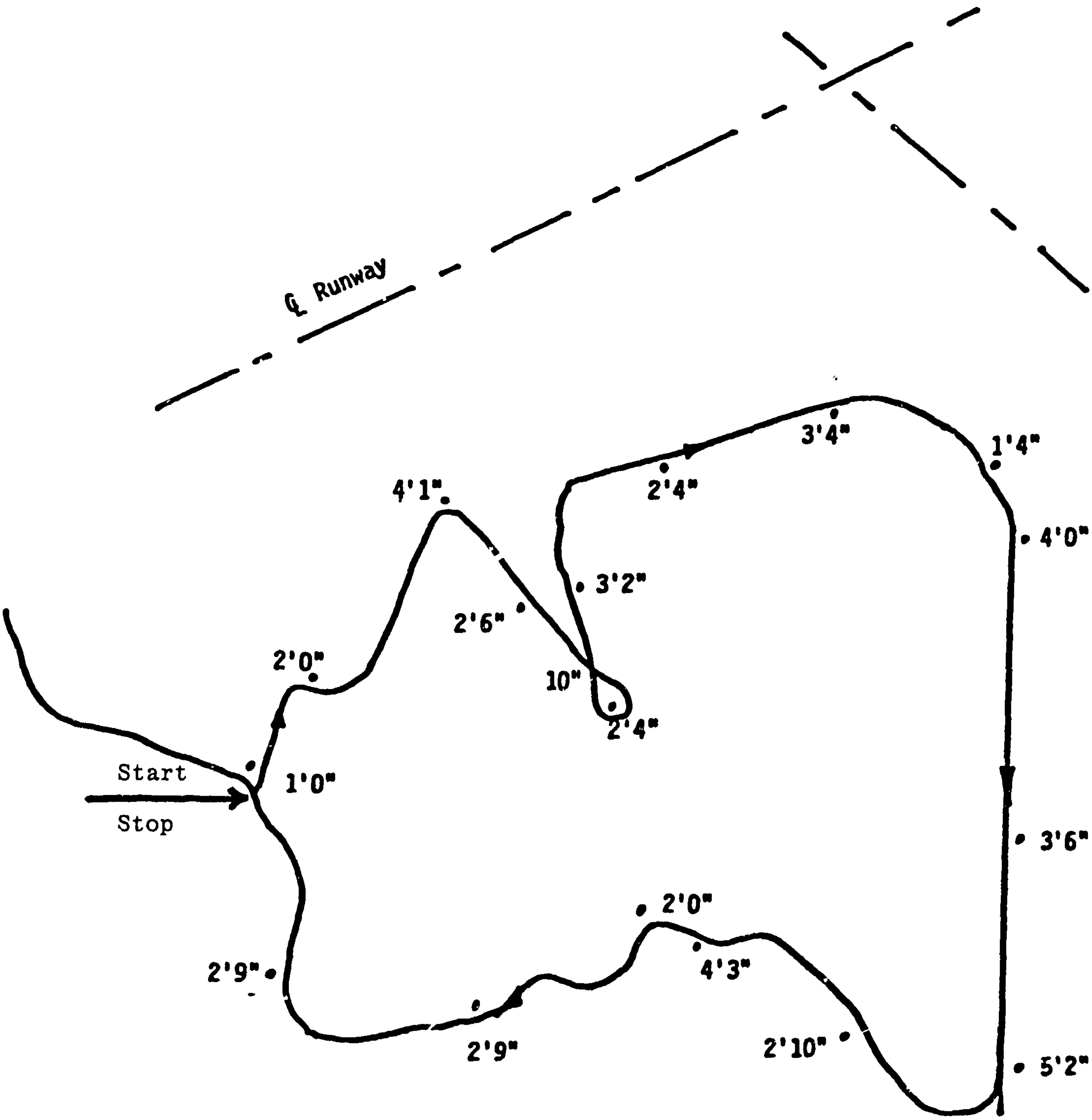


Figure 10. Closed Loop Test Course
(Snow depth in feet and inches)

Figure 11. Vehicle Negotiating Deep Snow

4.1 Deep Snow

Deep snow operation with the standard track was limited because the vehicle response to steering input was sluggish and the vehicle would drift during turning. The vehicle would compress the snow 6 to 12 inches when traveling in a straight line.

