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FIELD EVALUATION OF TANK TRACK PAD FAILURES

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April, 1983

by Lawrence Livermore National Laboratory
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This report describes a series of experiments that were performed at the Yuma Proving Grounds to better understand the problem of track pad failures. In one series of tests, high speed motion photography was used to study the deformation and operational characteristics of the T142 track. In another series of tests, the temperature buildup in pads was studied on the T142 track. Testing was done on the paved, gravel, and cross-country courses at Yuma.

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The results of the movie studies show that significant tensile stresses were introduced into the pads as they scrubbed over obstacles. Localized loads and large applied shear stresses introduced during turning operations can also cause tensile stresses. We believe these factors have a dominant role in the cutting and chunking process.

The temperature data was taken for the surface as well as the interior of the pad and showed that high temperatures can be produced in track pads. There is also a large temperature difference between tests run on the three courses. These differences were shown to be due to the different heat generation rates produced on these three courses.

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1.0. INTRODUCTION

Lawrence Livermore National Laboratory (LLNL) is currently involved in a study of a tank track pad failure problem for the U.S. Army Tank-Automotive Command. The problem is one of limited service life and high replacement costs associated with the premature failure of the pads. The problem can be characterized by the service life obtained with the T142 track pad (used on heavy tanks — primarily, the M60) when it is tested at the Yuma Proving Grounds. On paved roads, the service life of the pad is limited by abrasion and blowouts. Up to about 3,380 km (2,000) miles of service can be obtained. On gravel or cross-country terrain, service life of the pad is limited to about 1,521 km (900 miles) and 432 km (250 miles), respectively. In addition, the mode of failure has changed from abrasion to modes that are identified in the field as cutting and chunking. Cutting is believed to result from "road hazards". These road hazards can be rocks or other rigid obstacles that produce localized loads on the pad. Cutting can also occur when the track pad is "scrubbed" over rocks. Chunking, on the other hand, can result when these cuts are propagated to failure. In other cases, chunking can result due to a single overload of a pad. A fourth type of failure, called a blowout, can also occur in tank track pads. The source of this failure is excessive internal pad temperatures produced by hysteretic heat production in the rubber. This program is primarily concerned with the failure processes that most severely limit service life — chunking, cutting, and blowout.

The objective of this study is to obtain information which can be used to extend the in-service life tank track pads. Several parallel and complimentary paths are being taken. Our first objective was to determine the source of failure. The means for solving this problem consists of analyzing failure through computational modeling, laboratory experiments, and field testing. This information will then lead to changes in the design of the track or the pad material. In addition, the information gained in this program will help identify relevant properties and parameters to be included in production or product specifications to help ensure product quality. This report is one in a series of reports on our study of this problem.

2.0. FIELD TESTING PERFORMED

This report is concerned with studies undertaken by LLNL at the Yuma Proving Grounds on the T142 track. It includes data from three separate field trips taken on May 13, 1980, January 6 and 7, 1981, and February 18 and 19, 1981. Tests were performed for a number of reasons. One was to provide some basic information on the characteristics of the pad failure problem. A second was to provide a basis for our computer modeling of the thermal and mechanical behavior of the pad. The third reason for these field tests was to provide some information that could be used to evaluate how well our computer modeling represents actual field response of the track.

Two different types of studies were undertaken in these field tests. One was designed to look at the deformation and tearing of the track pad. The second was designed to look at the temperature build-up in track pads on the three standard test courses at Yuma (paved, gravel, and cross-country). During the second series of tests we also examined the physical condition of the pads as a function of mileage on each of these test courses.

2.1. Pad Deformation Studies

The pad deformation studies were done using a high speed motion picture camera to record on film the deformation of the T142 track. The movie generated here also gave us valuable information on the kinematics and characteristics of track operation which was helpful in establishing a mechanical model of the track. The experimental setup is shown in Figures 1 and 2. One track of the tank was driven over a ramp and a movie was made of the track from both the side and underside of the pad. The ramp height was 11 1/2 inches. The track that was not being studied was supported by a hardwood beam approximately 11 1/2 inches high. Thus, the tank was level during testing. The length of the ramp was only about 6.1 feet, and since tests were started with one track on the ramp, speeds were limited. We estimate that the tank velocity varied between zero and seven miles/hour during the tests.

Figure 1. Experimental setup used in the pad deformation studies (View 1).

Figure 2. Experimental setup used in the pad deformation studies (View 2).

Testing was done to simulate different conditions of operation. In one series of tests, the track was driven over a flat surface and steel bars of three different shapes. In the flat surface tests, the track was driven over a piece of plexiglass so that the deformation of the pad could be observed from the underside of the track. The flat surface tests provided information on operating conditions in which the bottom surface of the pad is uniformly loaded (conditions such as a paved road). The three different steel bars simulated rigid obstacles that a track pad might encounter in cross-country terrain. The three bars had the following cross-sections: square, round, and L-shaped. The different shapes provided an interesting comparison of degrees of load concentration due to contact with a rigid obstacle.

2.2. Temperature Measurements:

The temperature measurement studies were undertaken to obtain the surface and internal temperature versus time response for T142 track pads. Measurements were taken for vehicle operation on each of the three standard courses at the Yuma Proving Grounds. The surface temperature were measured using a commercial surface thermometer. The pad interior temperatures were measured using a specially constructed thermocouple injection device. This apparatus pneumatically injects a fine needle (containing a thermocouple in the tip of the needle) to a preset depth in the track pad. Details of the thermocouple injection apparatus and the procedures used to calibrate this device and the commerical surface thermometer have previously been reported(1). Figures 3 and 4 show the apparatus being used in the field to measure the surface and internal temperature of a T142 track pad.

The operation procedure in this series of tests was to drive the tank and stop at predetermined distances to measure the surface and internal temperatures for a given track pad. In addition, the physical condition of the pad was visually asessed. For the gravel and cross-country courses, testing was done on a track pad with no mileage at the beginning of the test. The tank was stopped for approximately 90 seconds so that temperature measurements could be made. During this time, no significant change in temperature was recorded.

Figure 3. Surface temperature measurements being taken with the commerical surface thermometer.

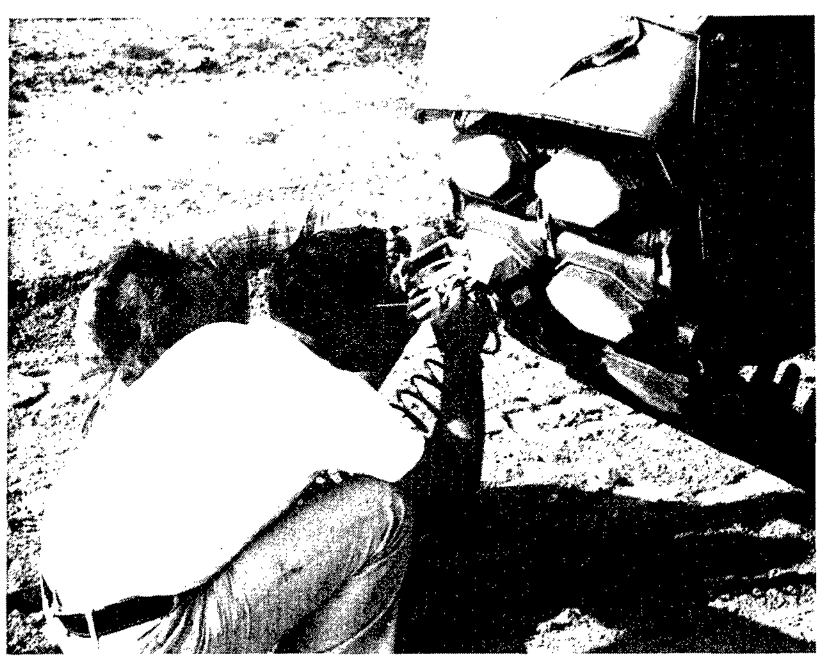


Figure 4. Interior temperature measurements being taken with the thermocouple injection device.

