T-TSC-FRA- 74-12

6/4/87
Return to Repora

REPORT NO. FRA-OR&D-75-57

BRUSH TESTING FOR THE TLRV POWER COLLECTION SYSTEM

C. H. Spenny
I. Litant

APRIL 1975
INTERIM REPORT

DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
Office of Research and Development
Washington DC 20590

Technical Report Documentation Page

1. Report No. FRA-OR&D-75-57	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle BRUSH TESTING FOR THE TLRV POWER COLLECTION SYSTEM		5. Report Date April 1975
		6. Performing Organization Code
7. Author(s) C.H. Spenny and I. Litant		8. Performing Organization Report No. DOT-TSC-FRA-74-12
9. Performing Organization Name and Address U.S. Department of Transportation Transportation Systems Center Kendall Square Cambridge, MA 02142		10. Work Unit No. (TRAIS) RR405/R5316
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Railroad Administration Office of Research and Development Washington DC 20590		13. Type of Report and Period Covered Interim Report Jan. 1973-Jan. 1974
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report describes work which has been completed to demonstrate the use of laboratory tests in simulating and measuring brush wear for application in the power collection system of the U.S. Department of Transportation's tracked levitated research vehicle (TLRV). Initial tests have demonstrated that materials exist for power pick-up from the wayside for speeds up to 300 miles per hour, when conditions exist similar to that of a brush on a motor commutator. Subsequent testing has been performed to determine what parameters of the brush-rail system can deviate from brush-commutator conditions and still provide acceptable performance. Parameters identified and studied in this report include brush material, current density, surface speed, and pressure. Other parameters are identified for future testing.

17. Key Words Electrification, Power Collection, Current Collection		18. Distribution Statement DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 62	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

The objective of this work was to develop a laboratory technique for determining brush wear for a sliding contract power collection system at speeds up to 300 miles per hour. The laboratory study described in this report was conducted by the Power and Propulsion Branch of the Transportation Systems Center (TSC) for the Federal Railroad Administration. Acknowledgement is made herein to Amir Raicar of Kentron-Hawaii, Limited, who performed the testing required for this report.

TABLE OF CONTENTS

Section   Page

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTINUED)

LIST OF TABLES

1. INTRODUCTION

This report describes work completed in the simulation and measurement of brush wear for selected materials that are candidates for use in the power collection system of the tracked levitated research vehicle (TLRV). Initial runs indicated minimal wear, thus demonstrating that rated current can be picked up at 300 mph. There is some correlation with wear data generated by other researchers.[1 2] The results, however, correspond more closely to those of a motor brush running on a slip ring with ideal environmental conditions.

An interim report on these tests is offered here, including an indication of the capability for more closely simulating the expected operational and environmental conditions. The technique for producing correlation has been to adjust, one at a time, the variables that might affect brush wear to determine the most critical. While correlation has not yet been adequately demonstrated, it is felt that the most critical variables are surface finish and irregularity of the power rail.

2. DESCRIPTION OF THE TEST APPARATUS

Sliding contact is simulated in the laboratory by holding brush samples against the sides of a rotating wheel. The general configuration of the test apparatus is shown in Figure 1. The wheel is 24 inches in diameter and is made of aluminum. The rail material is bolted to both faces of the wheel. All testing to date has been with the copper alloys originally chosen as candidates for the TLRV system. The face shown in Figure 1 is designated brush side #1, and the material is Anaconda Hitenso 1622. The back side is designated brush side #2, and the material is Olin Alloy 194. Testing was iniated with the surface finish provided by the manufacturer.

Pairs of brush holders can be seen on opposite sides of the wheel at the top and at the level of the hub of the wheel. Each holder is designed to NEMA standards[3] for motor and generator applications. A spring, as shown in Figure 2, is used to apply the brush preload and restoring forces. The configuration and dimensional tolerances of brush samples being tested are shown in Figure 3.

In a typical run, the top pair of opposing brushes are the power brushes carrying current. The lower set of brush holders is typically left empty(as shown in Figure 1)or loaded with the brushes used for cleaning, guidance, and damping in the actual collector. The lower holder can also be used to hold power brushes when parallel current paths are desired.

Current is transferred through the brushes via a circuit, as shown in Figure 4. A transformer steps down line voltage so that rated current density can be passed through each brush. Because the current is alternating, there is no problem with polarity of the brushes and wheel. A Variac in the primary circuit of the transformer permits the current level to be varied.

The wheel is belt-driven by a 10 horsepower DC electric motor. Speed control permits the relative speed between the brush and wheel surface to be varied from 0 to 300 mph. A photodetector on the shaft of the wheel counts revolutions for transmission to the control

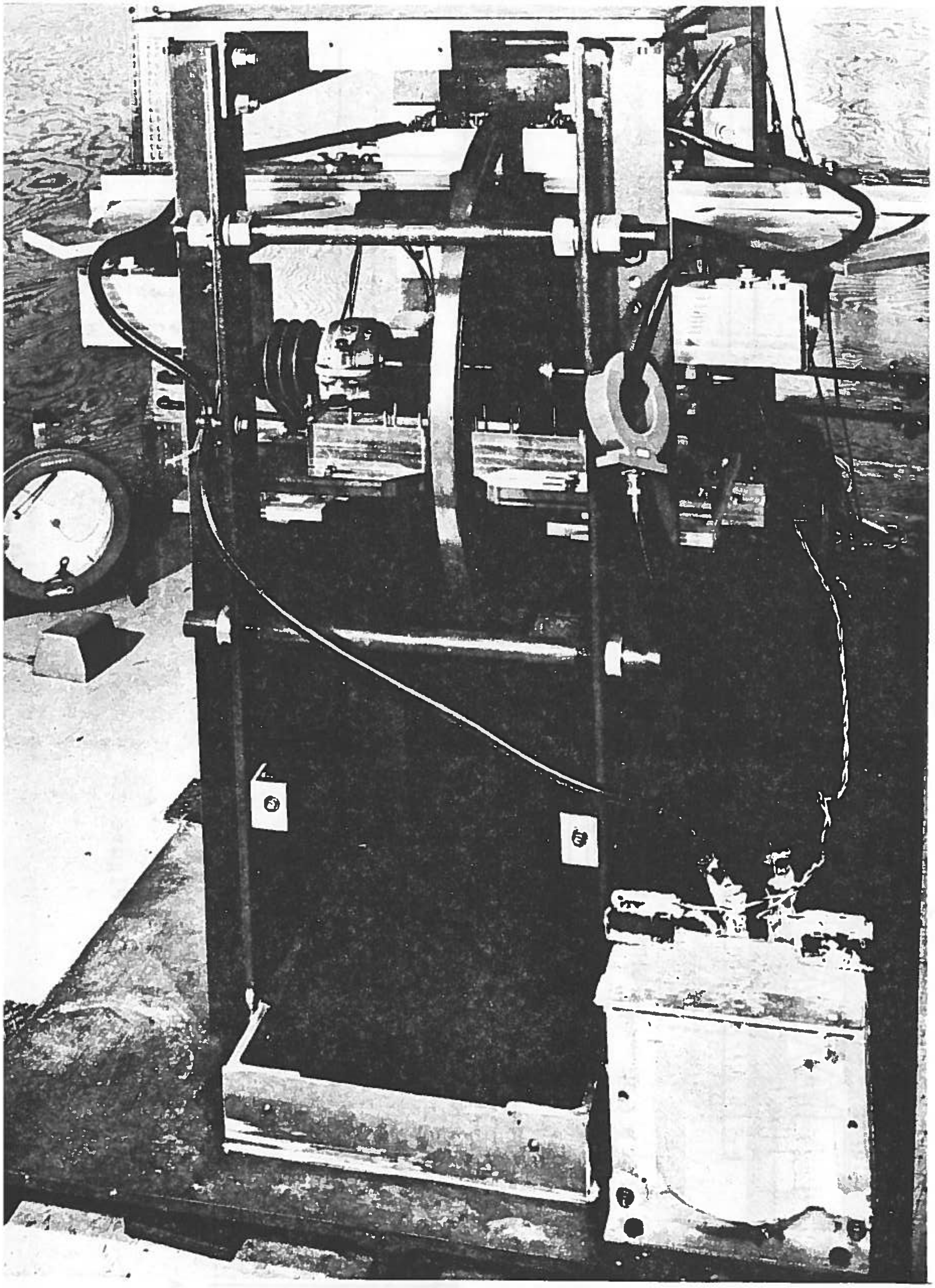


Figure 1. General Configuration of Test Wheel

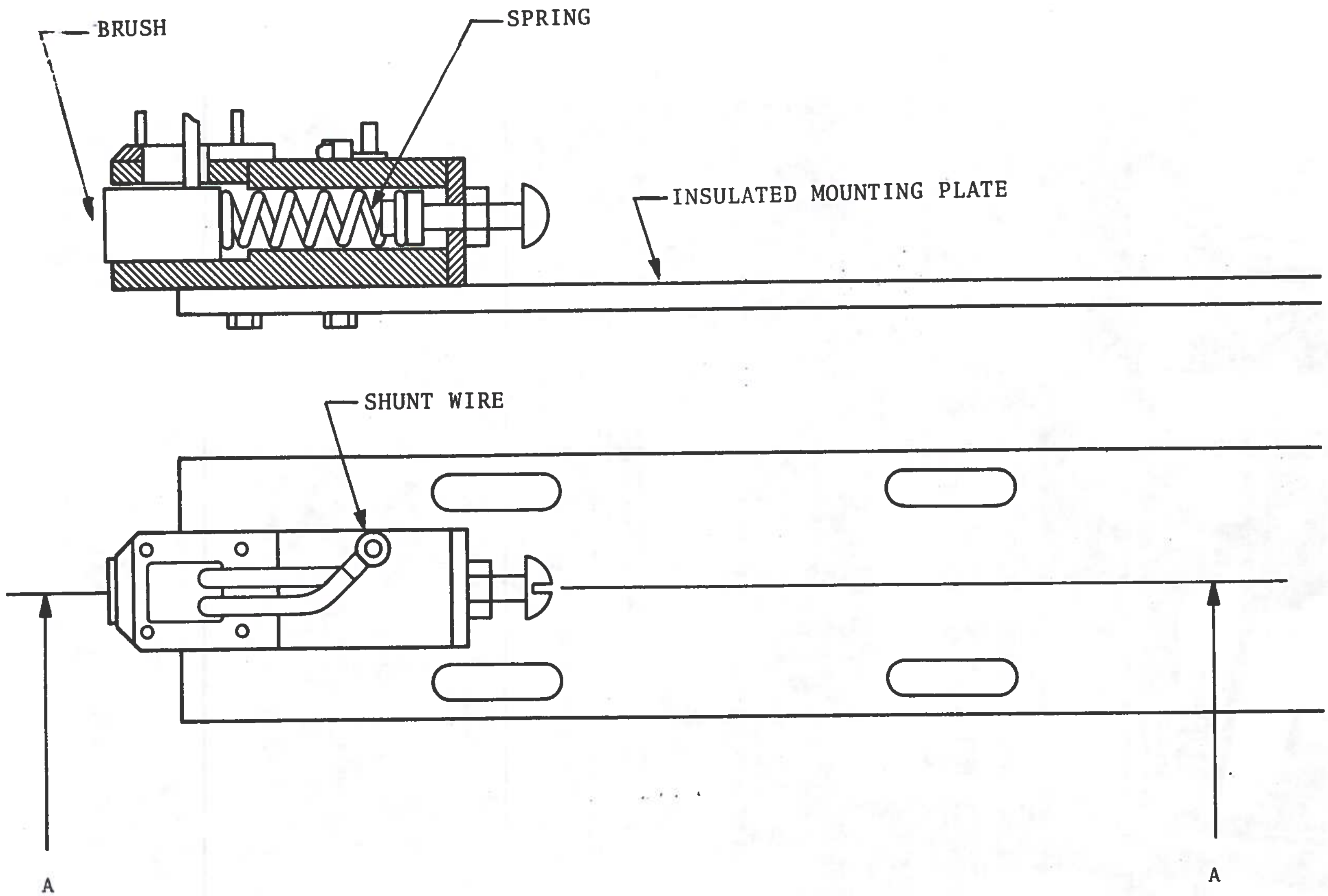
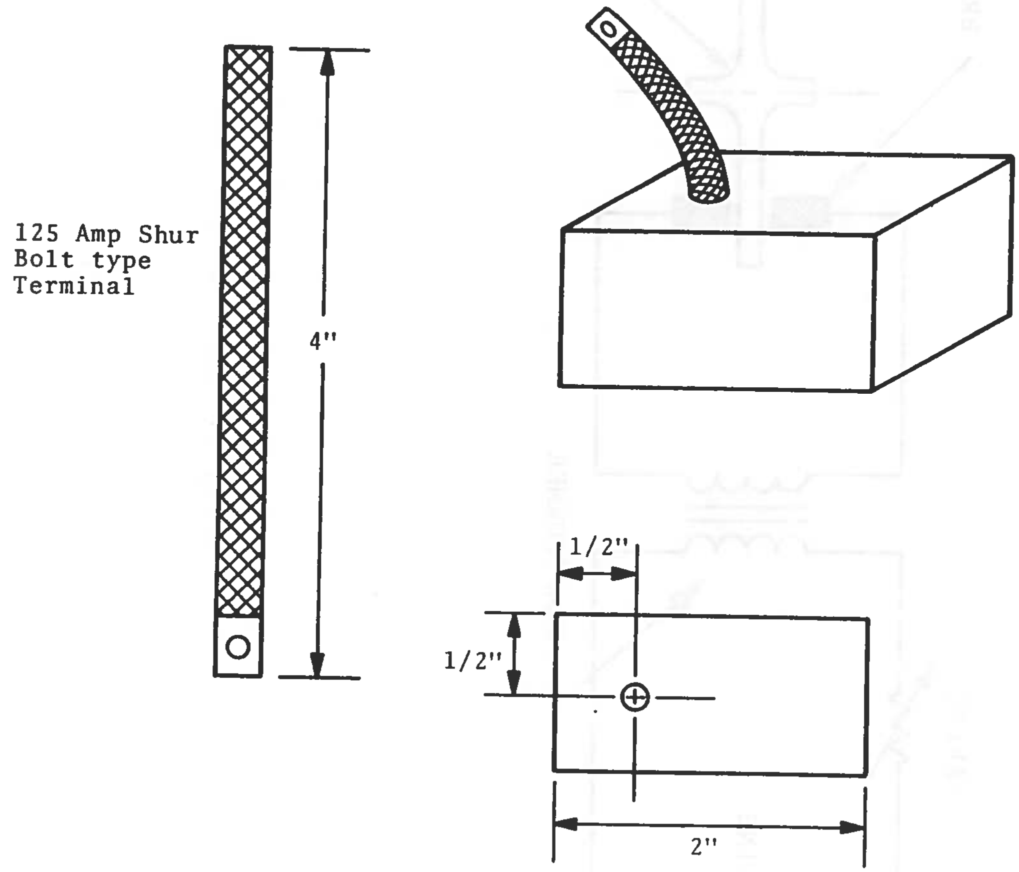