It should be noted that during deep snow operation, the vehicle would nose-dive into the snow. With the downward slope of the hull, the front of the vehicle would act like a snow scoop. This action results in snow build-up in the driver area where it can be a potential safety hazard.

At higher speed, snow build-up becomes an even greater problem because the wiper cannot keep up with snow build-up. This requires operation with the driver's hatch open, which allows snow to enter the driver's compartment. Figures 12, 13 and 14 show examples of one such instance. Most of the snow was removed from the driver's compartment before the photographs were taken.

It was felt that the driver would have to have considerable skill in driving in deep snow if the T156 track is to be used without traction aids.

4.2 Ice Operation

The general operation of the vehicle with the standard T156 track on ice was marginal. The vehicle could not negotiate the slalom course without backing up. Steering response was sluggish because the inside track would remain stationary and the outside track would spin. Trying to maneuver in a confined area would be very difficult. The same would be true when negotiating up or down icy slopes or hills.

The traction aids improved the steering response and maneuverability on ice, but the driver had to be careful on icy slopes because when the vehicle started to slide, it was out of control.

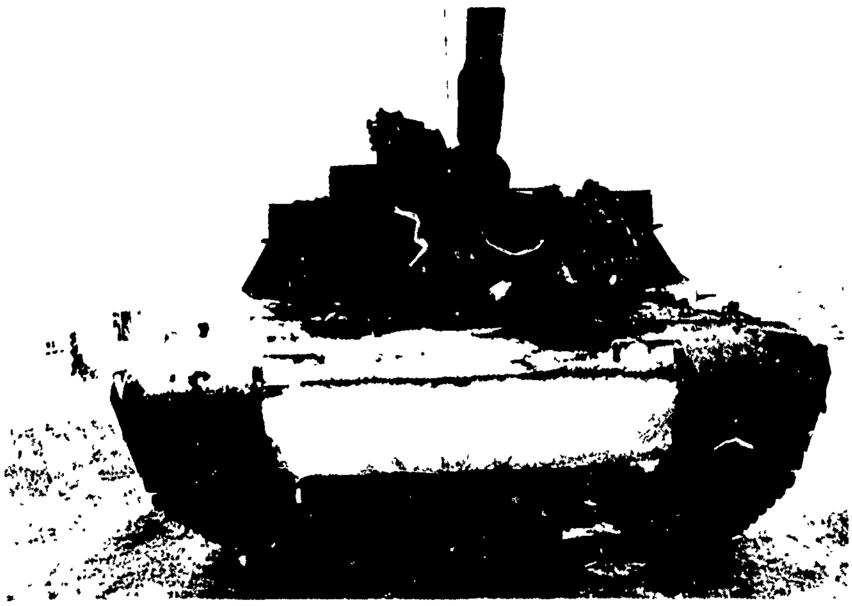


Figure 12. Snow on Front of Hull

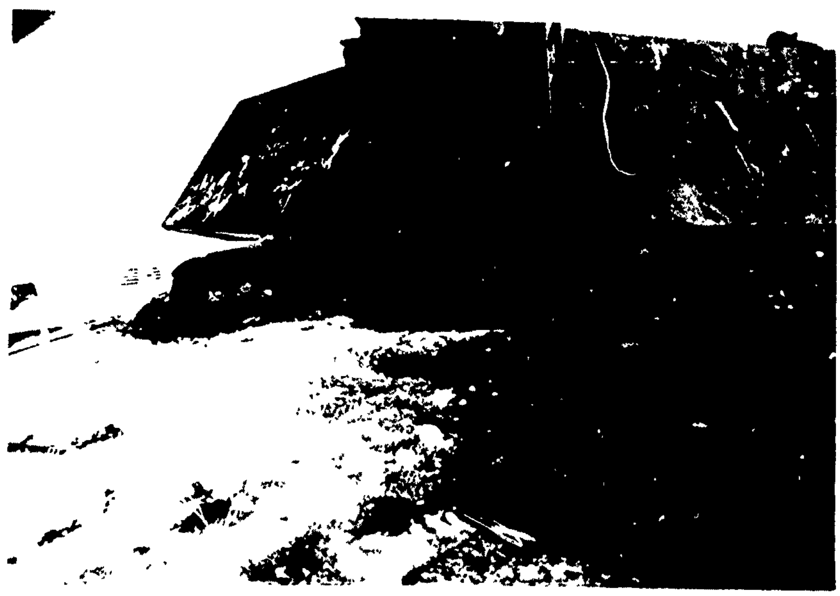


Figure 13. Snow on Top of Hull

Figure 14. Snow in Driver's Compartment

4.3 Hard-Packed Snow (Secondary Road)

A subjective evaluation of the vehicle maneuverability on hard-packed or plowed snow was conducted. The standard T156 track was ineffective in maneuvering the vehicle in confined areas. The driver had considerable difficulty in turning 90 degrees to put the vehicle into the maintenance garage. The area was covered with packed snow from support vehicles in the same area. Depth of the packed snow was 6 to 12 inches.