3.0. RESULTS

3.1. Pad Deformation Studies:

The pad deformation tests were conducted at ambient air temperature (approximately 30° C) and elevated temperature (96-126° C). For these high temperature tests, track pads were heated in an oven for approximately 1.5 hours so that the entire pad would reach a constant temperature. The pad was then bolted to the track and the test was run. During the test (approximately two minutes) no noticeable drop in interior temperature was obtained. A grid was placed on the pads so that deformations could be measured. All movies taken during these series of tests were copied and transferred to TACOM. In addition, the most informative tests were combined into a single five minute movie.

Figure 5 shows results for the flat surface test at 125° C. It is important to note that, as expected, the deformation was restricted to the plane perpendicular to the axis of the binocular tubes (no deformation along the long axis of the pad). Thus, the assumption of plane strain used in the mechanical model of the track is valid. One should also note the large frictional constaint that exists at the bottom of the pad. The side surfaces bulged but no deformation was evident along the bottom. This was also seen in the mechanical model.

Figures 6 and 7 show pads that have been heated to 97° C and 112° C, respectively, and run over the square obstacle. Figure 6 is taken from the side of the track, while Figure 7 is taken from the bottom. During contact with a rigid flat obstacle such as this, the track pad would slip and scrub over the surface. Only minimal slippage was observed in the flat surface tests. This "scrubbing" effect produced an applied shear stress on portions of the bottom surface of the pad. This shear stress produced tensile stresses and stains in the track pad. Figure 7 shows the tensile strain in the bottom surface of the pad. Tests done at different tank speeds showed that the amount of scrubbing increased with increasing tank speed. Data in the literature shows that cuts in rubber tend to propagate largely in response to tensile stresses[2,3]. Thus, one would expect this "scrubbing" process to play a significant role in the chunking phenomena observed in cross-country terrain.

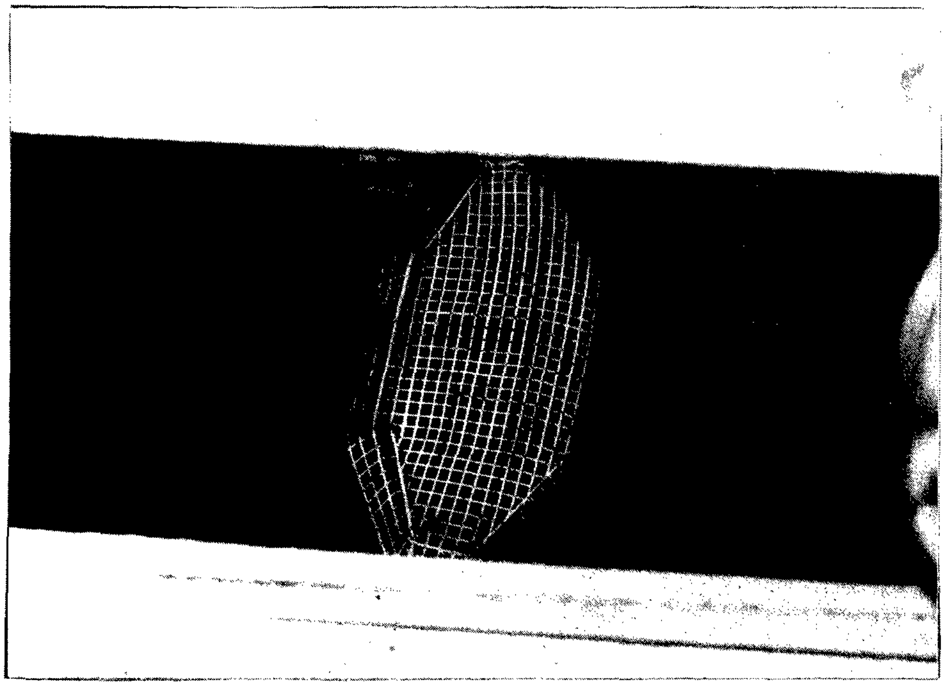


Figure 5. Photograph from the bottom of the pad showing pad deformation during contact with a flat surface. Pad temperature is 125° C.

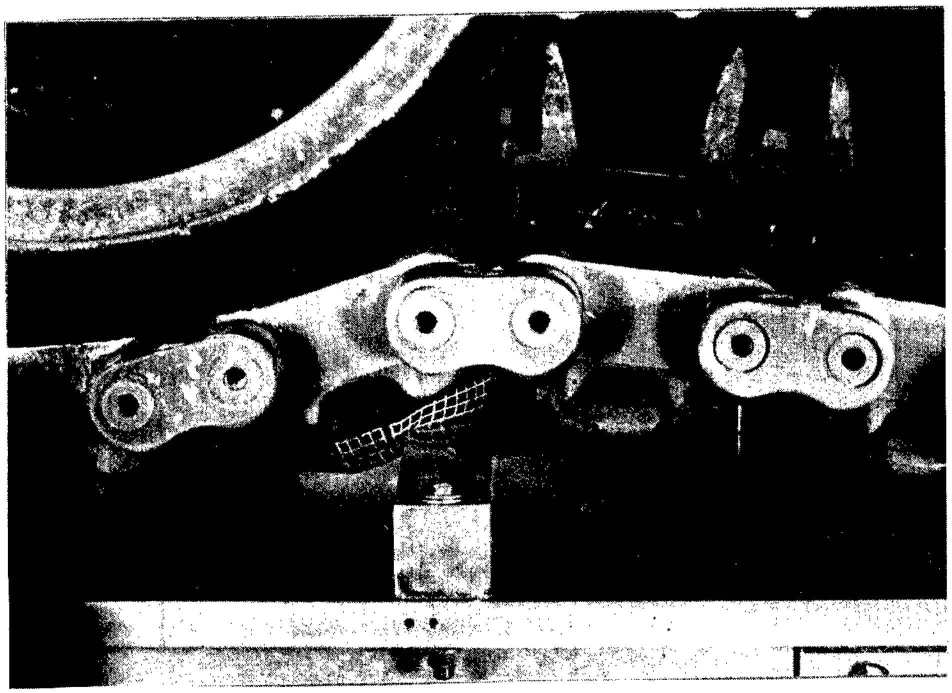


Figure 6. Photograph from the side of the pad showing pad deformation during contact with a square obstacle. Pad temperature is 97° C.

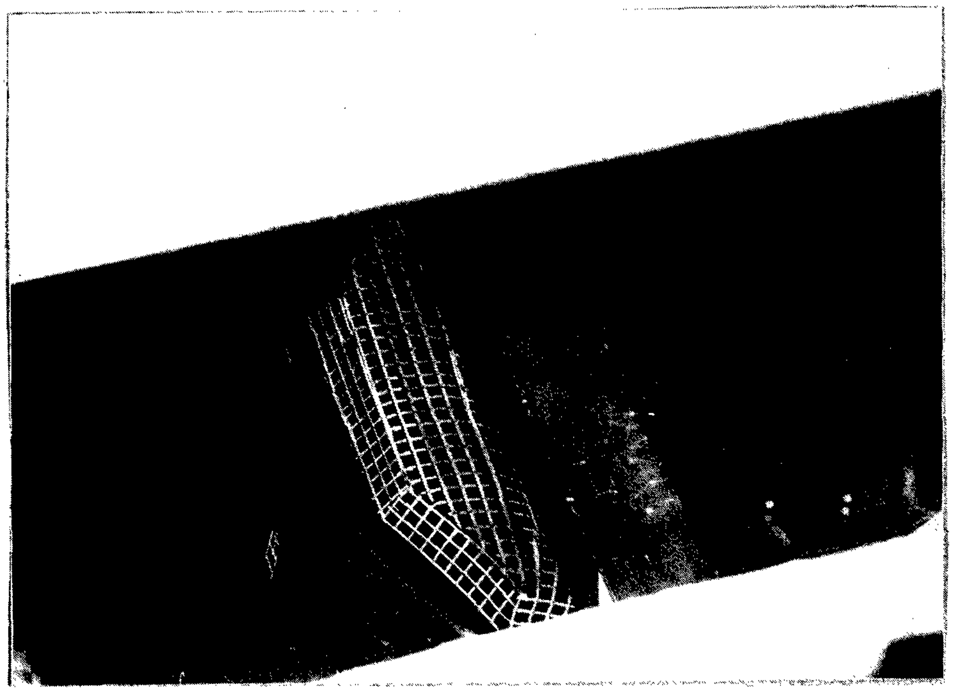


Figure 7. Photograph from the bottom of the pad showing pad deformation during contact with a square obstacle. Pad temperature is 112° C.

