NASA TECHNICAL
MEMORANDUM

NASA TM X-64542

CONTACT RESISTANCE OF ELECTROPLATED FLAT CONDUCTOR CABLE CONDUCTORS

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July 15, 1970

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (September 1968)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
TM X-64542		

4. TITLE AND SUBTITLE	5. REPORT DATE
Contact Resistance of Electroplated Flat Conductor Cable Conductors	July 15, 1970
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) T. H. Wilkinson	8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812	10. WORK UNIT NO.
	11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Manufacturing Engineering Laboratory, Science and Engineering

16. ABSTRACT

A series of tests were conducted to determine the contact resistances of gold-over-nickel-plated and nickel-plated Flat Conductor Cable (FCC) conductors engaged with a specially prepared FCC receptacle, MSFC Number 50M72689-3. Three conductor specimens — gold-over-nickel plated, cleaned nickel plated, and uncleaned nickel plated, prepared on a premolded plug, MSFC Number 50M72637-3 — were tested under room atmosphere conditions, under outside winter conditions, and after 500 mating and unmating cycles. These tests established that gold-over-nickel-plated contacts were the lowest in contact resistance, but nickel plated (cleaned) contacts were within the acceptable limits.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Contact Resistance Gold Plated Flat Conductors Nickel Plated Flat Conductors Flat Conductor Cable Conductors	STAR Announcement Joe W. Hollis

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	15	$3.00

MSFC - Form 3292 (May 1969)

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CONTACT RESISTANCE OF ELECTROPLATED FLAT CONDUCTOR CABLE CONDUCTORS

SUMMARY

A series of tests were conducted to determine the contact resistance of gold-over-nickel-plated and nickel-plated Flat Conductor Cable (FCC) conductors engaged with a specially prepared FCC receptacle, MSFC Number 50M72689-3. Three conductor specimens — gold-over-nickel plated, cleaned nickel plated, and uncleaned nickel plated, prepared on a premolded plug, MSFC Number 50M72637-3 — were tested and under room atmosphere conditions, under outside winter conditions, and after 500 mating and unmating cycles. These tests established that gold-over-nickel-plated contacts were the lowest in contact resistance, but nickel plated (cleaned) contacts were within the acceptable limits.

INTRODUCTION

The Manufacturing Engineering Laboratory conducted a series of tests to determine the contact resistances of gold-over-nickel-plated and nickel-plated (cleaned and uncleaned) Flat Conductor Cable (FCC) conductors engaged with the MSFC 50M72689-3 FCC receptacle. The purpose of the tests was to establish the feasibility of using nickel-plated conductors (without additional gold plating) in particular applications where gold plating would be unpractical. The tests also accounted for "before and after" conditions of environmental exposure and repeated mating.

TEST EQUIPMENT

The following is a list of the type of equipment needed for the tests (the numbers in parentheses indicate the instruments required):

1. Digital voltmeter — Hewlett-Packard 3440A (1).

2. Ammeter-Weston, Model 901 (1).

3. Variable power source.

4. Printed circuit (PC) boards — MSFC Number 5835-2 (3).

5. Durability tester (1).

TEST SPECIMEN

Three cable specimens (numbered consecutively 1, 2, 3), each 1.5 inches wide with 18 copper conductors having cross sections of 4×40 mils (center-to-center spacing 0.075 inch), were prepared and assembled with respectively individual plugs (MSFC Number 50M72637-3).

Number 1 specimen contained a plug with gold (20-carat hard gold, approximately 75 microinches thick) over nickel plated copper conductors. Number 2 specimen contained a plug, with nickel-plated copper conductors, that had been cleaned with pumice and soap. Number 3 specimen contained a plug, with nickel-plated copper conductors, that had not been cleaned. The nickel plating in all three cases was approximately 100 microinches thick. Each specimen (Fig. 1) consisted of a specially prepared FCC plug (same conductor on top and bottom — no break in front of plug), a FCC plug-to-PC board receptacle, a special PC board, and the wire needed for connecting instrumentation. Terminal boards and attached lugs were used for convenience in making connection changes.