The M1 test vehicle could not turn on the packed snow with the standard T156 track. If one track was locked (braked) for turning, the driver's side would slip. If a pivot turn was attempted, both tracks would spin in opposite directions. In order to get the vehicle into the maintenance garage, the driver would move the vehicle forward and backward a few feet at a time while turning slightly. The problem was finally corrected by sanding the snow and grading the snow away the next day.

Without traction aids the T156 track is ineffective in snow or on ice.

5.0 VEHICLE SNOW OPERATION

Vehicle snow operation consisted of monitoring cold start attempts with and without the rear deck covered. The vehicle was equipped with transducers to measure:

1. Air cleaner restrictions
2. Transmission main oil pressures (before and after filter)
3. Transmission clutch pressures at ports C1 and C4
4. Starter crank time, voltage and current
5. Temperatures
   - engine sump
   - transmission sump
   - fuel
   - turret
   - battery (6)

The following weather data was recorded each morning at start-up:

- ambient temperature
- barometric pressure
- relative humidity
- snow accumulation
- visibility
- windspeed
- wind direction

Figures 15 and 16 show the annual snowfall accumulation and the daily snowfall, respectively, for the test period.

5.1 Air Induction System

The vehicle air induction system was equipped with a differential pressure transducer to measure the air pressure drop across the air filter. Random checks of the air induction system's differential pressure were conducted during various phases of operation to examine the affects of snow in the system. There was no indication of air restriction from blowing or falling snow, but there was a small amount of residual water in the system.

5.2 Cold Start Operation

Except when maintenance was performed, the vehicle was stored out of doors. From 15 January 1982 to 14 February 1982, the rear deck was covered with a tarp when the vehicle was parked for the evening. After 14 February, the deck was left uncovered.

5.2.1 Rear Deck Covered

On the first day of the test, the first two cold start attempts failed. Investigation into the problem indicated that these failed attempts were due to low batteries. The third and all subsequent starts were successful in 20 to 28 seconds of crank time.