In Figure 8, we show a piece of rubber being torn from a track pad as it contacts the rigid obstacle.

Figures 9 and 10A-K show the large deformation that takes place when a pad strikes a highly localized rigid obstacle (L-shaped bar). In Figure 9, the pad is at ambient temperature while in Figures 10A-K the pad is at 96^{o} C. Figures 10A-K show a sequence of photographs taken as the roadwheels of the tank rolled over the track section of interest. The tension in the track from the drive sprocket is responsible for the asymmetric deformed geometry of the pad. Because the bar is deeply embedded in the pad, the tendency for scrubbing is reduced in this operating scenario relative to that for the square bar.

3.2. <u>Temperatures Measurements:</u>

3.2.1. Results on Paved Course:

Field data obtained on the paved course have been previously reported. We will repeat some of the information here so that results can be compared with data taken on the other courses. Testing was done on pads manufactured by the three vendors (arbitrarily designated as A, B, and C). In addition, for Vendor C, five pads with a distribution of previous mileage were studied. These pads included one with 724 km (450 miles), three with 1,528 km (950 miles), and one with 2,333 km (1,450 miles). In a second test, pads from Vendors A and B each with 3,200 km (2,000 miles) were employed. All testing was done at a constant speed of 32 km/hr (20 miles/hr).

Test results of pads from Vendor C are shown in Figure 11 for both surface and internal temperatures. Data are expressed as temperature versus time. All Vendor C pads tested exhibited essentially the same temperature-time response. Thus, the present data indicates that accumulated mileage has little effect on the temperatures achieved in pads. Further, during the few minutes stop-time in which measurements were made, no appreciable temperature drop was observed. Surface temperature data for pads from the three vendors correlated very closely (maximum deviation was 1^{o} C or 2^{o} F). However, for the

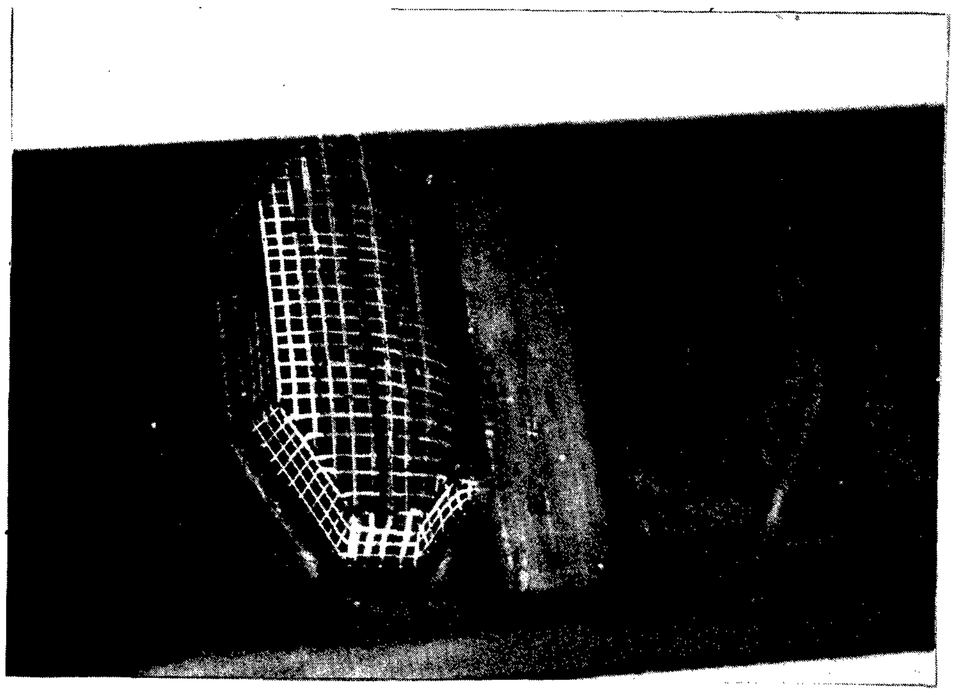


Figure 8. Photograph showing rubber being cut due to contact with the square obstacle. Pad temperature is 30° C.