Figure 2. Brush Holder Assembly

	CARBON CARBON GRAPHITE GRAPHITE, & METAL GRAPHITE UP TO 50% METAL (WT)	METAL GRAPHITE OVER 50% METAL (WT)
A"	1" +.000 -.004	1" +.000 -.007
B"	1" +.000 -.015	1" +.000 -.007



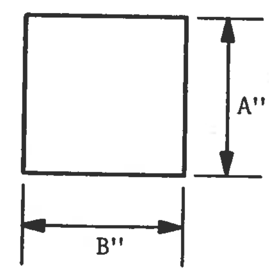


Figure 3. Dimensions of Brush Samples

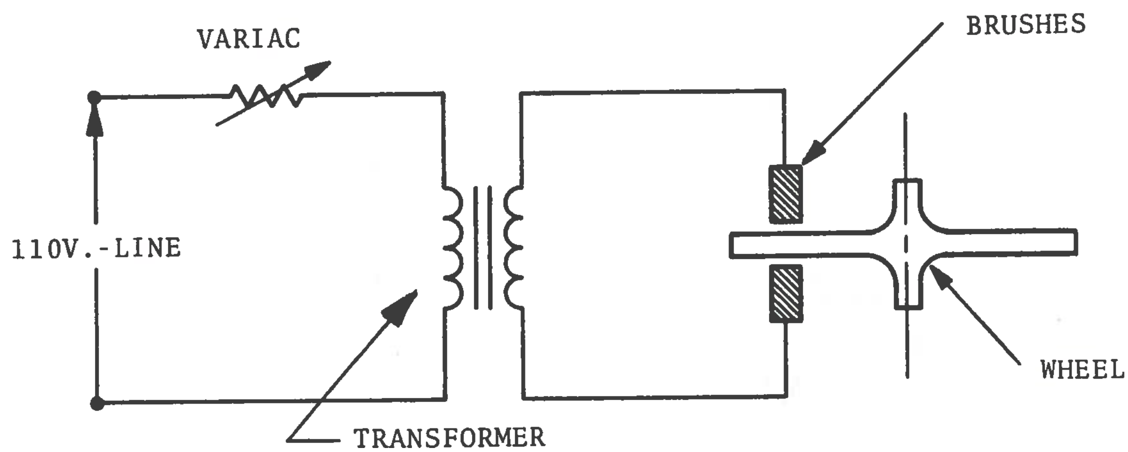


Figure 4. Brush Test Electrical Circuit

console; here surface speed and miles of travel are calculated and displayed in real time.

An infrared thermometer is used to monitor temperature of the wheel, as shown in Figure 5. A bulb thermometer and a seven day recording barometer are kept in the room to record average test cell temperature and humidity. A supplementary air conditioner is used to maintain relatively constant temperature (22 to 25°C) and humidity (15 to 68% range during testing) in the room.

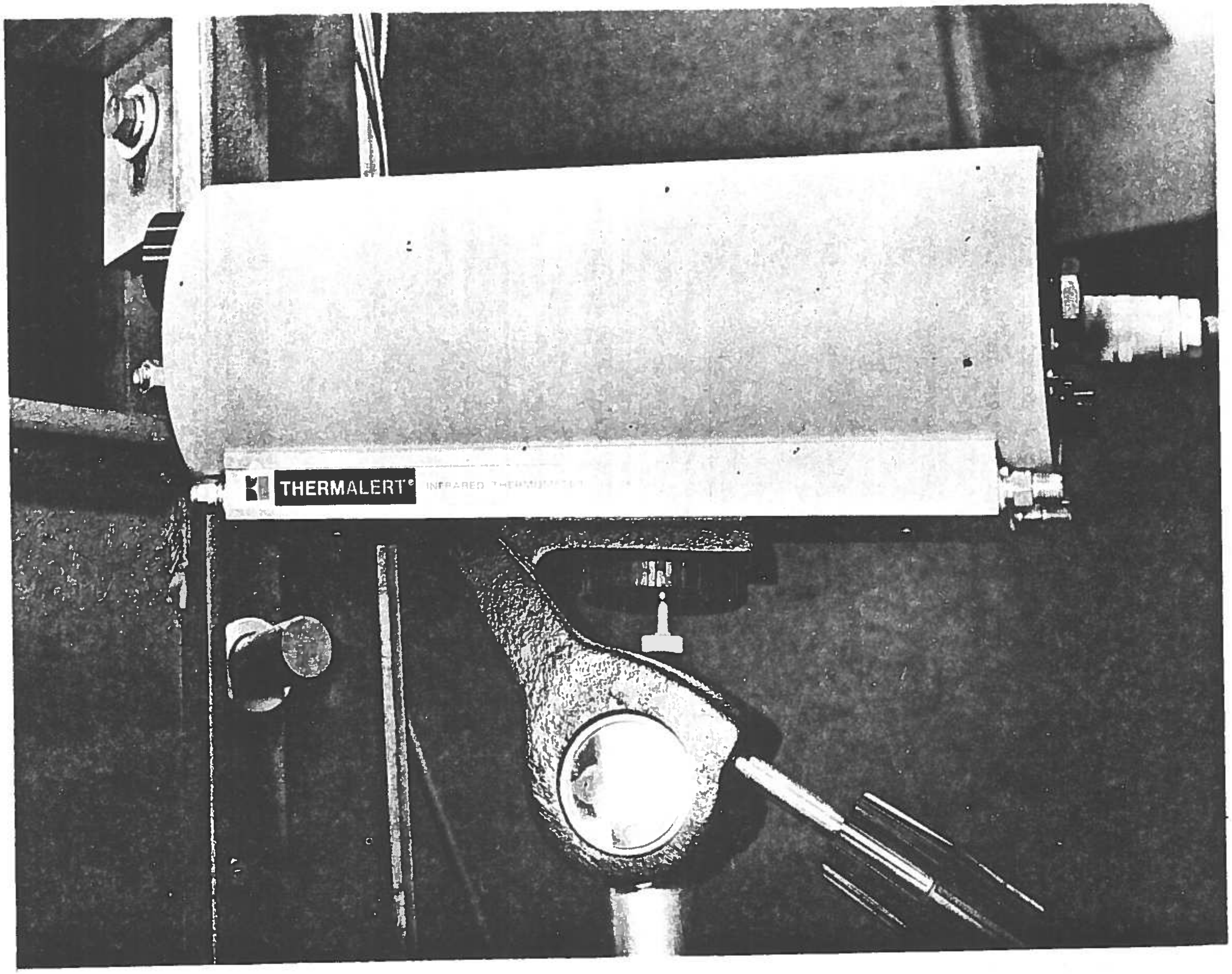


Figure 5. Infrared Thermometer for Measuring Wheel Temperature

3. SAFETY

For the operator's safety, all testing is controlled from a console outside the test cell. Automatic shutdown of the wheel occurs if the signal from an accelerometer mounted on one of the bearing housings exceeds a predetermined threshold. The wheel is enclosed by a steel frame for containment, should it break away as a rotating disk. Steel plate and plywood covered walls have been installed to protect the operator from brush particles and test gear that could become projectiles if they hit the wheel. Operating procedure requires that the wheel be stopped and that the brush current circuit be opened before entering the test cell. General safety procedures as specified in reference 4 were observed.

4. BRUSH SCREENING TESTS

Brushes listed in Table 1 have been tested at "nominal" conditions to determine their suitability for power collection application. Nominal conditions include a brush relative speed of 300 mph and current-carrying capability of 37.5 amperes per square inch. Operating pressure for each brush was chosen to provide the most stable operation, based upon observation of current fluctuation in the brushes during wear-in. The two exceptions were Morganite MY7D and Ringsdorf M132, which, because of excessive heat buildup, had to be tested at less than optimum operating pressure. Each test run was preceded by a wear-in period which permitted the brush to become properly seated and the wheel properly conditioned.

Brush wear was measured in two ways. The dimensional change in brush length was measured using a micrometer. Measurements were taken before and after a 1,000 mile test run. Loss in brush weight during the test was also used to calculate change in length. The wear column of Table 2 is an average of these two techniques. There are two exceptions:

1. Stackpole 605 was found to be very porous. The increase in relative humidity content from start to completion of test caused the weight of the brushes to increase, indicating that considerable water was absorbed by the material. This characteristic was verified in a previous test by measuring the weight loss of a brush stored in a desiccator. The wear of Stackpole 605 listed in Table 2 is therefore based on micrometer measurements only.

2. The two specimens of Morganite MY7D showed no loss in length but exhibited the expected weight loss. This is attributed to an irreversible expansion, resulting from stress relieving when the brush is heated. The wear of MY7D is based upon weight change only.

Table 2 shows that the harder materials, in general, exhibit the least wear. Wear test results are comparable for the Carbone

TABLE 1. CANDIDATE BRUSH MATERIALS FOR TLRV POWER COLLECTION

			Hardness	Density	
Designator*	No. Samples	Composition	** (Measured)	(g/cc) (Spec)	(g/cc) (Measured)
S-566-XX	20	Electrographitic	49	1.69	1.72
S-605-XX	22	Carbon/Graphite	49	1.72	1.78
S-Z328-XX	24	Carbon/Graphite	8	1.21	1.21
S-710-XX	24	Metal/Graphite	19	4.90	4.98
M-MY7D-XX	10	Metal/Carbon	91	2.38	
R-M130	12	Metal/Graphite	90	2.714	2.57
R-M132	11	Metal/Graphite	74	2.196	2.20
R-507	12	Carbon/Graphite	94	1.75	1.73
C-8710			76	1.90	1.87
C-722			89	2.50	2.90
C-845			76	1.75	1.80

*Key to Manufacturers:

S-Stackpole Carbon Company
M-Morganite, Incorporated
R-Ringsdorf Corporation
C-Carbone Corporation
**-(Shore Scleroscopic)

TABLE 2. BRUSH WEAR CHARACTERISTICS AT NOMINAL TEST CONDITIONS

Material	Test Pressure (psi)	Optimum Pressure (psi)	Wear (in./1,000 mi.)		Arcing	Remarks
			Side #1	Side #2		
Stackpole:						
#566	5	5	.021	.012	Light	Very steady current, coats wheel
#605	5	Higher	.006	.002	Light	Unsteady current, shines wheel, excessive brush heating evident
#Z328	5	5	.011	.009	Light	Very steady current, shines wheel
#710	5	5	.014	.014	Heavy	Steady current, scores wheel
Carbone:						
#8710	7	7 or 8	.004	.004	Light	Unstable current, coats wheel
#722	6	-	.006	.006	Medium	Unsteady current, copper pitting observed on wheel
#845	-	-	-	-	-	Edges of brush chipped excessively during wear-in
Morganite:						
#MY7D	5	6 or 7	.006	.004	Heavy	Steady current, copper pitting observed on wheel
Ringsdorf:						
#M132	6	8	.005	.005	Medium	Unsteady current, brush chatter
#M130	-	-	-	-	-	Exuded copper, causing brush to stick in holder
#507	-	-	-	-	-	Exuded aluminum, causing excessive chatter and wheel scarring

8710, Carbone 722, Morganite MY7D and Ringsdorf M132. However, optimum operating pressure increases with material hardness. Thus, more frictional heat was created by these materials, and all eroded the copper running surface to some degree. Figure 6 shows the typical shiny wheel surface that results from testing the hard materials listed above. Another characteristic common to the hard materials is a very erratic change in resistance across the contact surface. This made it difficult to maintain a fixed current level for the duration of a test. In the case of Carbone 8710 and Morganite MY7D, arcing was observable. The contact surface of Ringsdorf M132 glowed noticeably at high current densities, resulting in burn spots, as shown in Figure 7. Carbone 722 exhibited a similar characteristic. Horsepower and heating limitations prevented testing some harder materials at their optimum contact pressure. However, no significant change in wear rate would be expected when run at optimum pressure.