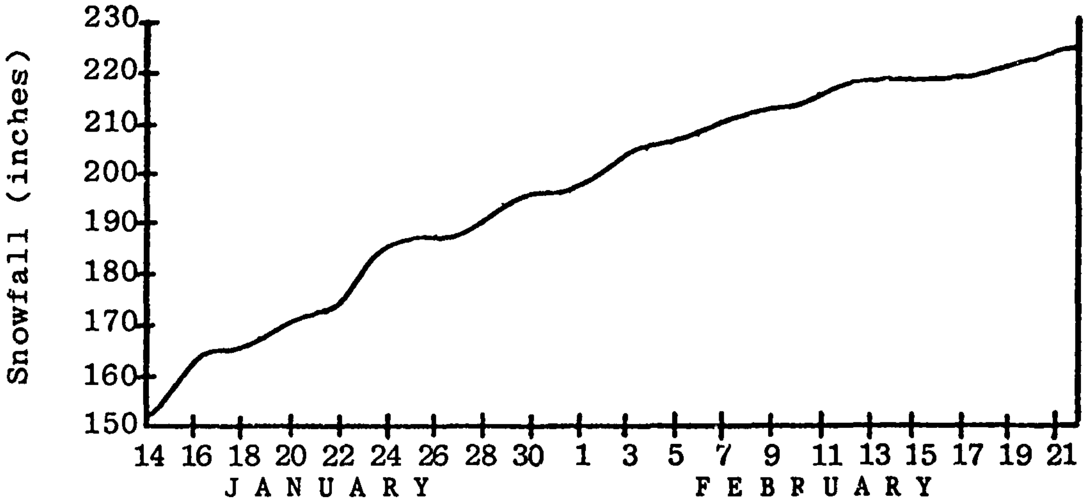


Figure 15. Annual snowfall accumulation

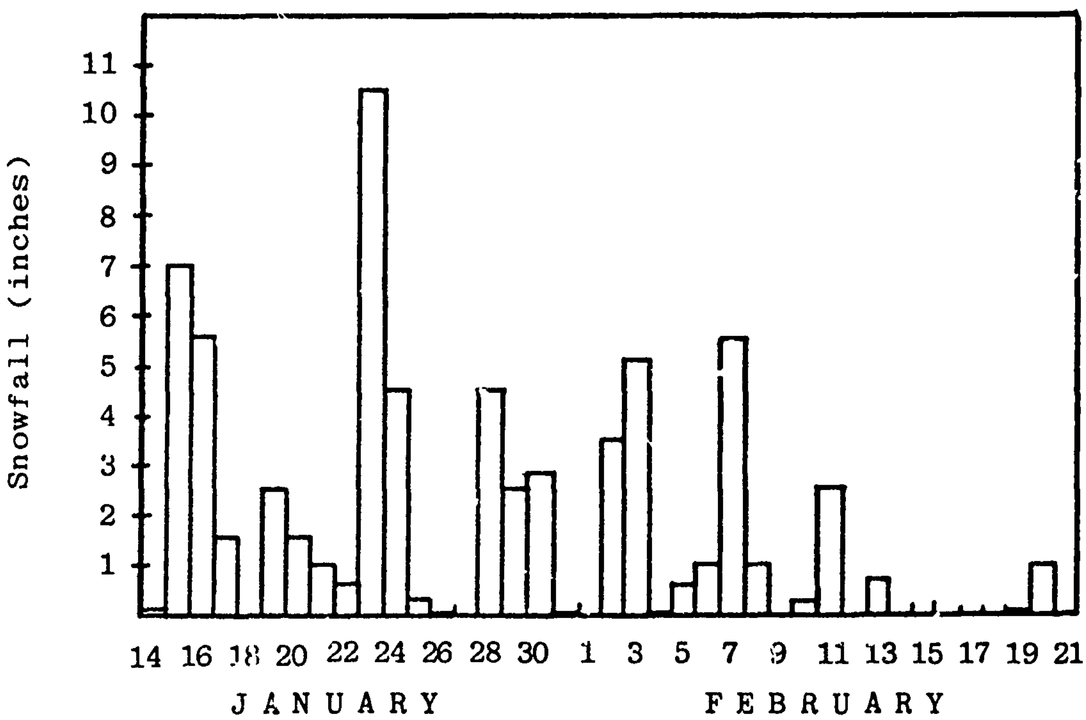


Figure 16. Daily snowfall

5.2.2 Rear Deck Uncovered

When the vehicle was stored out-of-doors with the rear deck uncovered, snow entered the air intake system. It is recommended that the rear deck be covered to prevent this from happening.

The first two start attempts with the vehicle rear deck uncovered were aborted by the driver because starter noise and voltage indicated the starter drive unit did not engage. Again, all subsequent starts were successful. Table 7 is a summary of all cold start data. Figure 17 is a daily temperature profile for the test period.

5.3 Powertrain Testing

Powertrain tests consisted of measuring the transmission clutch pressures, main oil pressures before and after the filters, and the transient time for the pressures to stabilize. The data was recorded at each start in the morning and is shown in Table 7. Table 8 lists transmission oil pressure build-up times for five random dates. The average build-up time and standard deviation are also included.