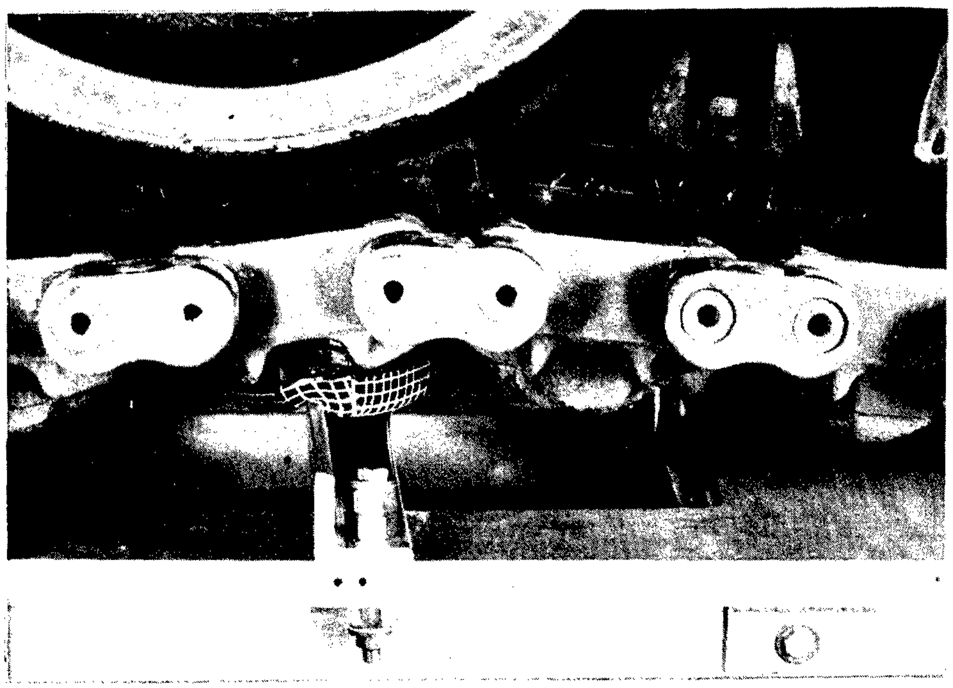
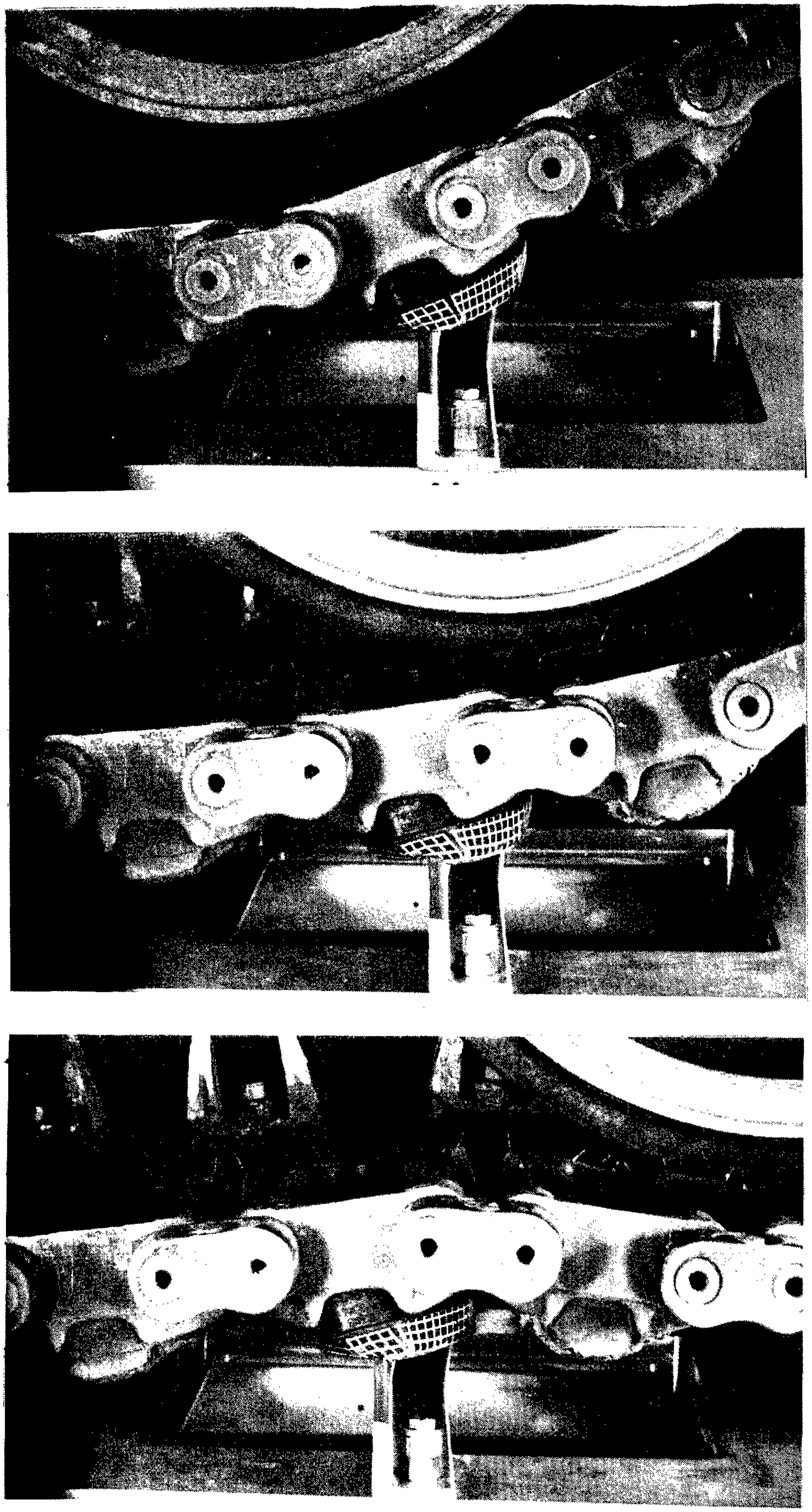
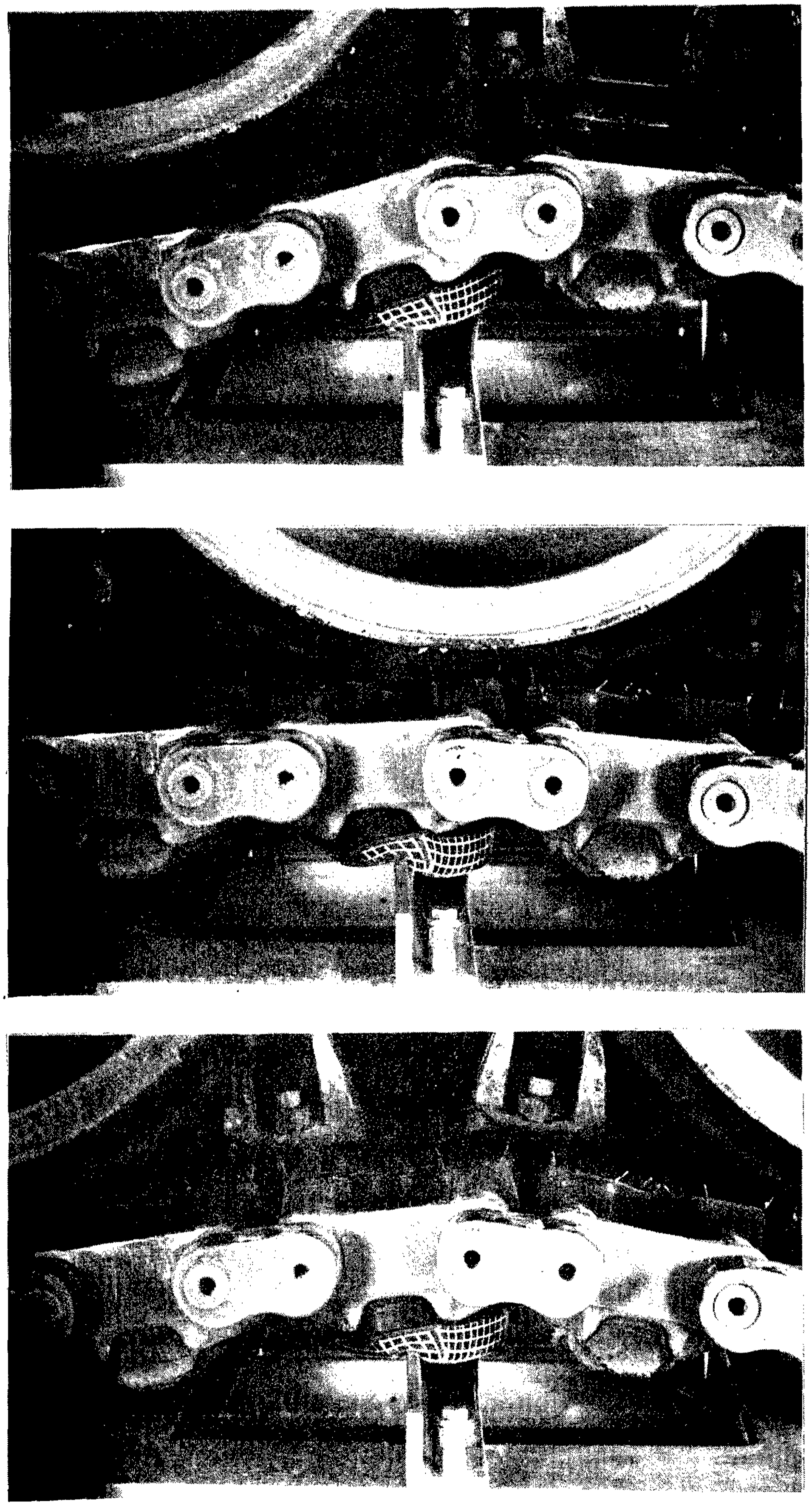


Figure 9. Photograph from the side of pad showing deformation during contact with the L-shaped obstacle. Pad temperature is 30° C.