PROCEDURE

The basic procedure consisted of applying 1 ampere through each of the 18 conductors, recording the voltage drop at the contact point, and calculating the contact resistance. Figure 2 shows the test schematic.

Each specimen was tested after being subjected to the following conditions:

1. Initial insertion of plug.

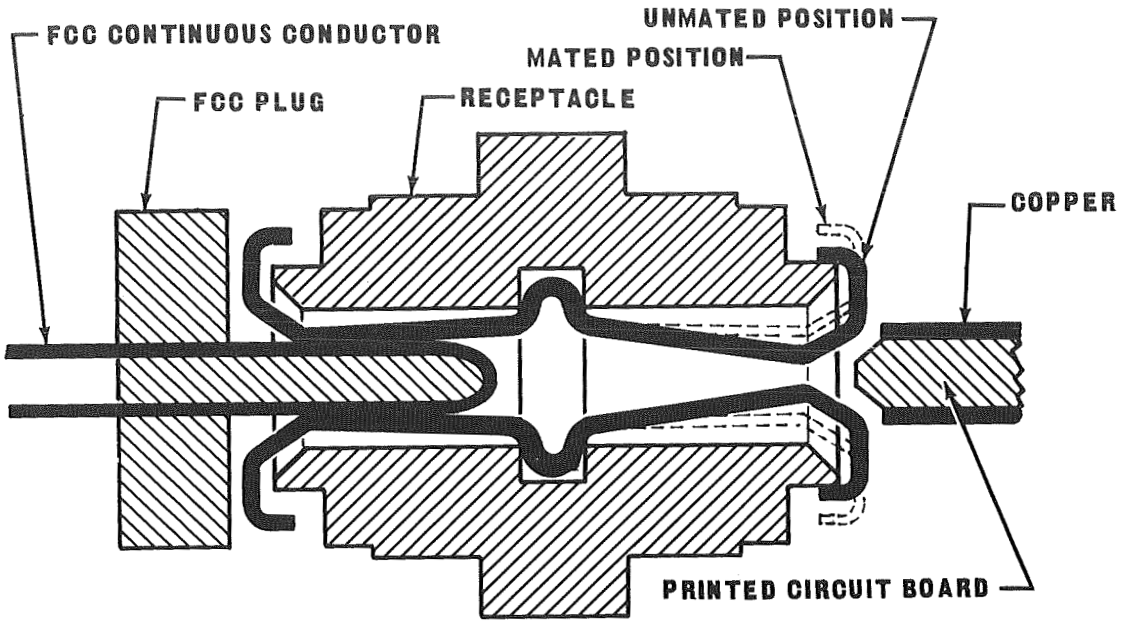

Figure 1. Typical test specimen assembly.

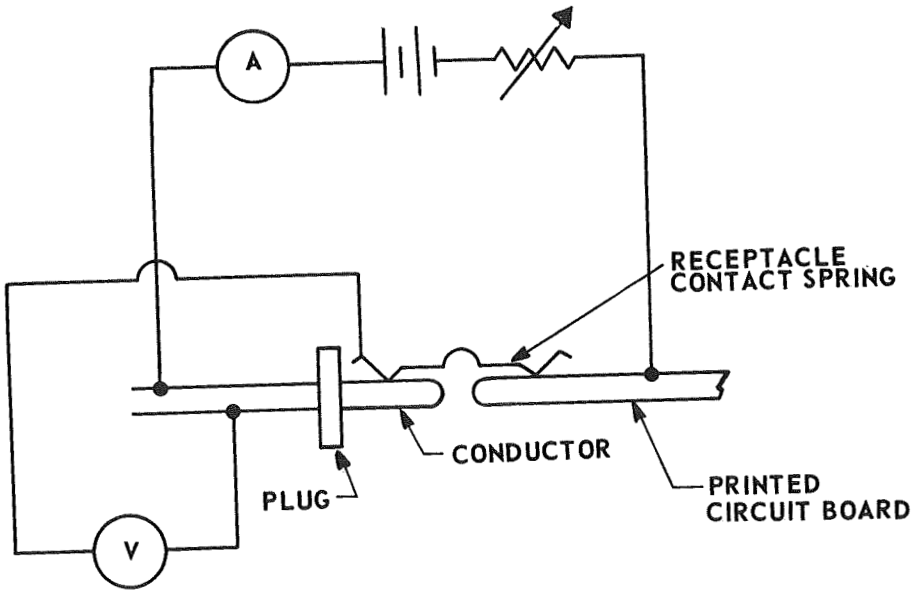

Figure 2. Test schematic.