A transmission cold soak was performed over a 60-hour period. It required approximately 24 hours for the transmission temperature to drop from 70°F to 10°F (ambient temperature). Figure 18 shows the transmission and ambient temperature versus time.

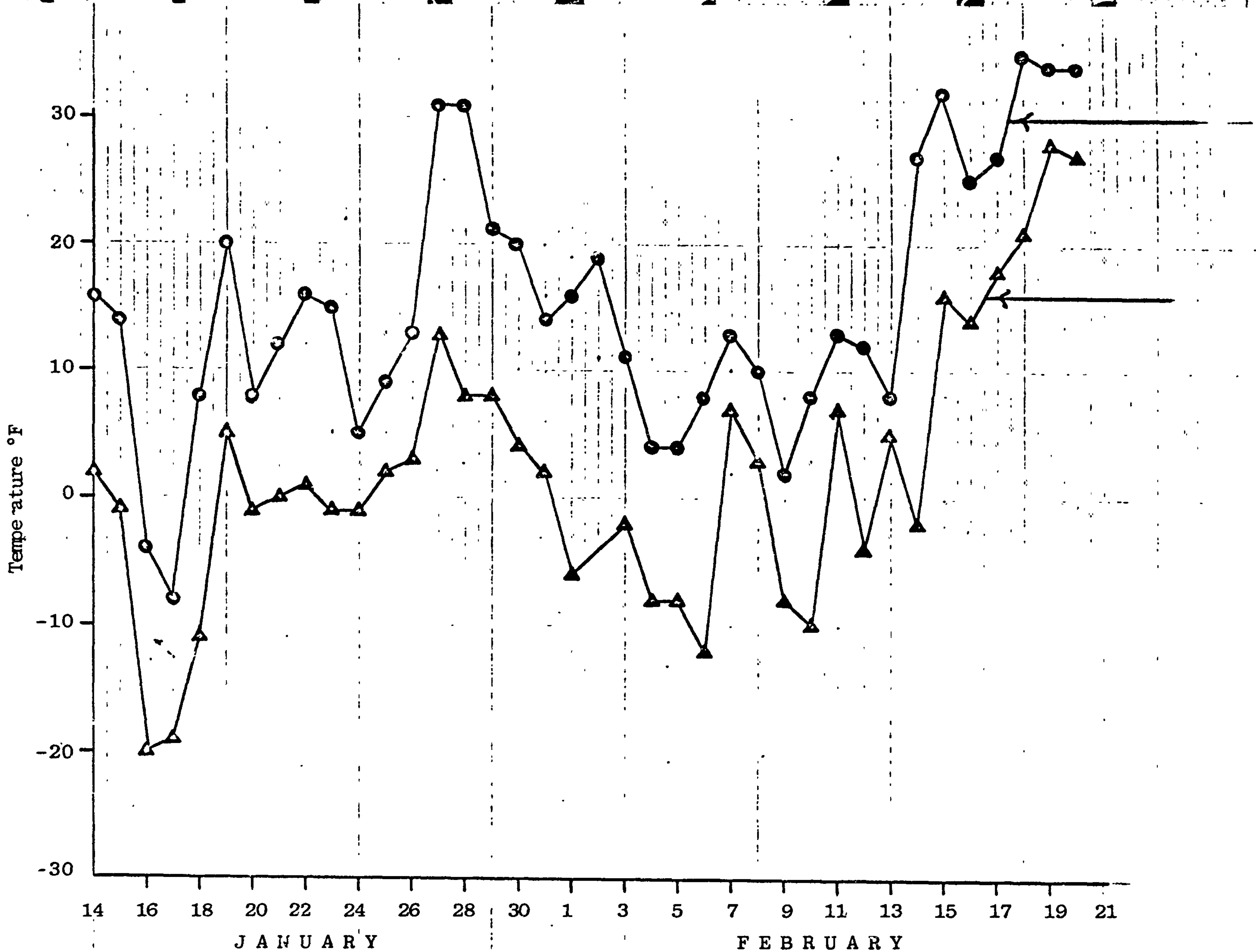


Figure 17. Daily Temperature Profile

DATE	AMBIENT TEMP. (deg. F)	BARO. PRESSURE (mB)	TIME (EST)	RELATIVE HUMIDITY (dp °F)	SNOW ACCUMULATION (inches)	Visability (miles)	WIND SPEED (knots)	WIND DIRECTION (deg. from N)	TEMPERATURES (deg F) ENGINE SUMP	TRANS SUMP	FUEL	TURRET	BATTERY (sp. gravity) 1	2	3	4	5	6	CURRENT, PEAK[1] (amps)	VOLTAGE, AVE. (volts)	CRANK TIME (sec).	TRANS. PRESSURES (psi) (RISE TIME, SEC) Main Before	Main After	C_3	C_4	COLD SOAK LOW TEMP. (deg F)	
1-1?-82	-5	29.97	10:00	83 %	11	30	0	•	-6	-7	-9	-8	-8 (1100)	-3 (1200)	-3 (1250)	-7 (1250)	-8 (1230)	-10 (1240)	2000+	18	60	[illegible]	4	•	•	-20	Abort[2]
																			2000+	18	60	•	•	•	•	•	Abort[2]
																			2000+	19	52.4	300	300	•	300 (3.2)	•	Start
1-23-82	2	•	8:00	100%	4	10	6	45	42	41	21	24	30 (1230)	32 (1230)	32 (1225)	47 (1200)	33 (1230)	24 (1225)	2000+	22	23.0	300	275	250 (1.6)	290 (2.3)	-2	Start
1-19-82	14	28.70	8:40	•	0	5	13	183	22	40	37	21	23 (1200)	22 (1175)	22 (1220)	23 (1200)	24 (1215)	24 (1190)	2100+	22	20.4	•	•	260 (1.3)	310 (3.1)	5	Start
1-?-82	5	28.90	9:40	•	15.5	4	10	0	7	14	3	•	5 (1225)	1 (1100)	3 (1175)	- (1235)	1 (1275)	1 (1260)	2100+	21	28.0	300	300	290 (1.0)	300 (4.2)	-1	Start