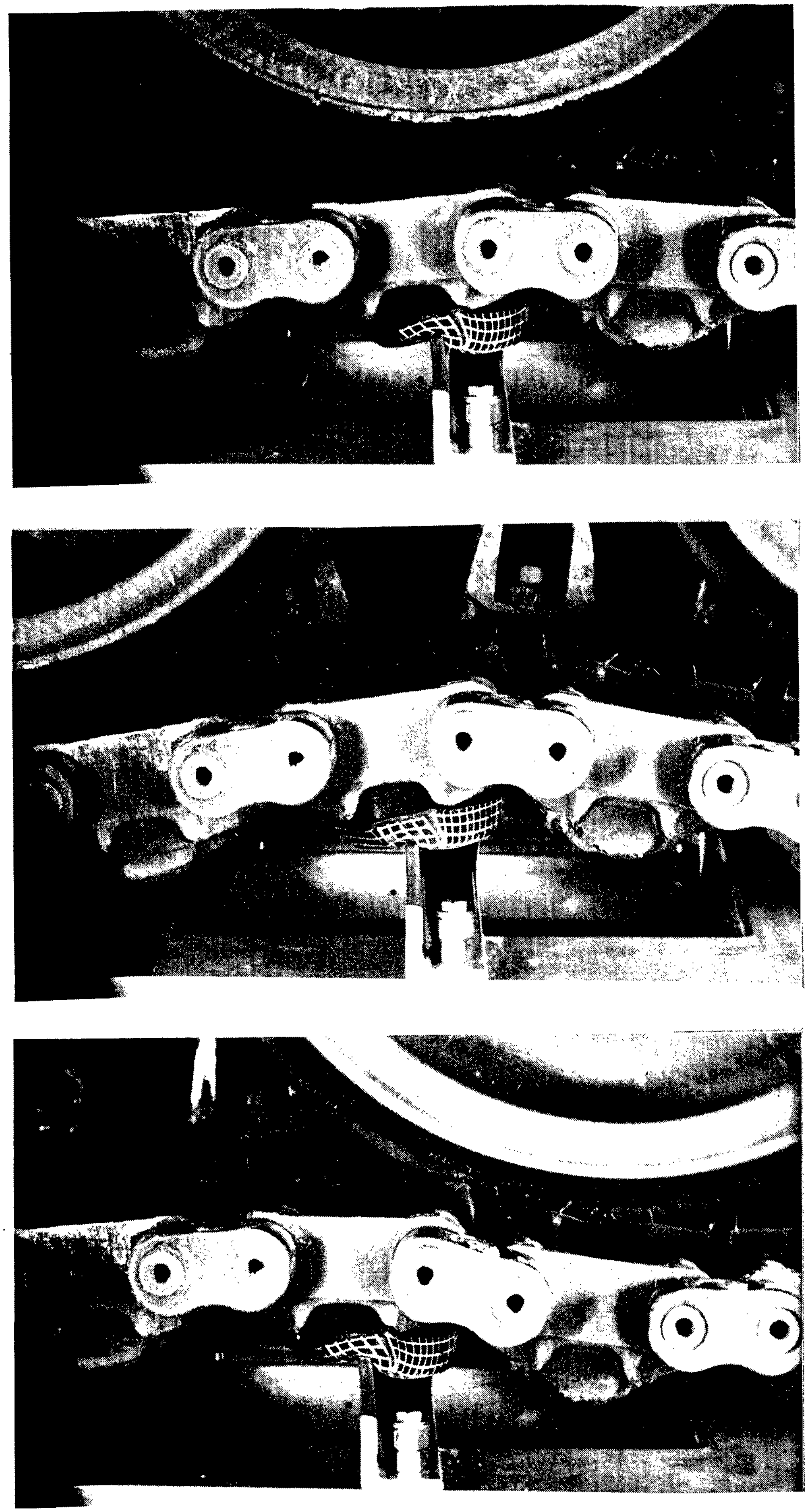


Figures 10A, B, & C.

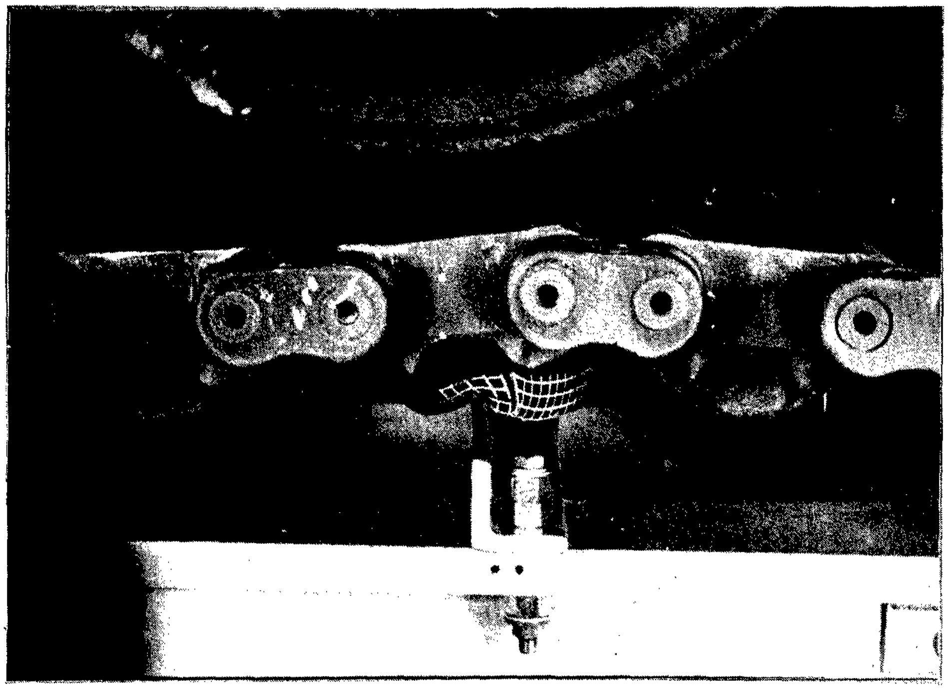
Photographs from the side of the pad showing deformation during contact with the L-shaped obstacle. Pad temperature is 96° C.

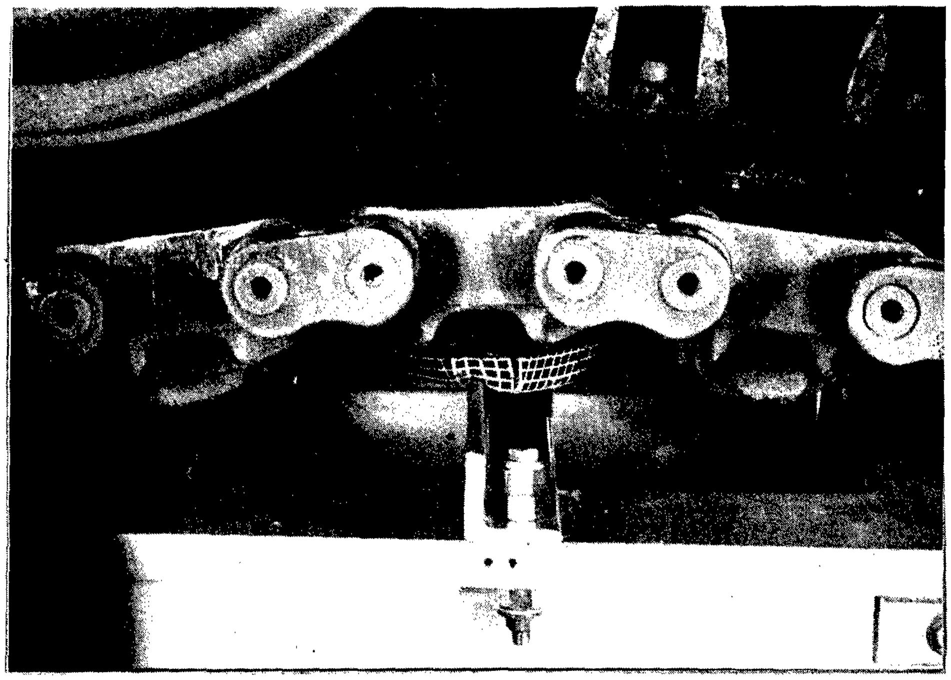


Figures 10D, E, & F.
Photographs from the side of the pad showing deformation during contact with the L-shaped obstacle. Pad temperature is 96° C.



Figures 10G, H, & I.
Photographs from the side of the pad showing deformation during contact with the L-shaped obstacle. Pad temperature is 96° C.





Figures 10J & K.