Testing was abandoned on three of the harder carbon materials when they were subjected to the nominal test conditions:

1. Ringsdorf M132, a metal/graphite brush, exuded metal (probably Babbit) when the brush became heated. Figure 8 shows the small balls of metal that migrated to a non-sliding surface and the melted metal that smeared on the sliding surface. Buildup within the aluminum brush holders caused the brushes to bind, so that constant brush pressure could not be maintained.

2. Ringsdorf 507, a carbon/graphite brush, caused excessive copper picking of the wheel along with excessive chatter and clinging. Tests were abandoned to prevent damage to to the wheel.

3. Carbone 845 chipped during wear-in, as shown in Figure 9. This material was judged too fragile for the application.

The softer materials exhibited wear rates two to three times those of the harder materials. However, there was little arcing or fluctuation in resistance across the contact surface. Visualizing the brush dynamics on a microscopic level, the softer

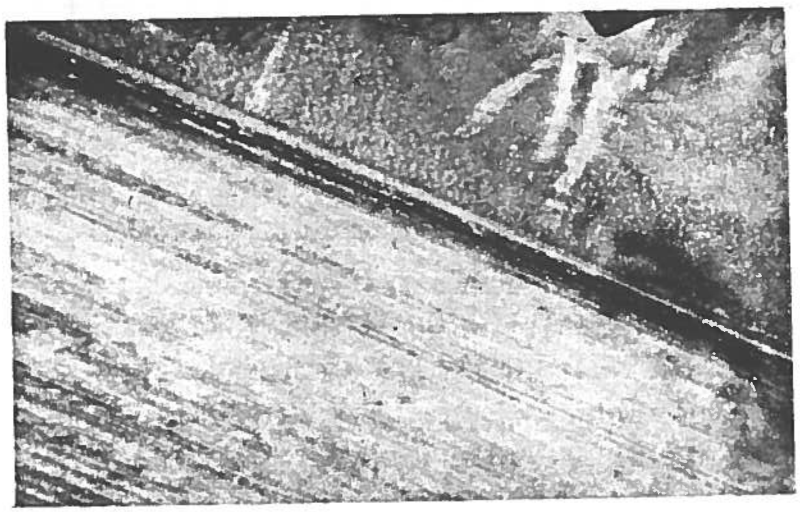


Figure 6. Copper Surface After Wear-in with Morganite MY7D

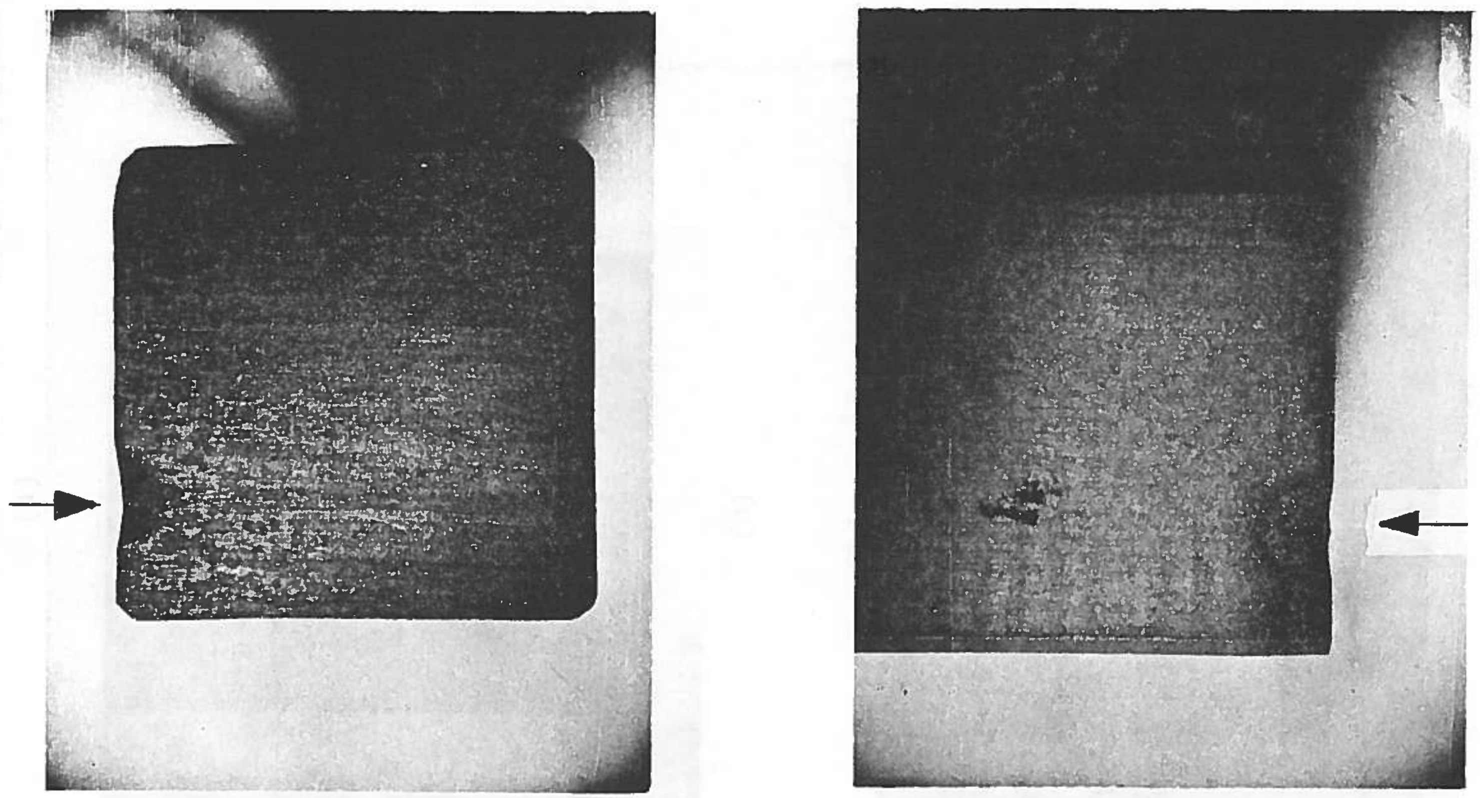
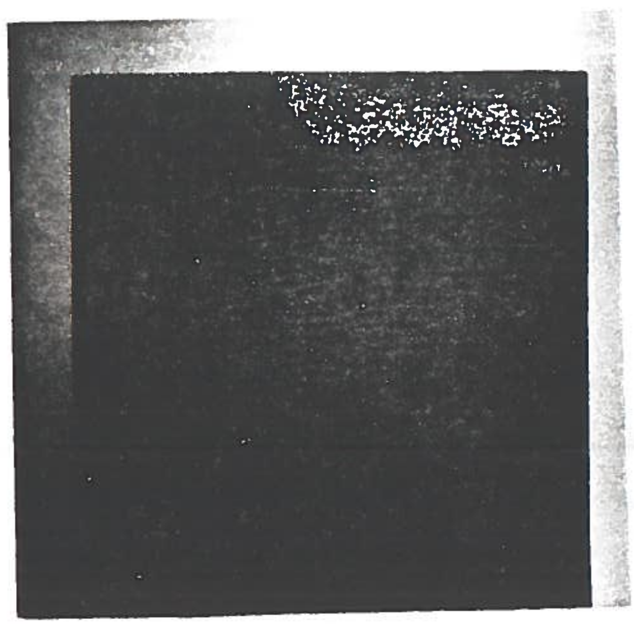


Figure 7. Burn Type Erosion of Ringsdorf M132

(a)



(b)

Figure 8. (a) Smearing of Metal on Sliding Surface of Ringsdorf M130
(b) Metal Migration on Side of Brush Material Ringsdorf, M130

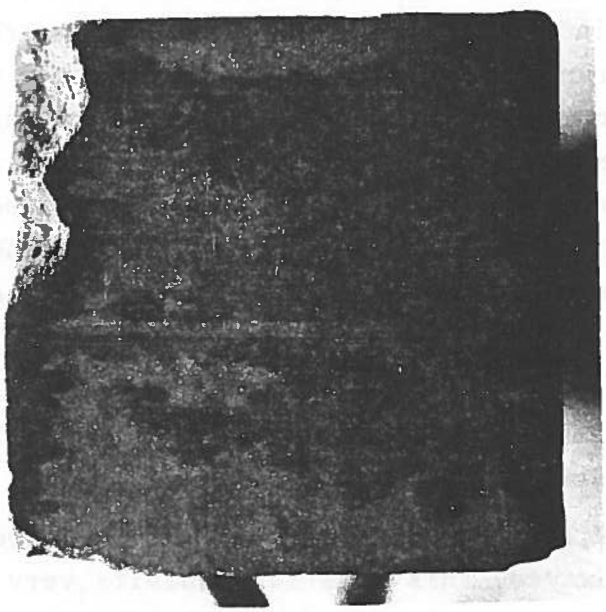


Figure 9. Chipping of Carbone 845

brush surfaces appear to score as they pass over small protuberances of the running surface, thus permitting the brush to remain in contact with the surface.

A harder brush either 1) bounces as it encounters protuberances, thereby permitting arcing, or 2) mechanically clips the protuberances from the running surface. In either case, degradation of the running surface will result. At this time it seems advisable to recommend against the use of a hard brush, due to the costs of replacing worn power rail versus replacing worn brushes.

The greatest wear rate was observed for Stackpole 566, an electrographitic material of medium hardness. This material coats the wheel, as shown in Figure 10. Copper picking tests performed on the brush contact surfaces after testing indicate that this material also has a tendency to remove copper from the rail surface. However, in the numerous tests performed with this material, no degradation of the copper was observed. It is hypothesized that a stable balance is achieved between the amount of carbon and copper interchanged between the two surfaces in sliding contact, after which no further gross transfer occurs. Low friction and high conductivity are attributes of this material.

Stackpole 2328 has similar characteristics, but it shines the wheel, an indication that rail wear could be significant.

Stackpole 605 has a lower wear rate than would be predicted based upon hardness. However, this material exhibits very little capability to handle current overload. In preliminary tests, an instability in the voltage drop across the burshes during testing resulted in high current levels (75 amps/in^2) and overheating of the brushes. The heated areas of the brush assumed a skeletal structure quite susceptible to frictional wear. Figure 11 shows a specimen which heated to a glow when the current density jumped during a test. This material is also suspect for operation where there are large changes in humidity (see above discussion on measurement of wear rate.)

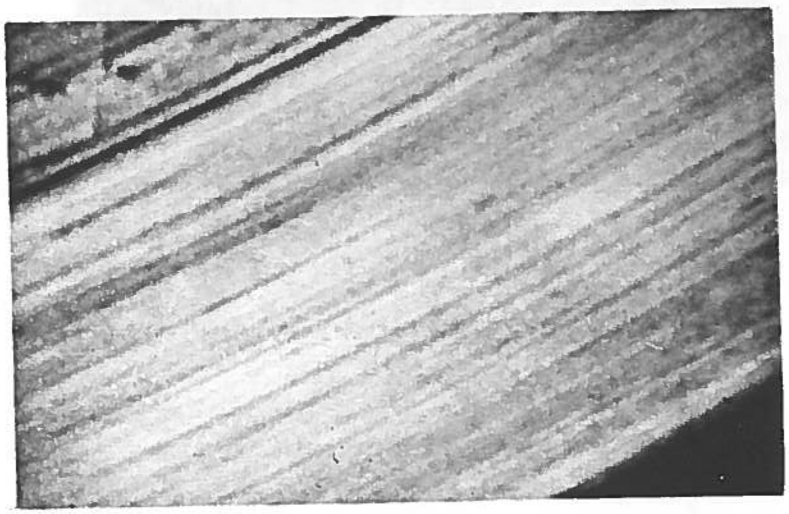
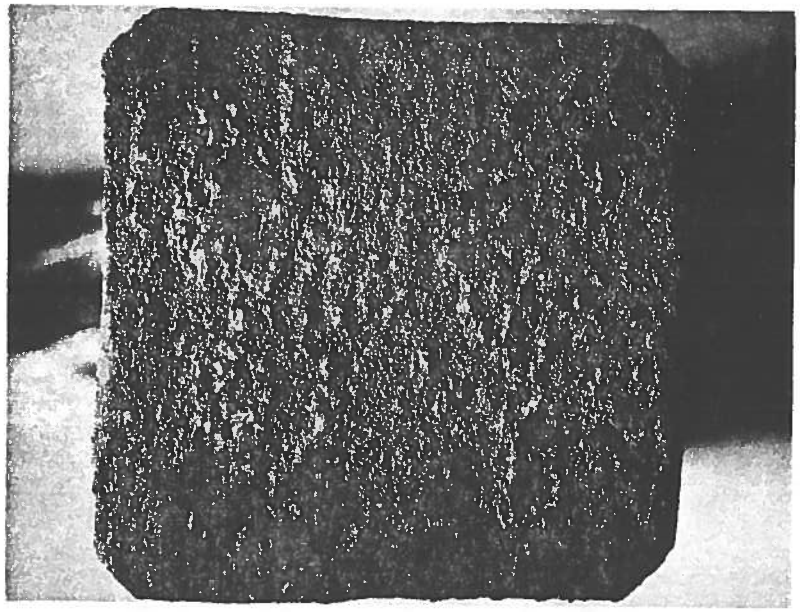


Figure 10. Carbon Coating of Wheel by Stackpole S-566



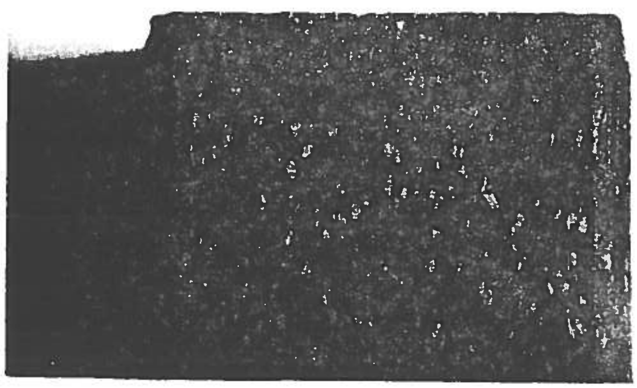


Figure 11. Heating Degradation of Stackpole S-605

Stackpole 710 is the softest metal graphite brush tested. It also contains the largest percentage of metal (copper), and is hence the best conductor. However, the most severe pitting of the wheel was observed with this brush material, as shown in Figure 12.