1-26-82	4	29.36	6:50	•	0	3	.04	253	51	31	10	20	26 (1260)	27 (1260)	28 (1260)	32 (1275)	29 (1260)	25 (1255)	2100+	22	20.4	290	200	270 (1.5)	260 (1.0)	1	Start
2-4-82	-7	29.29	8:45	dp -11	2.0	15	3	243	•	•	•	•	•	•	•	•	•	•	2200	21	22.0	300	300	300 (1.2)	290 (2.0)	-5	Start
2-5-82	-3	29.22	8:30	dp -8	•	18	10	273	46	24	•	3	20	21	22	24	24	21	2900	21	21.8	300	300	290 (1.5)	300 (1.0)	-8	Start
2-?-82	3	28.??	8:45	dp 0	1.5	20	12	243	8	2	6	•	20	22	16	28	•	22	3200	20	24.8	300	300	290 (1.0)	300 (4.5)	3	Start
2-12-82	0	29.31	8:30	dp -3	0	20	0	240	46	21	20	7	24	26	26	27	25	21	2000	22	22.0	295	295	295 (2.0)	295 (2.0)	-4	Start
2-13-82	12	29.99	8:15	dp 9	1.6	3	5	360	58	40	30	19	32	33	34	40	38	36	2800	22	21.6	200	200	200 (4.0)	190 (2.0)	4	Start
2-15-82	29	30.47	6:15	dp 27	0	3	16	360	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	Abort[3]
									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	Abort[3]
									-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	Start
2-16-82	19	29.07	8:00	13	0	40	11	80	47	19	24	19	31	33	34	37	36	33	2800	22	22.0	200	200	160 (1.6)	150 (1.0)	14	Start
1-18-82	23	28.84	7:30	18	0	20	12	140	50	32	28	26	33	34	35	35	35	33	3000	22	22.0	300	300	300 (1.5)	300 (2.2)	23	Start
1-19-82	32	28.75	7:45	31	0	1.0	17	260	32	•	20	11	25	26	25	30	31	30	3200	22	22.0	300	300	300 (1.6)	300 (1.6)	20	Start

1. Scaling and zero adjusted) Current readings 2-4-82 to fully record spike input.
2. Abort Due to time out, Low battery voltage cause of problem.
3. Starter did not engage on first two attempts, driver aborted start.