Photographs from the side of the pad showing deformation during contact with the L-shaped obstacle. Pad temperature is 96^{o} C.

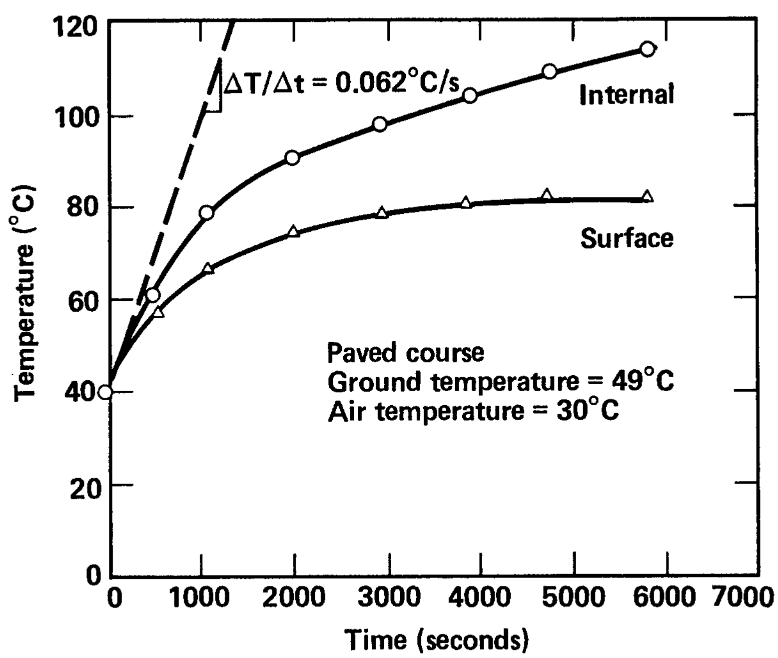


Figure 11. Temperature-time response for surface and internal points of a track pad as measured on the paved course.

interior temperature data (taken 15.9 mm (0.625 in.) below the surface) pads from the three manufacturers showed some variation. Pads from Vendors B and C exhibited the same temperature-time response and showed a maximum temperature deviation of 7^{o} C (13^{o} F) from the pads of Vendor A.

The heat generation rate at ambient temperature was also calculated from the data in Figure 11 and found to be 108 kW/m^3 (10.4 x 10^3 Btu/hr ft^3). As discussed previously, the heat generation rate is proportional to the slope of the temperature-time curve at t = 0 seconds.

3.2.2. Results on the Gravel Course:

Results obtained on the gravel course are presented in Table 1. Testing was done at a nominal speed of 20 miles/hour. Interior temperature measurements were taken at two points — one 15.9 mm (0.625 in.) and the other 25.4 mm (1.0 in.) below the surface of the pad. In these tests, more data were taken at early times so that an accurate evaluation of the heat generation rate could be made.

The surface temperature data are plotted in Figure 12. Considerable scatter was noted in the beginning portion of the test. The interior temperature results are plotted in Figure 13. As expected, the temperature taken 25.4 mm (1.0 in.) below the surface are higher than those 15.9 mm (0.625 in.) below the surface. The heat generation rate was calculated to be 233 kW/m^3 (225 x 10^3 Btu/hr ft^3). A comparison between results obtained on the three courses will be given later.

3.2.3. Results on the Cross-Country Course:

Data on the cross-country course were taken in a number of pad locations. Figure 14 shows the four different interior pad locations and three different surface pad locations that were studied. All interior measurements were taken at 15.9 mm (0.625 in.). The field data are given in Tables 2 and 3. The speed of the vehicle varied considerable during these tests. The tank climbs hills on the cross-country course at speeds estimated at approximately 2.2 m/s (5 mph). However, descending from a hill, vehicle speed was estimated to exceed 9 m/s (20 mph). The average speed during the tests was 7.23 m/s (16.2 mph).

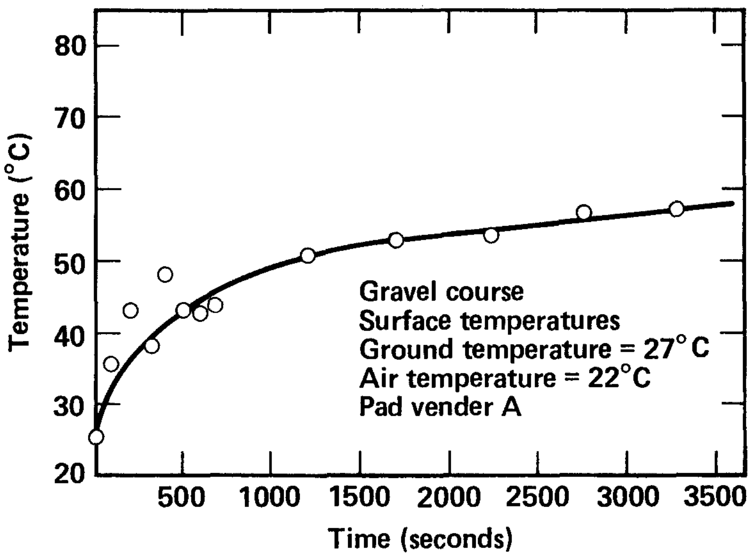


Figure 12. Temperature-time response for the surface of a pad as measured on the gravel course.

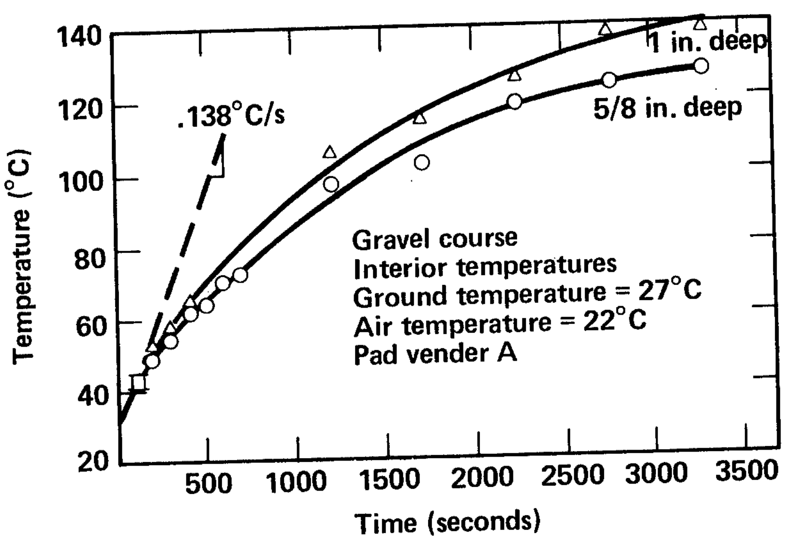


Figure 13. Temperature-time response for two interior locations in a track pad as measured on the gravel course.