The wear rates of Table 2 are based upon a single run of 1,000 miles at the nominal conditions. Table 3 summarizes the wear rates for two materials where the nominal test was repeated for comparison. In the case of Stackpole 566, the wear in the second test was significantly greater. This is attributed to the difference in state of the wheel rubbing surface. For the first test the surface was well coated by the brush, since all previous testing had been with the same lubricating material. The second run was made after a test of another material, Stackpole 710, which had completely removed the lubricant. Increased wear would be expected of the Stackpole 566 sample when reinstalled on a clean wheel.

In the case of Stackpole 2328, the wheel was equally clean for both tests. However, the finish of the rubbing surface was improved with each run, as reflected in Table 4. Thus, reduction in wear rate would be expected.

Further tests are required to quantitatively determine repeatability. The first step, however, is to determine the most critical wear parameters and then adequately monitor and control them during the tests. The following section describes the work to date in reducing the critical variables of brush wear in high speed current collection.

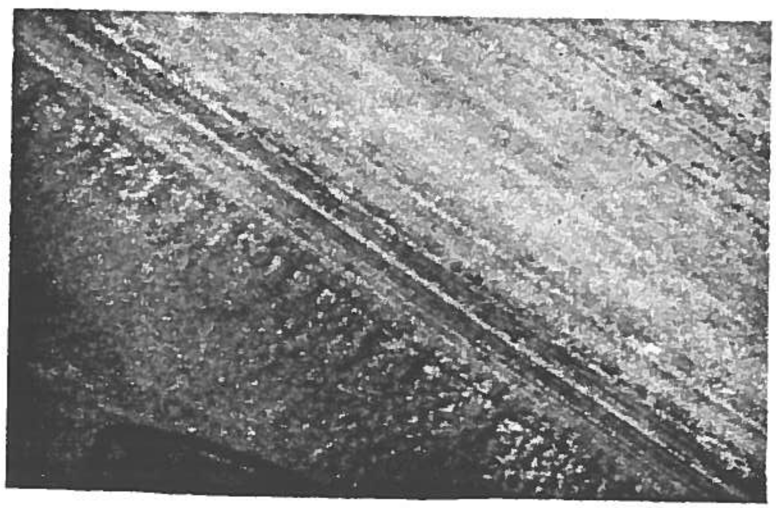


Figure 12. Wheel Pitting Observed While Testing Stackpole S-710

TABLE 3. REPEATABILITY OF WEAR RATES AT NOMINAL CONDITIONS

Material	Wear Rate (inches/1,000 miles)		% Difference
	1st Test Run	2nd Test Run	
Stackpole #566			
Brush Side 1	.021	.030	+43%
Brush Side 2	.012	.022	+83%
Stackpole Z328			
Brush Side 1	.011	.009	-18%
Brush Side 2	.009	.005	-44%

TABLE 4. WHEEL SURFACE FINISH

Before testing:

Brush Side No.	Unused Surface	Across Path	Along Path
#1	5	6-10	2-5
#2	3-4	7-12	2-5

After completion of screening and parametric testing:

#1	3-4	2-4 (Outer edge) 5-7 (Inner edge)	2-5 & 5-15 (Pitted)
#2	3	2-5	2-4

5. PARAMETRIC STUDY

Figures 13, 14, and 15 show the effect of variation in speed, current density, and pressure, respectively, when other parameters are held fixed. In these cases, the wear rate is the average for brushes 1 and 2 for a single run. Wear is seen to grow more than linearly with increasing current and speed. Figure 15 suggests there is a pressure at which minimum wear rate is achieved. The increase in wear above the pressure of minimum wear results from increased mechanical wear. The increase in wear below the minimum results from increased electrical erosion due to increased arcing.

From the dynamic analysis of brush bounce given in Appendix A, it is possible to determine a minimum pressure below which the brush separates from the rail. This is a function of amplitude and wavelength of rail irregularity and is applicable for wavelengths longer than the brush dimension along the wave. Operation at or below this pressure results in excessive electrical wear. The pressure of minimum wear is somewhat higher, and is believed to be a function of material hardness, as noted in the previous section. The asperities which determine rail surface finish (i.e., rail irregularity much less than brush width) can cause arcing if the brush surface lifts up or can cause tearing of the brush surface if it does not lift. The hardness of the brush, which is related to the modulus of elasticity, determines the pressure at which the brush should pass the asperities to produce the minimum combination of mechanical and electrical wear.

Only material #566 has been examined parametrically. However results of similar tests on other brush materials conducted by the Garret Airesearch Corporation[1] and the Carbone Corporation[2] are available for comparison (see Figure 16). The Garrett data are for a single run of each of Stackpole materials #605 and Z328. The Carbone tests were conducted with Carbone material #722, and the data are presented as extreme of wear at two speeds, 187.5 mph and 312.5 mph. The magnitude of wear for each material is comparable. Since operating conditions and wheel surface finish were not the same, it is not possible to make an accurate comparison of materials.