Table 7. Cold Start Summary

Table 8. Transmission Oil Pressure Build-Up Time

Date	Build-Up Time (Sec)	$r_k - \bar{r}$	$(r_k - \bar{r})^2$
02/05/82	21.5	-.70	.49
02/12/82	22.4	.20	.040
02/13/82	22.0	-.20	.040
02/16/82	22.5	.30	.090
02/19/82	22.8	.60	.36

where r_k = build-up time

$\bar{r}$ = average build-up time

N = number of trials

$$\text{Standard Deviation} = \sqrt{\sum_{i=k} (r_k - \bar{r})^2/N}$$

Average Build-up Time = 22.2 seconds

Standard Deviation = .45 seconds

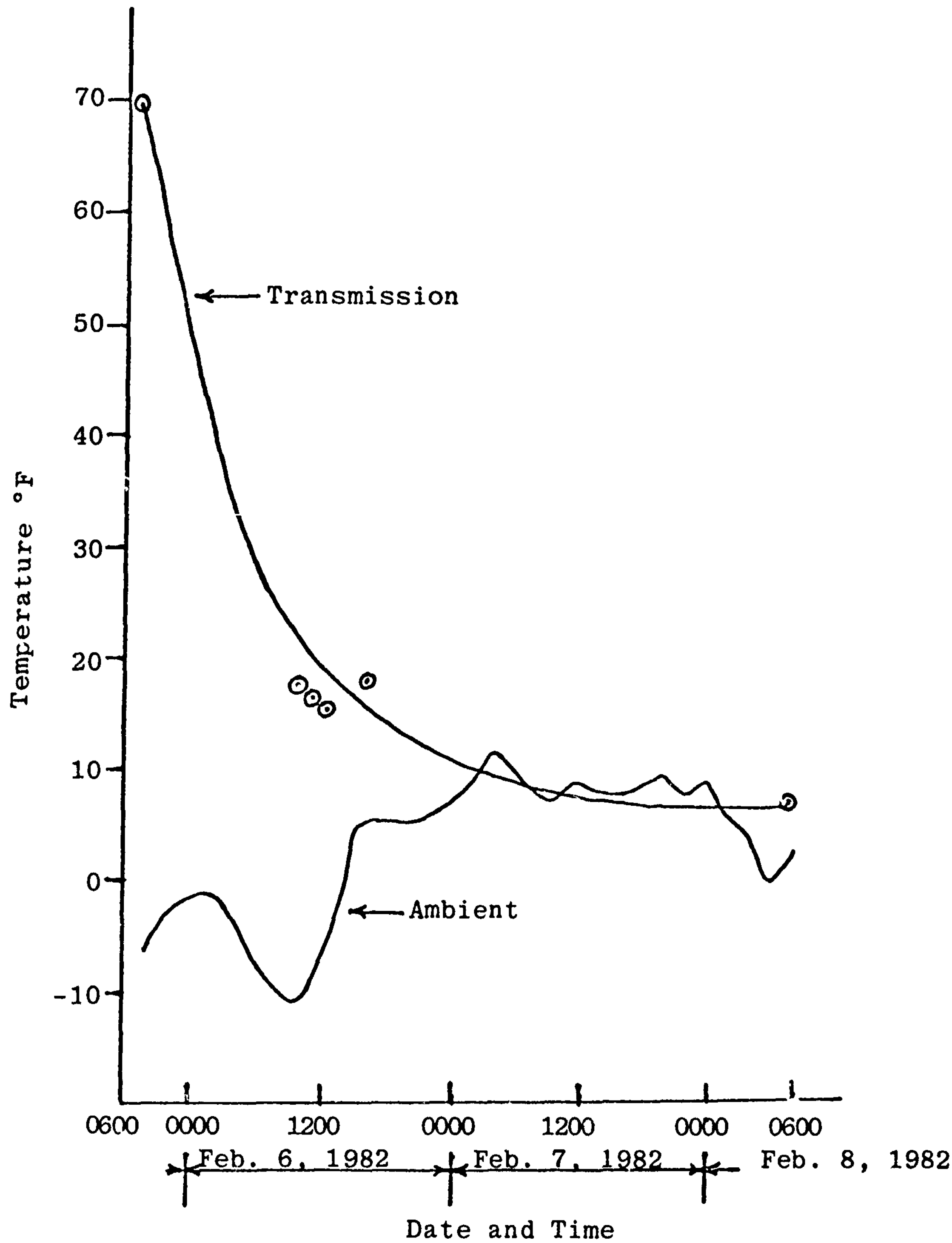


Figure 18. Transmission and Ambient Temp vs Time

6.0 Conclusions

1. Ice shoes and studs improve the snow and ice mobility over the T156 track.

2. The T156 track is not recommended for use in deep snow or on ice without traction aids.

3. The air induction system was not affected by snow ingestion.

4. Transmission oil temperature did not exceed design limits.

5. Transmission oil pressure did not exceed design limits.

6. Transmission oil pressure build-up time was well within limits.

APPENDIX A

A-1 ICE SHOE INSTALLATION

The ice shoes used were furnished by the government. They were installed on every second track shoe.