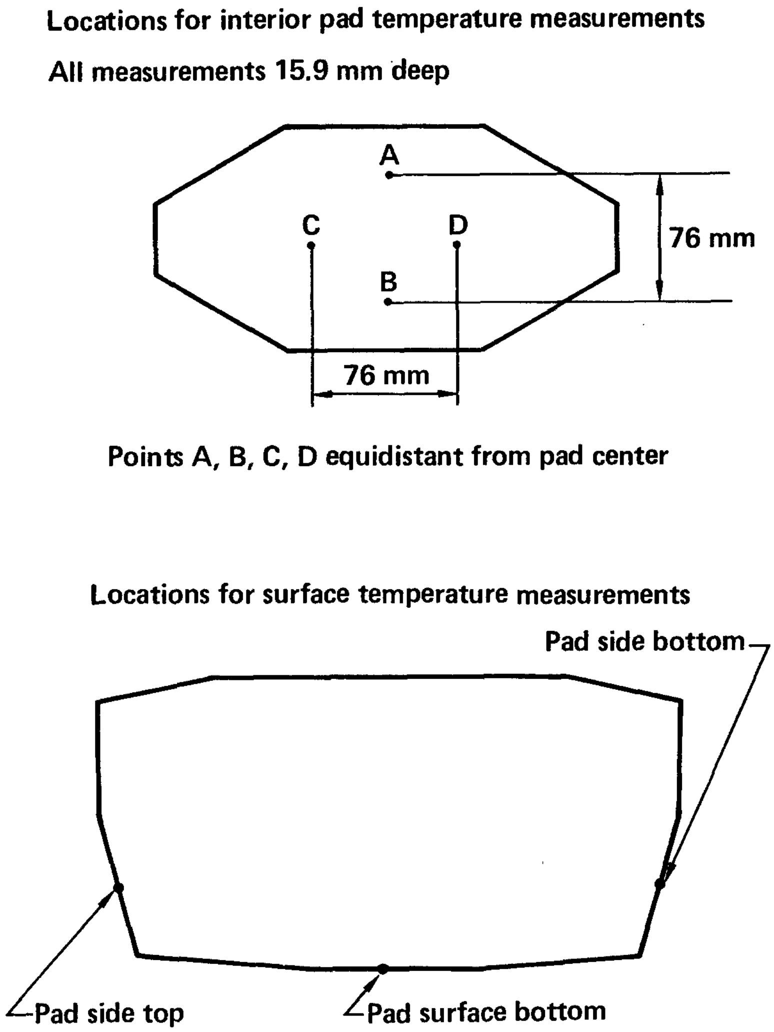


Figure 14. Pad locations for surface and internal temperature measurements made on the cross-country course.

TABLE 1

TEMPERATURE DATA TAKEN ON THE GRAVEL COURSE

Stop No.	Total Miles Driven	Time Elapsed Between Stops (s)	Average Speed Between Stops (mph)	Time Stopped (s)	Total Running Time (s)	Corrected Temperature T_{surf} (°C)	$T_{5/8"}$ (°C)	$T_{1"}$ (°C)
	0.0	—	—	—	—	26.5	31.5	31.5
1	0.5	110	16.4	70	110	35.4	42.7	42.7
2	1.0	91	20.0	89	201	42.8	49.5	52.9
3	1.5	105	17.1	81	306	38.3	55.1	58.5
4	2.0	99	18.2	70	405	48.0	61.9	65.2
5	2.5	85	21.2	120	490	42.8	64.1	—
6	3.0	95	18.9	75	585	42.8	69.7	—
7	3.5	95	18.9	115	680	43.7	72.0	—
8	7.0	516	24.4	64	1196	50.4	96.7	105.7
9	10.5	513	24.6	125	1709	52.5	102.4	114.7
10	14.0	525	24.0	87	2234	53.6	118.1	126.0
11	17.5	519	24.3	111	2753	56.3	123.7	137.2
12	21.0	526	24.0	—	3279	57.1	127.1	138.4

TABLE 2

SURFACE TEMPERATURE DATA TAKEN ON THE CROSS-COUNTRY COURSE

Stop No.	Total Driven (miles)	Total Running Time (s)	Time Elapsed Between Stops (s)	Average Speed Between Stops (mph)	Surface Temperature T_{Bottom} (°C)	T_{Side} (°C)	T_{Side} (°C)
	0	0	—	—	48.8	48.8	48.8
1	0.5	169	169	10.7	65.0	62.0	61.7
2	3.0	727	558	16.1	91.1	90.4	92.6
3	5.5	1328	601	15.0	97.0	91.1	95.7
4	8.0	1895	567	15.9	108.9	108.2	97.0
5	10.5	2424	529	17.0	105.2	103.7	105.4
6	13.0	2952	528	17.1	115.6	103.0	100.5

TABLE 3

INTERIOR TEMPERATURE DATA TAKEN ON THE CROSS-COUNTRY COURSE

Stop No.	Total Running Time (s)	T_A (°C)	T_B (°C)	T_C (°C)	T_D (°C)	Pad Condition Two New Pads
0 Start	0	48	49	46	46	No change
1	169	71	79	75	72	No change
2	727	105	134	120	117	No change
3	1328	120	139	128	133	No change
4	1895	126	136	136	133	Deep cut on edge of bottom pad
5	2424	139	152	147	145	Chunking evident on bottom pad
6	2952	—	153	138	145	Severe chunking on bottom pad

The surface temperature data are plotted in Figure 15. All surfaces studied produced essentially the same temperature-time response. The interior temperature data for Locations A and B are plotted in Figure 16 and for Locations C and D are plotted in Figure 17. Locations A and B showed that temperature-time responses differed by approximately 19^{o} C (34^{o} F) after 1900 seconds of vehicle operation. This was due to the difference in the heat generation rate at these two locations. The heat generation rate for Region B was 326 kW/m^3 (31.5 x 10^3 Btu/hr ft^3) while the rate for Region A was 253 kW/m^3 (24.5 x 10^3 Btu/hr ft^3). Location B struck the ground or any obstacle before Location A and is believed to experience more deformation. This produced the higher heat geeneration rate. It is important to note that the measured temperatures at Region B exceed 150^{o} C after 2400 seconds and were still increasing, although at a decreasing rate. The temperature-time response for Regions C and D were essentially the same. This later result is important since it shows that even for the complex situation of cross-country terrain, there was no thermal gradient along the long axis of the pad. Thus, all heat flow was in the plane perpendicular to the axis. This verified the planar heat flow assumption used in our thermal modeling of the T142 track.

We also examined the track pads for physical condition at each stop during which temperature measurements were made. Two track pads with no "previous" mileage were studied. Results are summarized in Table 3. Only one pad showed obvious physical damage during the 13 miles of testing. This damage consisted of severe cuts. These cuts did not appear until pad surface temperatures exceeded 100^{o} C (212^{o} F).

3.2.4. Comparison of the Temperature Measurements on the Three Courses:

In Figure 18, the internal temperature histories (measured 15.9 mm (0.625 in.) below the pad surface) measured on the three courses have been plotted on a common set of axes. The temperatures were highest in the cross-country tests and lowest in the paved surface tests. In Table 4, we have compiled the heat generation rates measured in these tests. It is important to note the heat generation rates reported in Table 4 are valid at the initial temperatures of the pads. The heat generation rates decreased as the

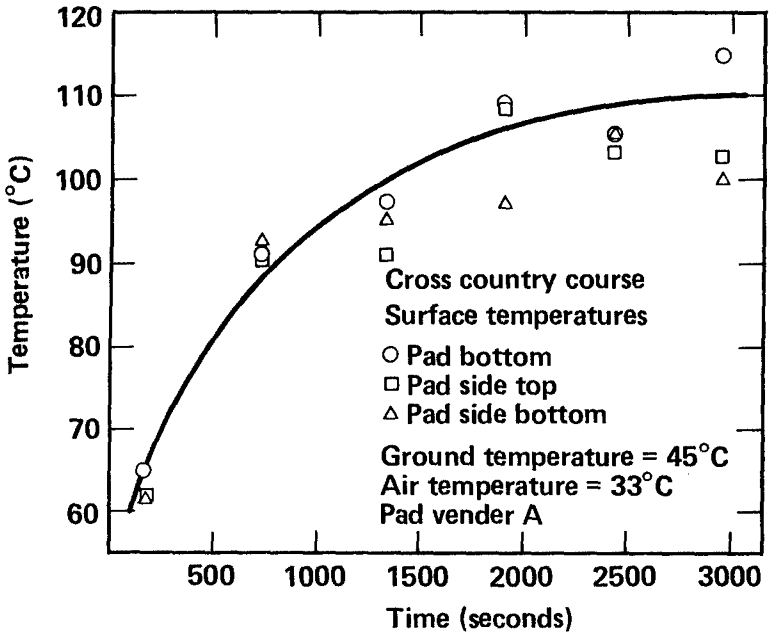


Figure 15. Temperature-time response for three surface locations on the pad as measured on the cross-country course.