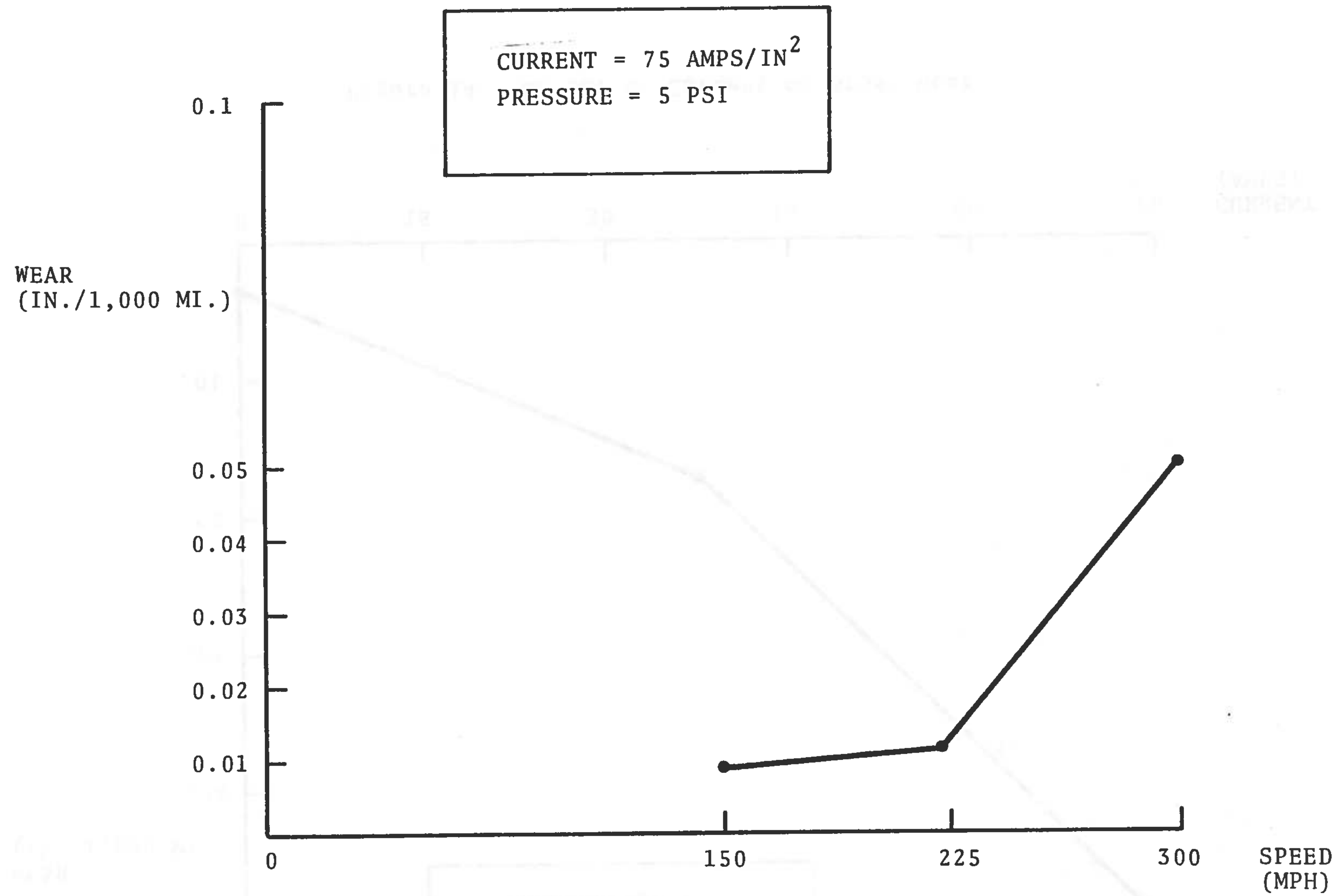


Figure 13. Effect of Speed on Brush Wear

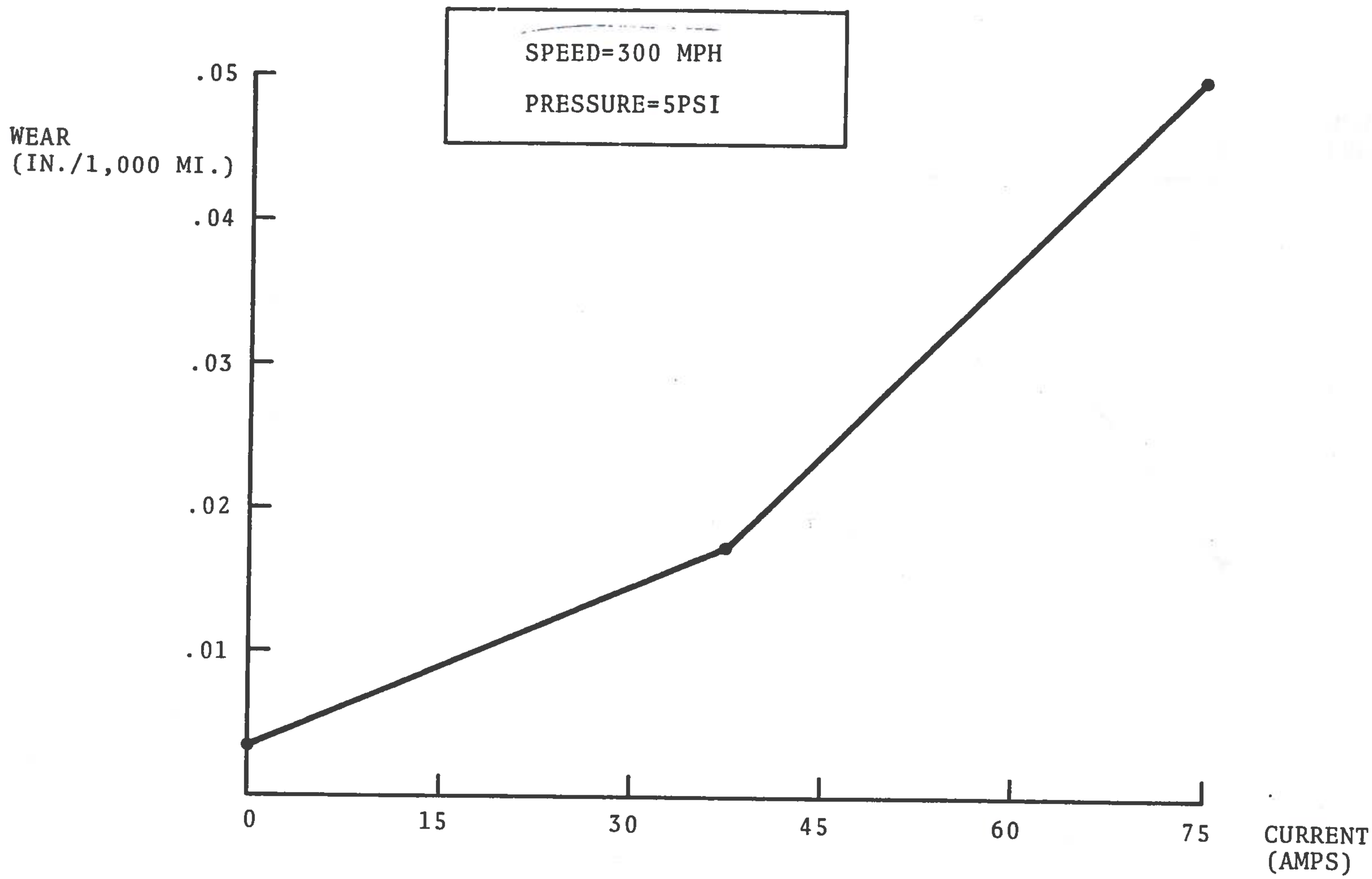


Figure 14. Effect of Current on Brush Wear

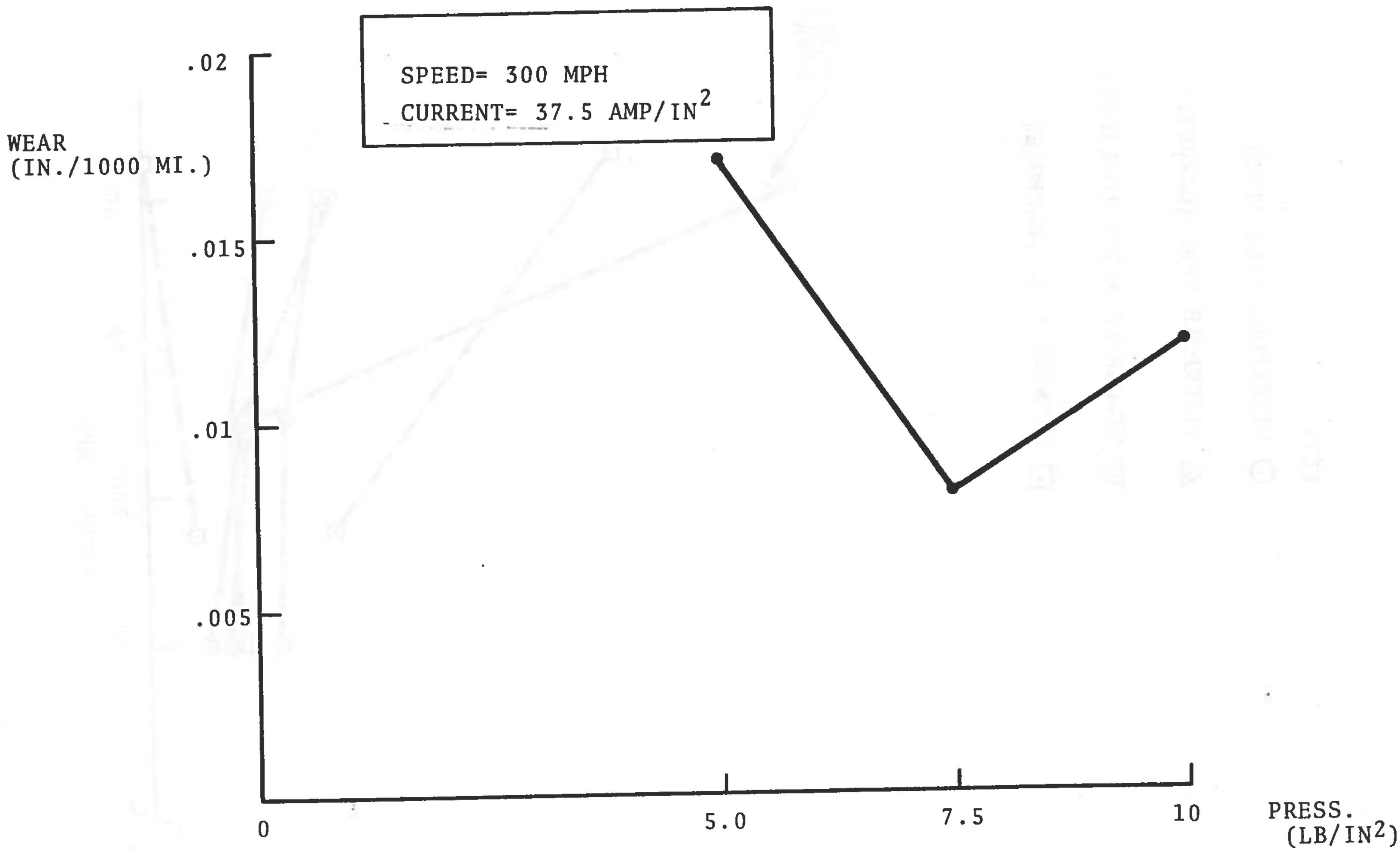


Figure 15. Effect of Pressure on Brush Wear

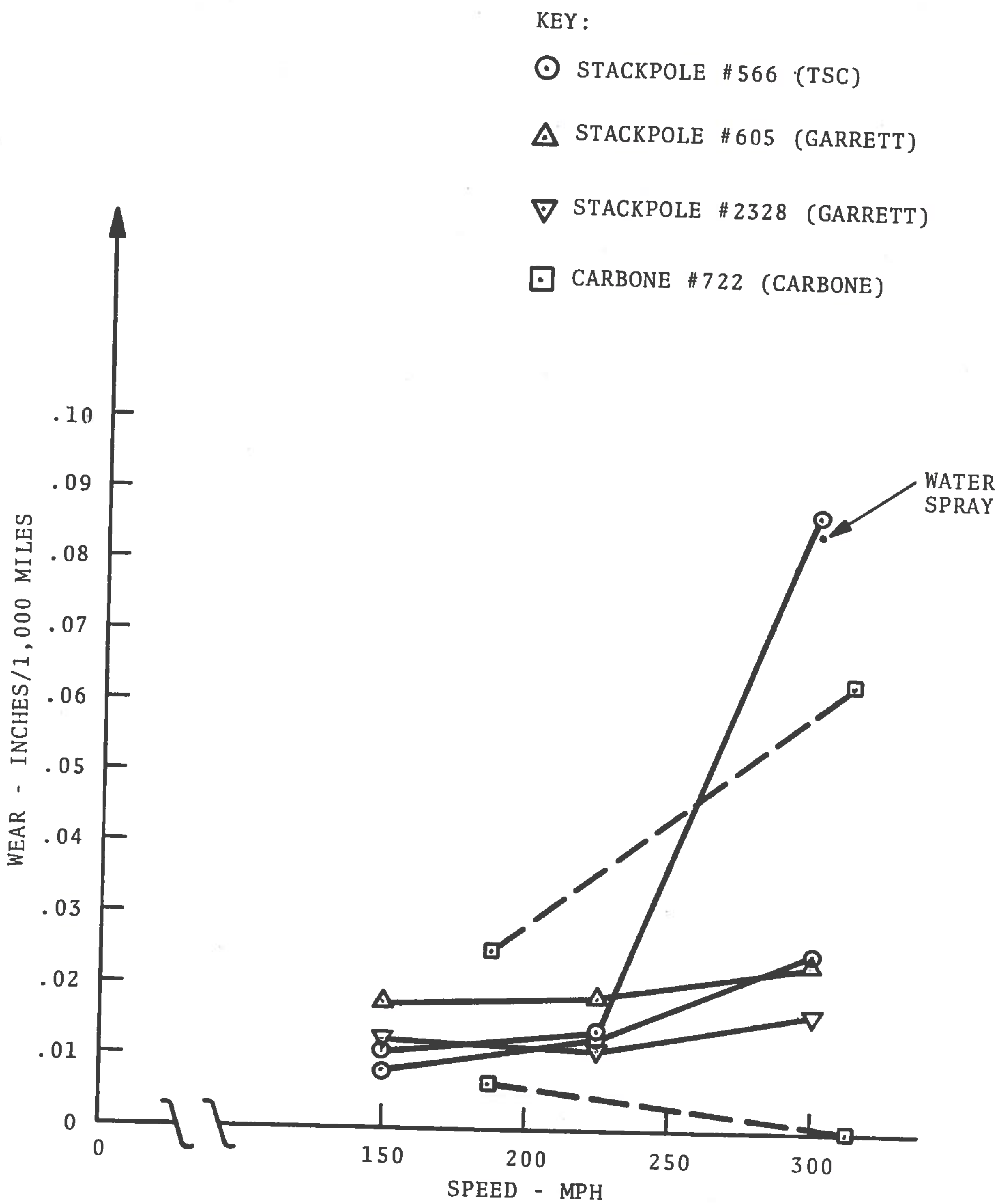


Figure 16. Comparison of Brush Test Data

Additional wear data have been gained from the bushes used for the dynamics test at the rocket sled test facility at the U.S. Naval Weapons Center, China Lake, Calif. (see reference 1). Wear of brushes carrying rated current was made by Mr. I. Litant of TSC. Appendix B, a memo to the sponsoring agency, summarizes the results. Wear rates of 3-4 inches per 1,000 miles of travel were quoted, a factor 100 to 500 times that measured with any of the three test wheels. The China Lake wear is probably excessive due to

1. the lack of proper wear-in of the rail;
2. the high degree of rail irregularity, due to manufacturing and welding techniques; and
3. the extreme rail roughness due to blowing desert sand and rocket blast from the sled.

Likewise, the wheel test wear results are probably low, because the irregularity and finish of the simulated rail are much better than can be expected of a power rail installation. This results from the difference in surface erosion caused by environmental effects and a difference in surface polishing due to the different brush pass rate. Surface finish measurements similar to Table 4 have not been made at China Lake, but it is expected that the finish is not as good.

The single data point at 300 mph in Figure 16 is the measured wear for the case where the brush was exposed to a water spray, as shown in Figure 17. Wind around the wheel prevented any water from wetting the wheel. Therefore, the test is best described as a high humidity test, and the wear is not significantly different from the result for "normal" humidity. The results are expected to be significantly different when the water wets the wheel, because loose carbon and water can then form a lapping compound on the wheel.

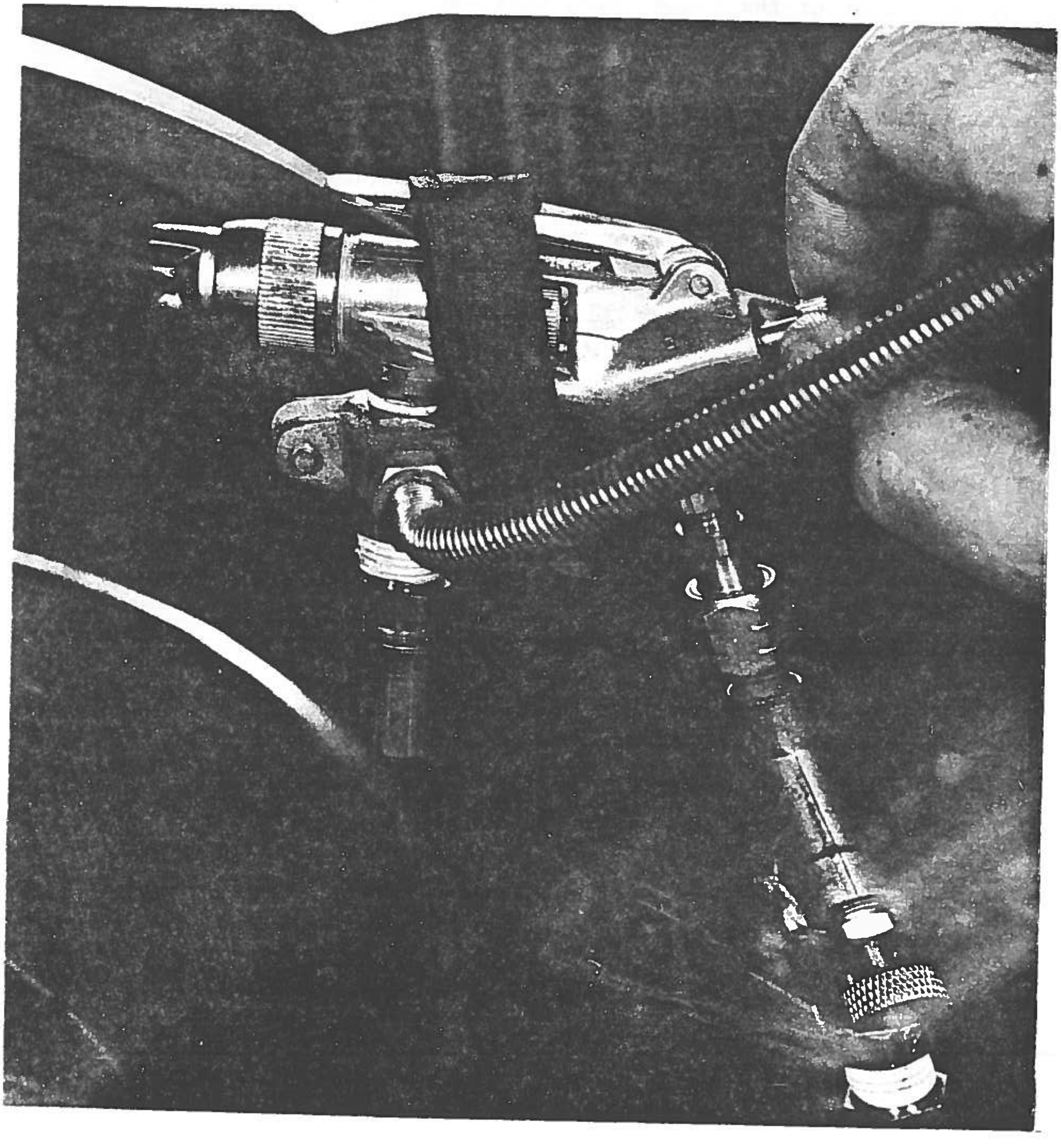


Figure 17. Water Spray on Brush Path

6. RAIL SURFACE WEAR

Only the gross effects of the brushes on the rail surface have been observed and recorded during this initial test phase; the primary concern was brush wear. Photographs of the wheel rubbing surface, as in Figures 6, 10, and 12, provide a visual record of the condition of the rail material. Surface finish has been measured periodically, as discussed in the last section and shown in Table 4. In addition, runout and material loss on the wear path have been measured.

Figures 18 and 19 illustrate the change in contour of the path from the beginning to end of this test phase, which represents approximately 50,000 miles of brush travel or 10^8 passes by the brush of any point on the wheel surface. The depth of the groove is an indication of copper wear. For Olin Alloy 194, the average wear is 0.0013 inches. For Anaconda Hitenso 1622, the average wear is 0.0019 inches. From these results it is concluded that copper wear by the current brushes will be insignificant. The time required to make 10^8 passes of a point on a rail, assuming one minute headways, would be greater than 500 years. Note that while the magnitude of runout has been reduced significantly there is not a corresponding variation around the wheel in depth of the groove, as measured from the unused copper surface. The reduction in runout is attributed to a closer fit of the copper disc to the test wheel, resulting from the pressure applied by the brushes over the testing period.