Ice shoes were mounted as an accessory and therefore could be installed and removed without any modifications to the track. They are held in place between the two pads with a 5/8-in. lock-tight bolt. Figure A-1 shows the ice shoe installation and track pad relation. The ice shoe protruded 1/2 in. to 5/8 in. above the pad surface. Figure A-2 shows the ice shoe installed on the track.

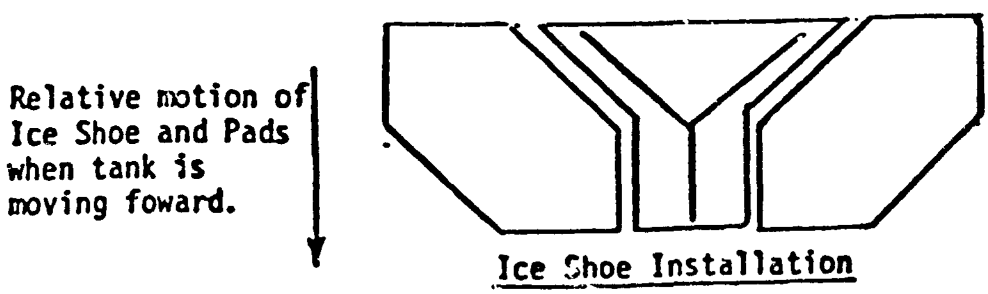


Figure A-1. Ice Shoe Installation

Figure A-2. Ice Shoe Installed on Track.

A-2 TUNGSTEN CARBIDE STUDS INSTALLATION

Tungsten carbide studs were installed five per track pad in a random pattern a minimum of 1 in. from the edge of the pad. A 3/8-in. hole was drilled in the pad surface 55/64-in. deep. The hole would close to 21/64-in. in diameter after drilling. A pneumatic studding gun was used to insert the studs, and the studs were seated with a lead mallet.

The studs were made by Fagersta Burks AB of Sweden, Part No. BRK-326. Figure A-3 shows the stud's dimensions.

Dimension code	Dimension
A	.450"
B	.318"
C	1.035"
D	.525"
E	.595"
F	.092
G	.345
H	.065

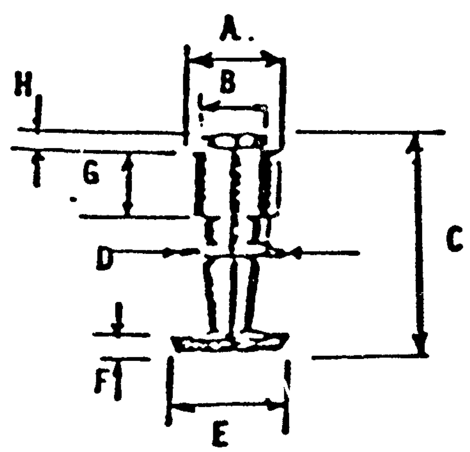


Figure A-3. Tungsten Carbide Tipped Stud.