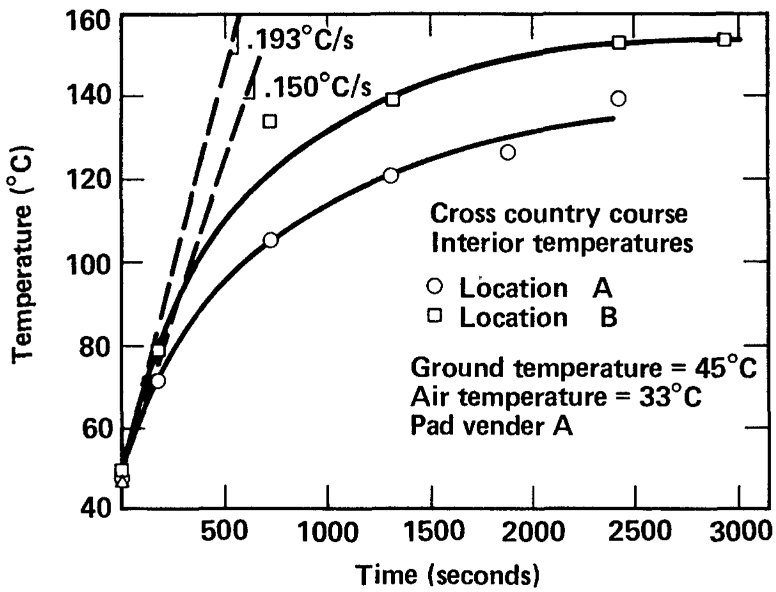


Figure 16. Temperature-time response for interior Locations A and B as measured on the cross-country course.

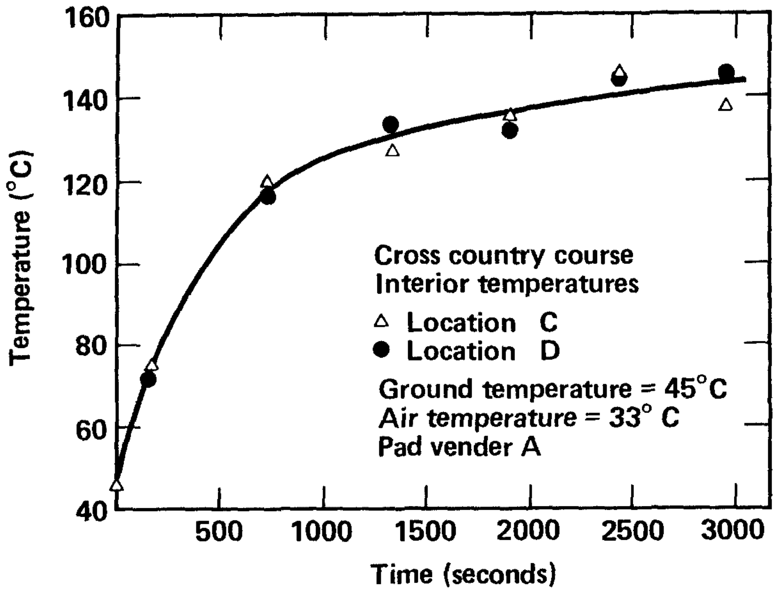


Figure 17. Temperature-time response for interior Locations C and D as measured on the cross-country course.

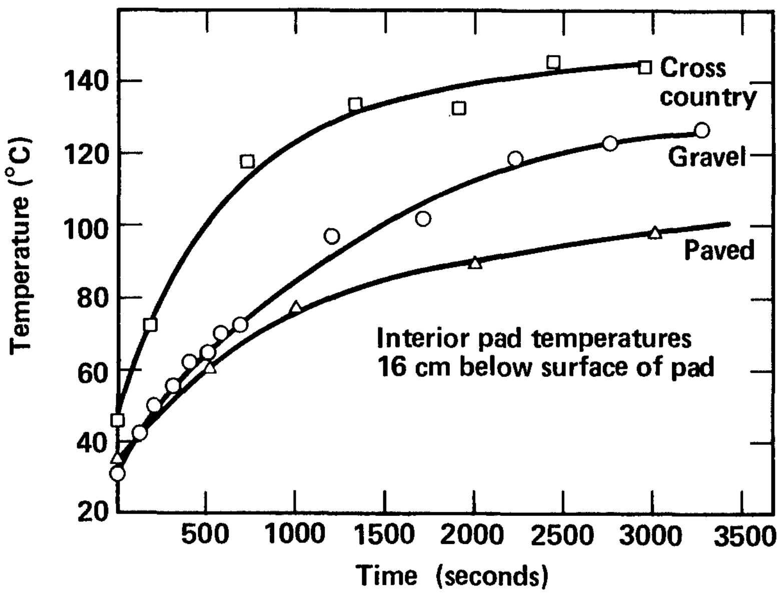


Figure 18. Temperature-time response for the pad interior as measured on the three test courses.

TABLE 4

HEAT GENERATION RATES AT AMBIENT TEMPERATURE
OBTAINED DURING FIELD TESTING

Test Course	Average Speed m/s	(mph)	Heat Generation Rate kW/m^3	$(Btu/hr\ ft^3)$
Paved	10.3	(23.0)	108	(10.4×10^3)
Gravel	10.4	(23.3)	233	(22.5×10^3)
Cross-Country (Location B)	7.2	(16.2)	326	(31.5×10^3)
Cross-Country (Location A)	7.2	(16.2)	253	(24.5×10^3)

temperature of the pads increased. The cross-country testing produced the highest rate while the paved surface testing produced the lowest rate. This occurred despite the fact that the speeds during cross-country testing were lower than in the other tests. This higher heat generation rate was due to the larger deformations put into the track pads as the tank climbed hills, descended from hills, and negotiated obstacles. It should be noted that one of the primary factors producing the deformation that caused the heat generation rate in the factors producing the deformation that caused the heat generation rate in the gravel tests was probably the numerous turns that the vehicle must make in negotiating the course. Thus, it appears that the primary driver for the internal temperature of the pads is the heat generation rate.

It is also informative to examine the difference in pad surface temperatures observed on the three courses. The cross-country testing produced the highest surface temperatures while the gravel testing produced the lowest. We believe the surface temperatures on the paved course were higher than those on the gravel course because of the higher air and roadway temperatures on the paved couse. The ground temperature of the paved course was similar to that on the cross-country course. On this latter course, the "scrubbing" process experienced when the tank tranversed hills frictional heating of the pad surface. This heating may be a factor in the high surface temperature recorded here.

4.0. SUMMARY AND CONCLUSIONS

This report described two sets of experiments that were performed at the Yuma Proving Grounds on the T142 track. In the first set, movies were taken of the pad as it encountered various idealized surfaces. In the second set of experiments, measurements were made of track pad surface and internal temperatures as a function of time for constant velocity operation on the three standard test courses at Yuma.

The movie studies showed the large deformation that the pads experienced striking rigid obstacles. The results also showed that, although track pads are primarily subjected to compressive loading, they can experience tensile stresses of significant magnitude when they encounter obstacles. Tensile stresses can also be produced by localized loads from rigid obstacles and from the large applied shear stresses produced during turning operations. We believe that these conditions are the primary sources of damage and chunking in track pads.

The temperature data showed the high temperatures that can be produced in track pads. There was also a large temperature difference between tests run on the three courses. After 3000 seconds (50 minutes) of vehicle operation, pads tested on the cross-country, gravel, and paved courses showed interior temperatures (taken 16 cm (5/8 in.) below the pad surface) of 146° C (295° F), 126° C (259° F), and 99° C (210° F). We have shown that these differences are due to the different heat generation rates produced on the three courses. For a given SBR track pad formulation, these rates are largely determined by the amount of pad deformation and vehicle speed. We believe that the combination of high temperatures and significant tensile stress are the primary factors influencing cutting and chunking.

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