Some correlation can be made between copper wear and runout. Note that many of the short period fluctuations of the initial runout curve have been smoothed by wearing away copper (i.e., short period peaks of runout occur at the same angular position as short period peaks in the depth of groove curve). In addition, at a point just beyond the point of minimum runout in both Figures 18 and 19 there is a peak in depth of the copper wear. This is attributed to the inertia force created in accelerating the brush as it moves back to clear the peak runout of the wheel.

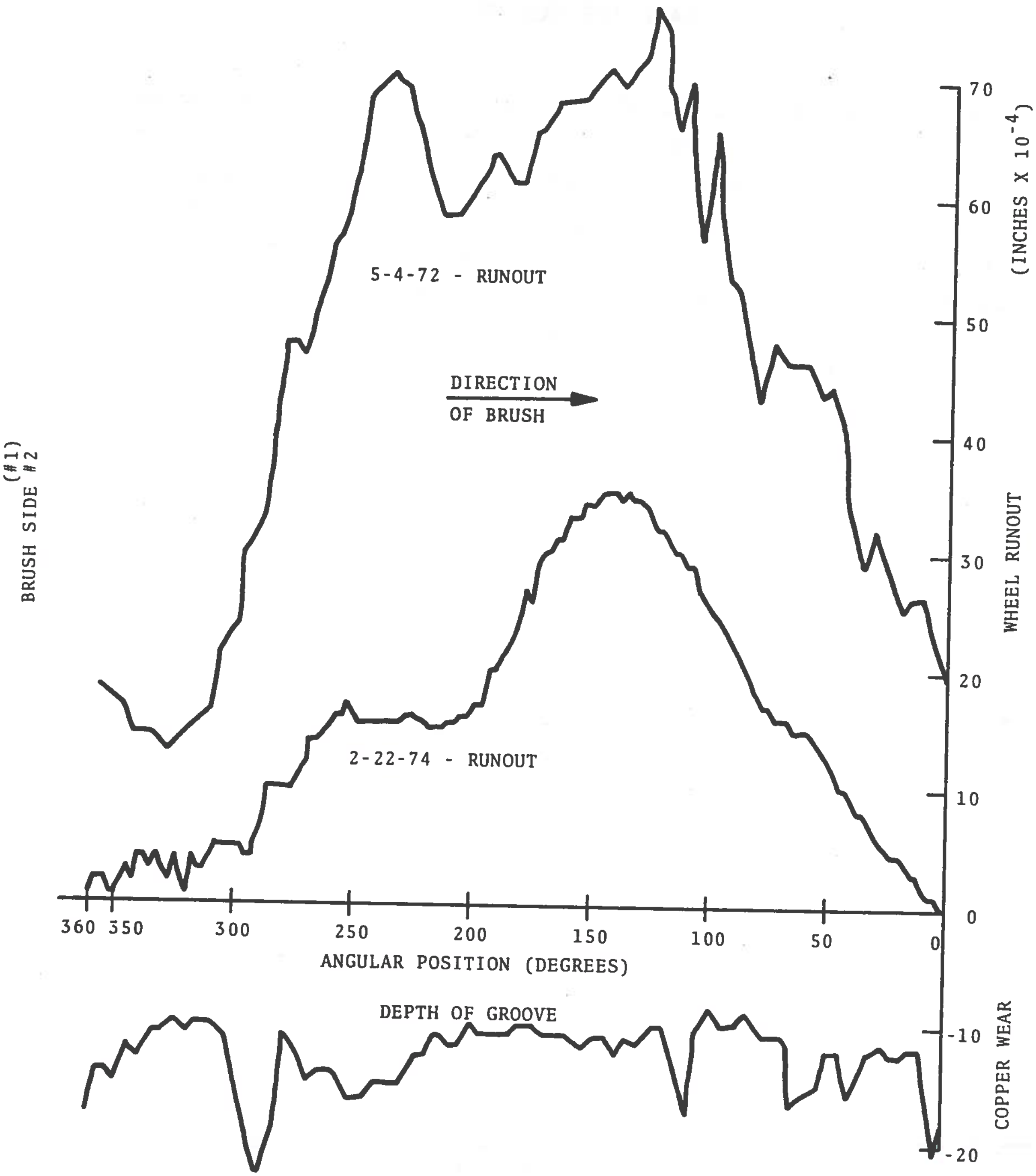


Figure 18. Runout and Groove Depth on Brush Path of Side 1 (Olin Alloy 194)

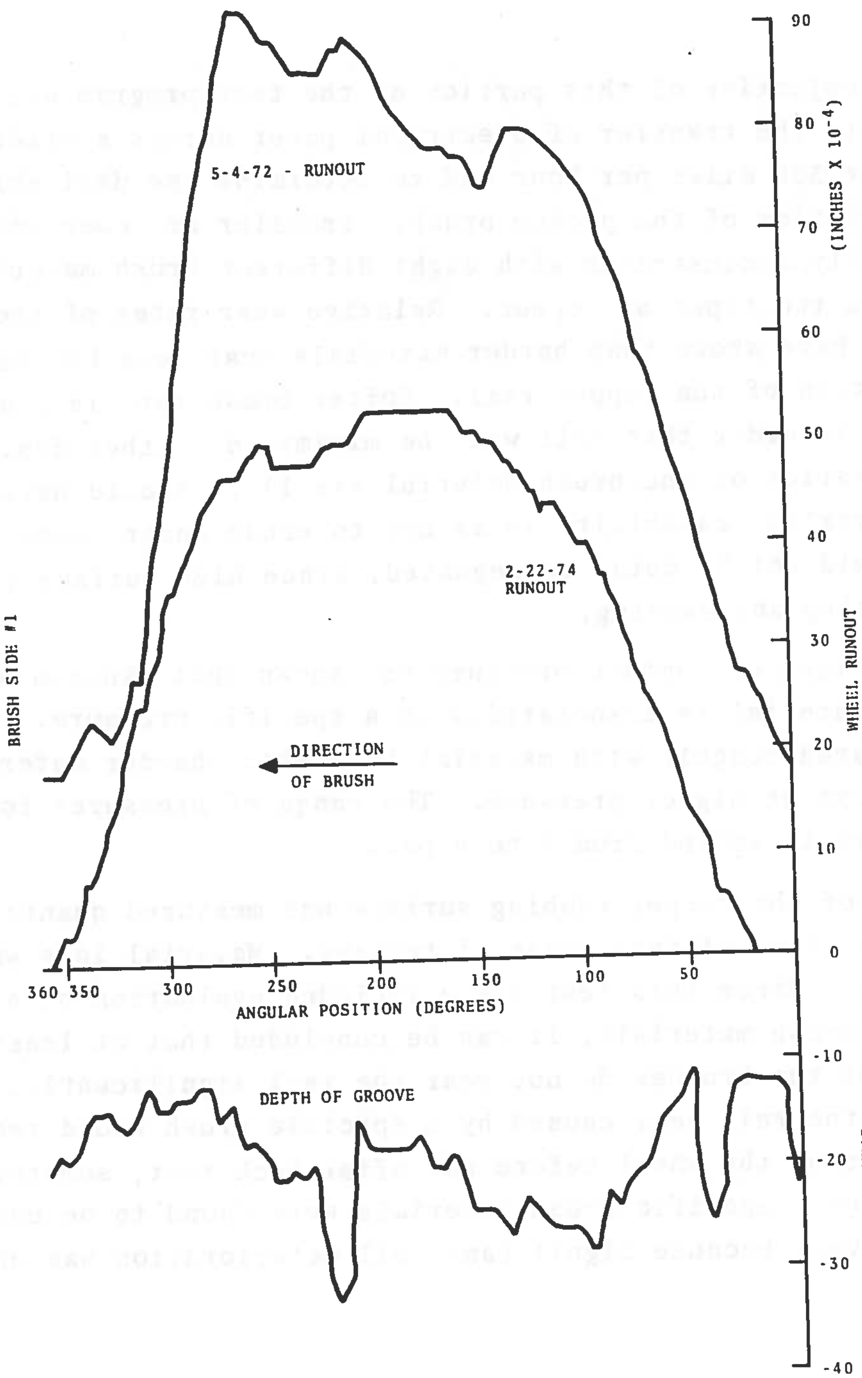


Figure 19. Runout and Groove Depth on Brush Path of Side 2 (Anaconda Hitenso 1622)

7. SUMMARY

The objective of this portion of the test program was to demonstrate the transfer of electrical power across a sliding surface at 300 miles per hour and to determine the desirable characteristics of the pickup brush. Transfer of power was successfully demonstrated with eight different brush materials sliding on two types of copper. Relative wear rates of the brush materials have shown that harder materials wear less but cause greater deterioration of the copper rail. Softer brush materials are recommended in order that rail wear be minimized. Other desirable characteristics of the brush material are 1) it should have adequate current overload capability so as not to erode under heavy arcing and 2) it should not be metal impregnated, since high surface temperatures cause melting and exuding.

Variation of contact pressure has shown that minimum wear rate for each material is associated with a specific pressure. Pressure is correlated roughly with material hardness: harder materials operate best at higher pressure. The range of pressures for the soft materials varied from 4 to 6 psi.

Wear of the copper rubbing surface was measured quantitatively after completion of this phase of testing. Material loss was negligible. Since this test phase included evaluation of eleven different brush materials, it can be concluded that at least the majority of the brushes do not wear the rail significantly. To determine the rail wear caused by a specific brush would require measurement of the wheel before and after each test, something that was not done. Specific brush materials were found to be unacceptable, however, because significant rail deterioration was observed.

8. FUTURE WORK

Continuing experiments are being tried on the wheel to determine the affect of rail finish, rail irregularity and any other parameters that might provide a better simulation of the brush on a rail. For example, in an attempt to maintain a constant wheel finish as predicted for the actual power rail, two techniques will be tested 1) use of a sand blaster, as shown in Figure 20, either continuously while testing or prior to each test, and 2) use of a cleaner brush or metallic current brush with sufficient abrasive to scratch the wheel.

To examine rail irregularity, the first step, as mentioned above, was to determine the irregularity of the wheel in its present state. Other wheel surfaces will be implemented with prescribed irregularities to examine the specifics of brush bounce. If these results prove useful in attacking the brush wear problem, a wheel will be built with oscillating capability, so that irregularities of any wavelength can be studied.

Brush holding techniques will be given some consideration. All tests now being conducted are with a brush holder used in electric motors. This is not feasible for a power collector where brushes are sprung from a moving platform. The design for the TLRV with individual brushes free to rotate about a longitudinal axis has distinct advantages. However, the problem of uneven wear due to brush rotation was observed in the China Lake tests and in dynamic tests at TSC, and this problem must be adressed.

Environmental conditions of water, ice, sand and chemicals peculiar to certain locales will be examined to determine their effect on brush wear.

A second set of screening tests will be performed after the "brush on a rail" conditions have been satisfactorily defined, and repeatability of the tests will be quantified.

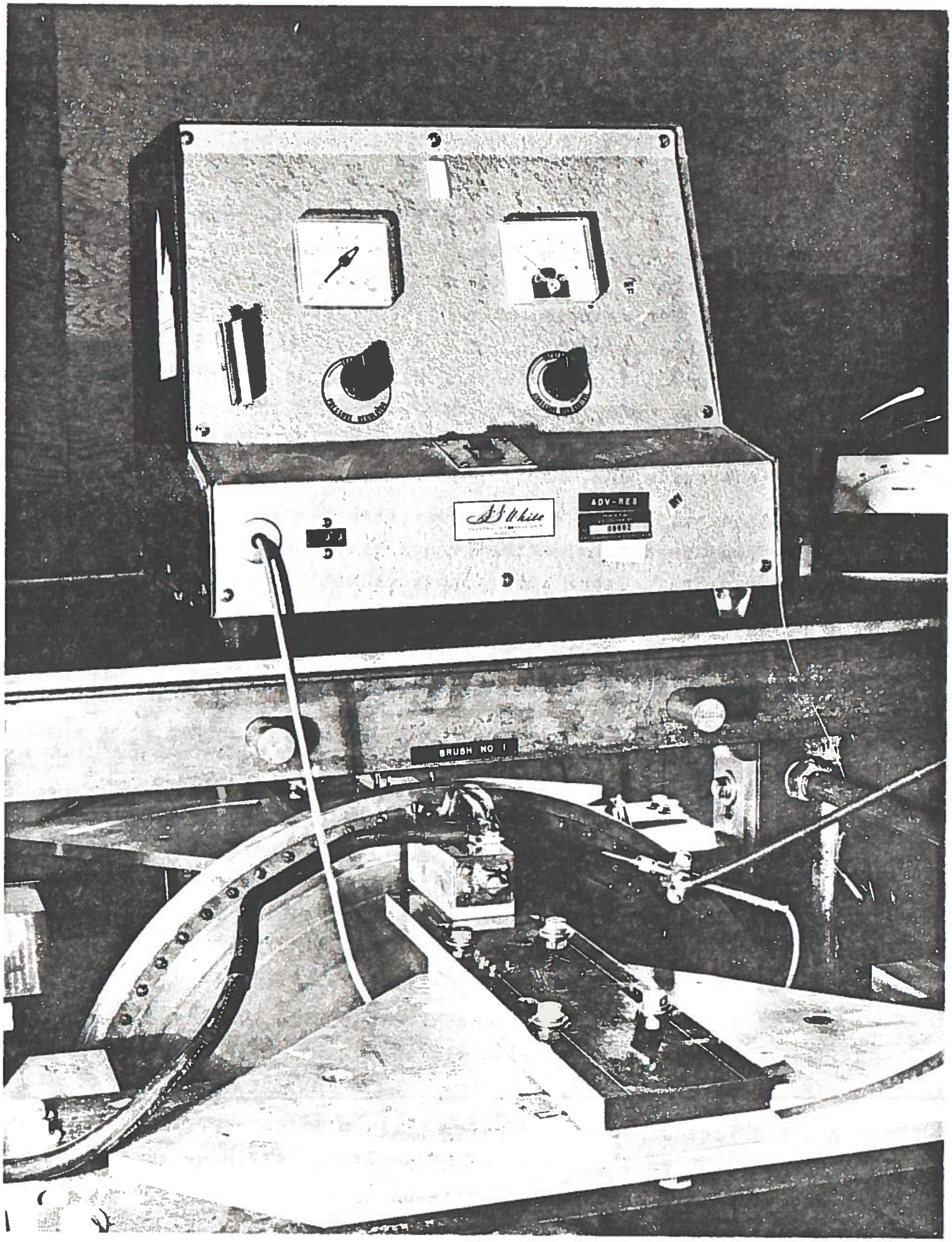


Figure 20. Surface Finish Control Using a Sandblaster

9. REFERENCES

1. "Design, Development, and Test of a Wayside Power Distribution and Collection System for the Tracked Levitated Research Vehicle," U.S. Department of Transportation, Federal Railroad Administration Report No. FRA/ORD&D 74-27, April, 1974.

2. The Carbone Corporation, Private communication with Mr. J. N. Shick.

3. "Brushes for Electrical Machines," NEMA Publication No. CB-1-1961, Aug., 1963.

4. "TSC Safety Manual," U.S. DOT/TSC publication TSC 3902.1A, October, 1973.

APPENDIX A

ANALYSIS OF BRUSH BOUNCE

UNITED STATES GOVERNMENT
Memorandum

DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
KENDALL SQUARE
CAMBRIDGE, MA. 02142

DATE: August 16, 1973

In reply refer to: TMP

SUBJECT: Brush Bounce

FROM: C. Spenny

TO: R. Novotny, FRA/RA-41

This memo presents results of an analysis of brush bounce. A spring preloaded brush was studied which slides against a power rail with sinusoidal irregularity of varying amplitude and wavelength. The variables on the abscissa and ordinate of figures 1, and 2 are defined in figure 3 and correspond to the definitions given in DOT report 72-8922, "Specification for the Manufacture, Acceptance and Handling of Wayside Power Rail."

The data presented by figure 1 is the distance, Δd, which a collector moves along the guideway while a brush which has bounced remains out of contact with the rail. The parabolic curve given by $L^2/36{,}000$ defines the maximum rail irregularity over which a brush with a 40g restoring acceleration can travel without bouncing. $\Delta d=0$ on this curve. For amplitudes above this curve, the brushes bounce and Δd is plotted as a parameter. The distance over which the brush remains in contact would be a fraction of one wavelength depending on where the brush returned to the rail.

If a sinusoidal irregularity model is applicable in analzing China Lake test data, then values of D for the rail at China Lake are extremely high. As I recall, the test data taken with the Bentley probes, values of $\Delta d=5$ feet were measured due to weld joint irregularities with L=2 inches.

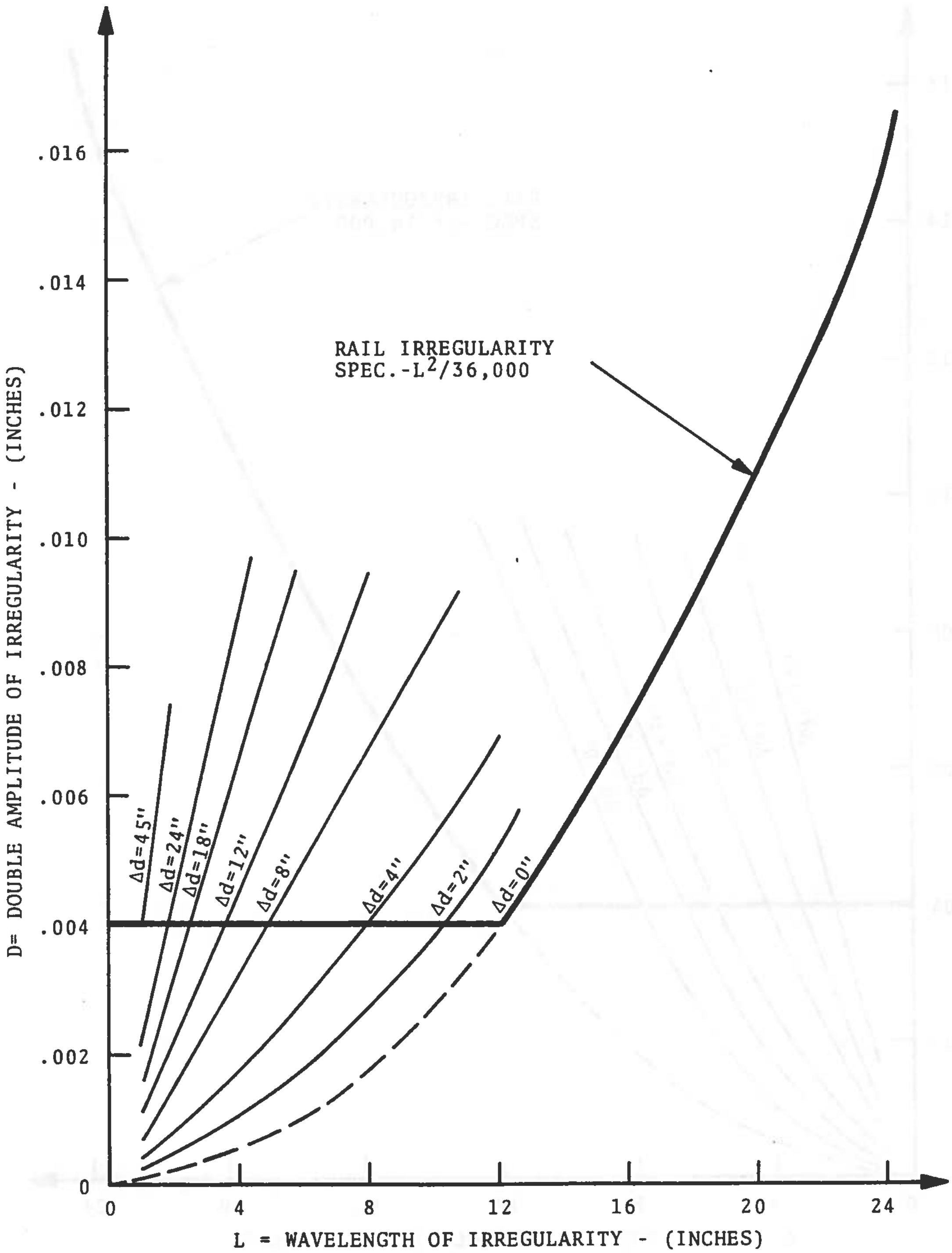


Figure A-1. Δd= Distance Traveled With No Contact by a Single Brush

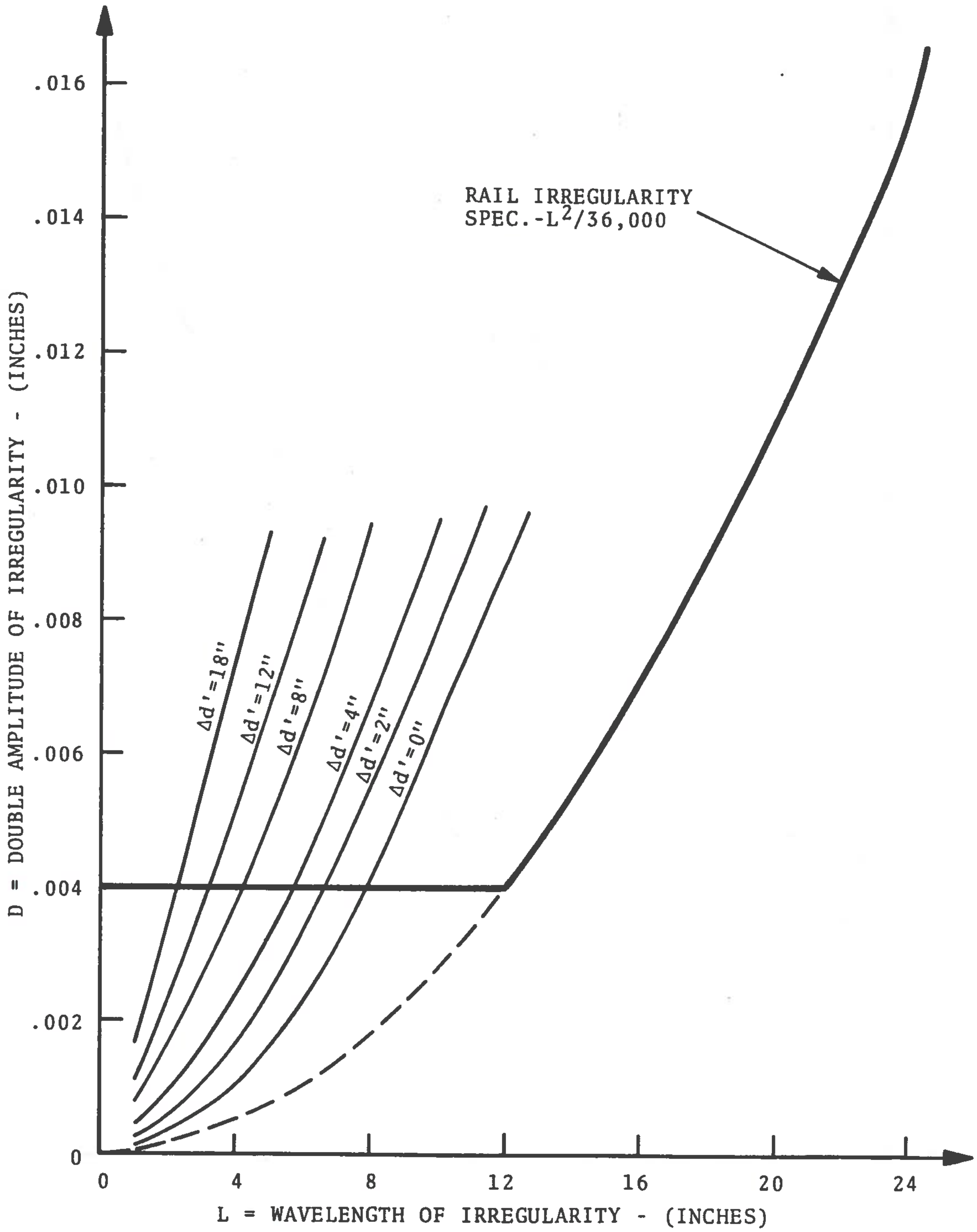


Figure A-2. Δd = Distance Traveled With No Contact by Either of a Pair of Opposing Brushes

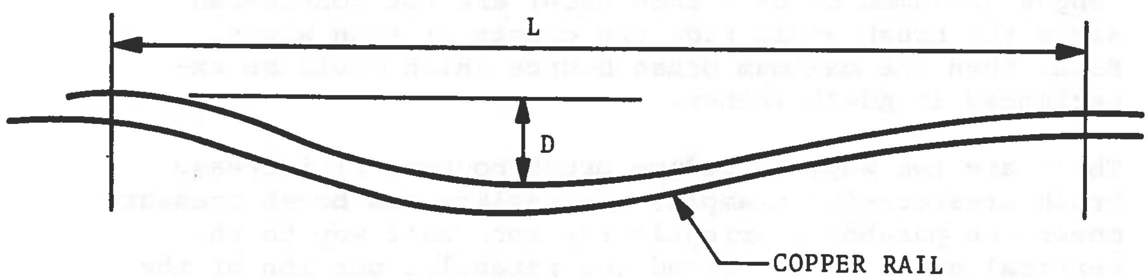


Figure A-3. Definition of Rail Irregularity Parameters

The attached graph suggests the corresponding D would be approximately 0.008-0.010 inches. Likewise irregularities caused by the procedure for unrolling the copper during rail manufacture had a wavelength of 6½ inches. Bentley data indicated skipping of 4 to 5 feet, thus requiring D=0.25 inches.

For rail installed at Pueblo the brush bounce will be reduced. The parabola, $L^2/36{,}000$ truncated by the horizontal line D=.004 inches defines the irregularity specification for Pueblo rail. Only the area below the line D=.004 inches in figure 1 represents brush bounce permitted by the spec. Wavelengths less than brush length (assumed to be 1 inch here) are not considered since the brush would ride the crests of such waves. Note, then the maximum brush bounce which could be experienced is Δd=45 inches.

There are two ways to reduce brush bounce: 1) increase brush pressure-for example, quadrupling the brush pressure moves the parabolic irregularity spec half way to the vertical axis, or 2) extend the parabolic portion of the rail irregularity spec down to the point where L=1 inch. The horizontal line which intersects is D=.000028 inches =28 microns (The finish on as rolled copper has been measured to be 5-7 microns). Alternatively to 2) above, bounce can be eliminated by increasing brush width to twelve inches and leaving the minimum irregularity tolerance at D=.004 inches. Again the brush rides the crests. However, the use of "wide" brushes has been discouraged by brush manufacturers because the current becomes concentrated at the points of contact with the crests, thereby causing localized heating and arcing and hence excessive wear.

In figure 2. $\Delta d'$ is the distance traveled with neither of two opposing brushes in contact. The effective area of permitted brush bounce is reduced. Each brush must be capable of handling twice the rated current.

In addition, since reduced arcing is the objective, the brushes must be connected with low inductance braids so that there is no delay in switching from one current path to another.

Further reduction in arcing results if additional brushes are wired in parallel which follow the first pair down the rail. However, arcing becomes more random in nature and it is not possible to completely eliminate arcing by using additional brushes. Further, the brushes must be designed to handle bigger current overloads. The correct approach is probably to choose a brush width and pressure that minimizes arcing for the particular rail which is installed. If wear is still unacceptable, then machining of the rail after installation would be recommended to eliminate the "permitted" irregularity.

The relation between wear and arcing is being examined in the laboratory at TSC to assure that a power collection system with a reasonable brush life is developed for the TACRV.

C.H. Spenny

C.H. Spenny

cc. FL Raposa

APPENDIX B

BRUSH WEAR, CHINA LAKE

UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER

DATE: June 21, 1973

SUBJECT: Evaluation of Brushes Run at China Lake

In reply refer to: TME

FROM I. Litant

TO R. Novotny, RA-41

On May 23, 1973, we received a set of brushes from Mr. John Webster of Garrett Airesearch. The brushes were scheduled to be run at China Lake, and were sent to us for inspection. They were weighed, measured, and the rubbing surfaces were photographed. The brushes were sent back to Mr. Webster on May 25.

The brakes, which were supplied by Stackpole Carbon Co., consisted of the following:

1. Six grade Z328 power brushes with shunts clipped off close to the brush body

2. Two grade S-1 cleaner brushes. All were of the same configurations as previously received.

The brushes were returned to us on June 6, after having been run, unpowered, on the rocket sled for approximately 2.5 miles (broad estimate) and at different velocities. They were then reweighed, measured and photographed.

Weight Changes

The differences between initial and final weight includes the loss by chipping as well as wear on the running surface.

Brush No.	Z328-L2A (#1 upper)	-L2B (#3 lower)	-L2C (#2 lower)	-L2D (#2 upper)
Initial Wt.	30.458g	30.558g	30.456g	30.500g
Final Wt.	30.343	30.422	30.373	30.310
	0.115	0.136	0.083	0.190

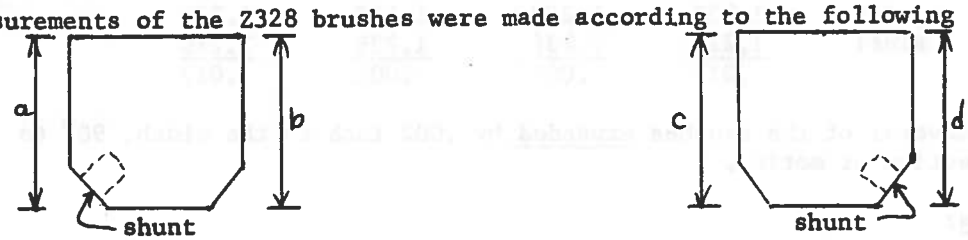
Brush No.	-L2E (#3 upper)	-L2F (#1 lower)
Initial Wt.	30.376g	30.262g
Final Wt.	30.062	30.236
	0.314	0.026

TSC F 1325.4

Brush No.	S-1-L2A	S-1-L2B
Initial Wt.	33.949g	33.710g
Final Wt.	33.641	33.480
	0.308	0.220

Measurements

Measurements of the Z328 brushes were made according to the following pattern:



Initial and final measurements are given in inches.

Brush No.		Corner a	Corner b	Corner c	Corner d
Z328-L2A	Initial	1.245	1.245	1.245	1.245
	Final	1.240	1.233	1.239	1.244
		.005	.012	.006	.001
-L2B	Initial	1.244	1.245	1.246	1.245
	Final	1.237	1.238	1.241	1.240
		.007	.007	.005	.005
-L2C	Initial	1.245	1.244	1.245	1.245
	Final	1.240	1.238	1.241	1.243
		.005	.006	.004	.002
-L2D	Initial	1.246	1.245	1.246	1.245
	Final	1.240	1.230	1.235	1.244
		.006	.015	.011	.001
-L2E	Initial	1.245	1.245	1.245	1.245
	Final	1.235	1.220	1.228	1.241
		.010	.025	.017	.004
-L2F	Initial	1.245	1.244	1.245	1.245
	Final	1.240	1.238	1.241	1.242
		.005	.006	.004	.003

Brush No.		Corner a	Corner b	Corner c	Corner d
S-1-L2A	Initial	1.238	1.238	1.238	1.237
	Final	1.228	1.222	1.228	1.237
		.010	.016	.010	.000
S-1-L2B	Initial	1.238	1.237	1.237	1.237
	Final	1.221	1.236	1.236	1.220
		.017	.001	.001	.017

NOTE: Several of the brushes <u>expanded</u> by .002 inch in the width, 90° to the direction of motion.

Comments:

1. Despite the lack of electrical erosion, the worst case, brush Z328-L2E, lost 0.025" in one corner. For a 2.5 mile run, this is the equivalent of the loss of one inch of brush in 100 miles. The wear increased in order from position #1 to position #3 in both upper and lower stations.

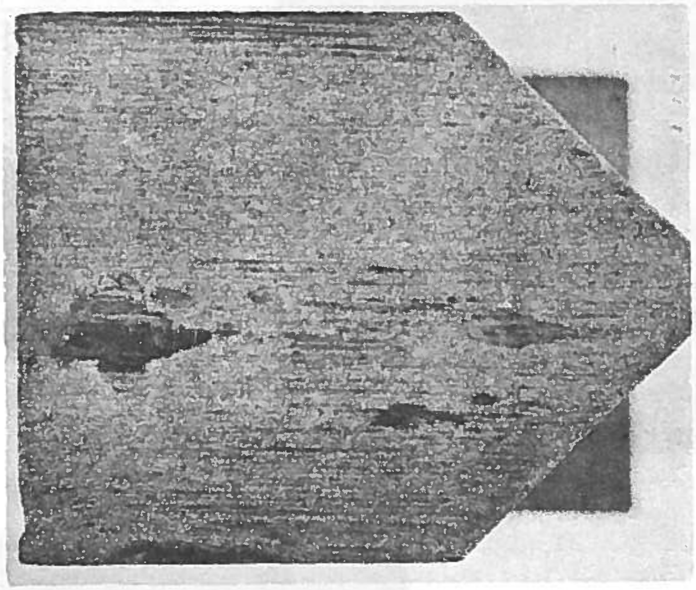
2. The stained appearance in the photographs of the cleaner brush is copper. There was an unusual amount of copper pick-up during this run, and it appears to have been picked up continuously from the rail and accumulated in the center of the brush face. The deep and irregular scoring of the face of the S-1 brushes noted in the previous run was absent.

3. Deep pitting in the face of the Z328 brushes appear to arise from original porosity as well as removal of discrete particles from this friable material.

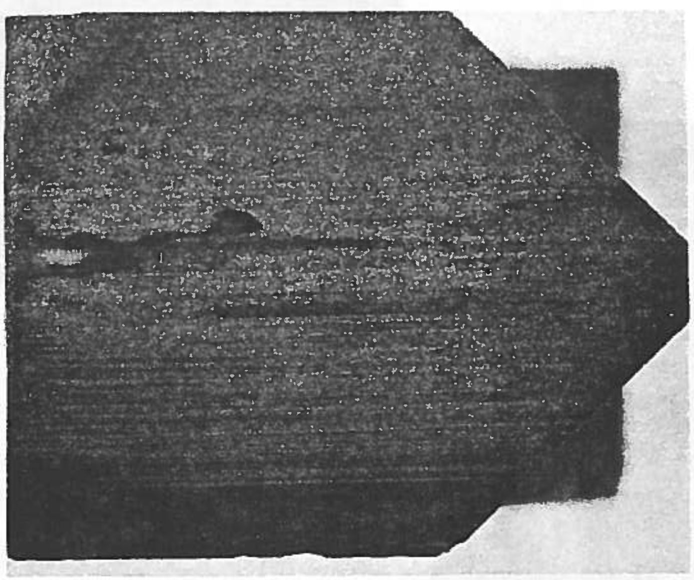
4. The face of one of the cleaner brushes was not flat, permitting the brush to be rocked on a flat surface. Under these circumstances, the force per unit area would be increased. This may account for the accumulation of copper down the center of the brush.

Irving Litant

cc:
TMP/C. Spenny
C. Weinstein (Garrett Airesearch)



SI-L2A



SI-L2B

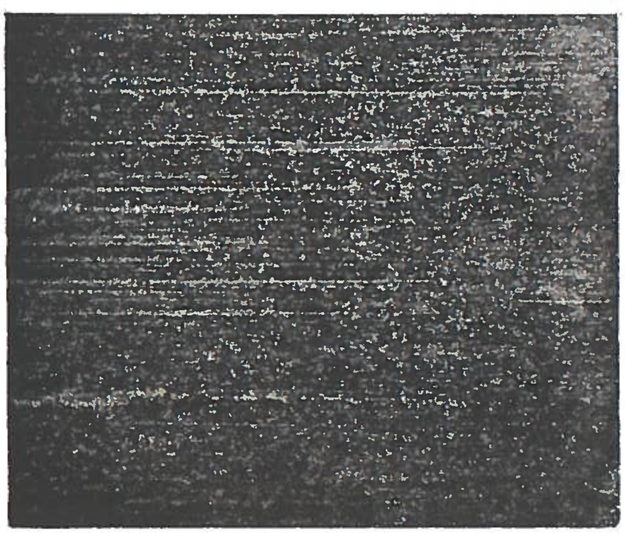
Z328-L2D
(#2 UPPER)

SHUNT SIDE

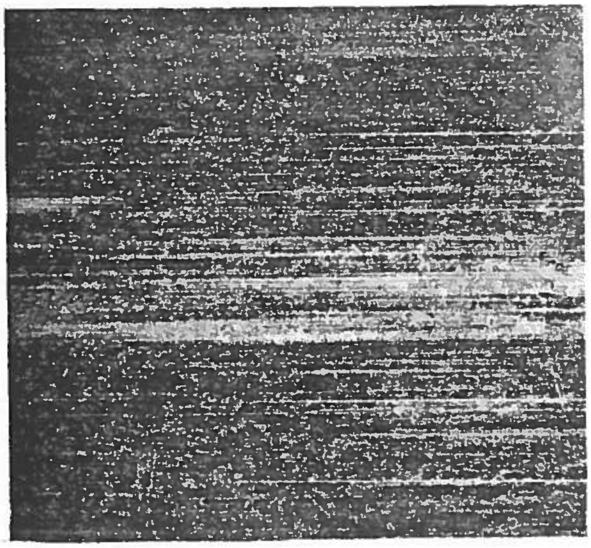
Z328-L2E
(#3 UPPER)

SHUNT SIDE

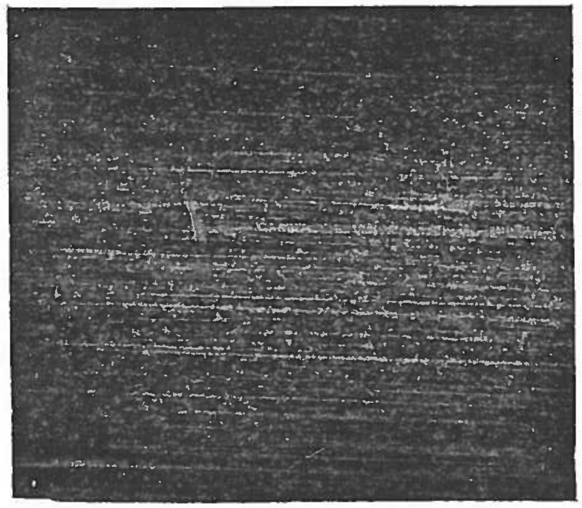
Z328-L2F
(#1 LOWER)



SHUNT SIDE



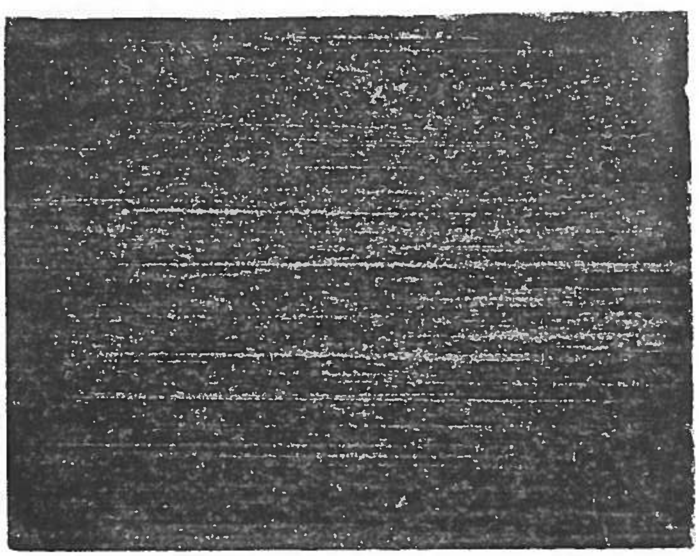
Z328-L2A
(#1 UPPER)



SHUNT SIDE

Z328-L2B
(#3 LOWER)

SHUNT SIDE



Z328-L2C
(#2 LOWER)

SHUNT SIDE