2. One week at room conditions (inserted and noncycled).

3. Five weeks in outside winter weather (measured at end of each week, inserted and noncycled).

4. After 500 cycles of mating and unmating (room condition).

Readings were recorded in each phase of the test, beginning with the initial insertion of each plug contact. The first readings were taken with each contact in a mated position using the same 50M72689-3 receptacle for each specimen. The samples were then exposed to 1 week of room atmosphere and readings were recorded at the end of the week. During this and subsequent phases of the test, new and different receptacles (50M72689-3) and PC boards were used for each specimen; the receptacles were numbered to correspond with the plug samples. Next, each of the samples was exposed to outside winter conditions for 5 weeks; the contact resistance was recorded each week. Then the samples were brought inside and placed in the durability tester and mated and unmated for 500 cycles; they were cleaned with alcohol and the contact resistance for each was measured and recorded.

RESULTS

Tables 1 through 3 are the data sheets for the tests of Specimen Numbers 1 through 3, respectively. Table 4 lists the average contact resistance for each specimen during the specified test condition and can be used to compare the performances of the three specimens.

The average reading for Specimen Number 1 (gold-over-nickel-plated) was 0.73 milliohm in the initial inserted condition, 0.57 milliohm after outside exposure, and 0.75 milliohm after 500 cycles of mating. Specimen Number 2 (nickel plated, cleaned) had an average reading of 0.73 milliohm in the initial inserted condition, 0.93 milliohm after outside exposure, and 0.87 milliohm after 500 cycles of mating. Specimen Number 3 (nickel plated, uncleaned) averaged 1.51 milliohms in the initial inserted condition, 1.14 milliohms after outside exposure, and 1.0 milliohm after 500 cycles of mating. Because different receptacles were used on the first phase and the remainder of the tests, the results are not necessarily correlatable.

TABLE 1. DATA SHEET FOR SPECIMEN NUMBER 1 — GOLD-OVER-NICKEL PLATED

Condition		Room Atmosphere		Outside Weather					Room Atmos.
		Initial Insertion	One Week	First Week	Second Week	Third Week	Fourth Week	Fifth Week	After 500 Cycles
Date of Reading		(12/9/69)	(12/16/69)	(1/5/70)	(1/12/70)	(1/19/70)	(1/26/70)	(2/2/70)	(2/16/70)
Resistance (milliohm) for each of the 18 contacts	1	0.68	0.85	0.54	0.56	0.55	0.43	0.49	0.42
	2	0.84	0.68	0.64	0.65	0.50	0.47	0.56	0.56
	3	0.93	0.83	0.45	0.34	0.30	0.28	0.29	0.39
	4	0.92	0.87	0.87	0.92	0.98	0.80	0.69	0.83
	5	0.47	0.67	0.64	0.69	0.58	0.54	0.60	0.83
	6	0.73	0.75	0.84	0.78	0.61	0.67	0.67	0.67
	7	0.79	0.47	0.43	0.39	0.31	0.42	0.42	0.46
	8	0.92	0.36	0.47	0.49	0.53	0.49	0.50	0.72
	9	0.67	0.73	0.71	0.56	0.59	0.52	0.52	0.67
	10	0.75	0.55	0.57	0.63	0.50	0.59	0.62	0.84
	11	0.84	0.35	0.45	0.48	0.41	0.36	0.38	0.49
	12	0.88	0.81	0.87	0.88	0.78	1.02	0.99	1.36
	13	0.94	0.50	0.67	0.52	0.60	0.92	0.54	0.81
	14	0.69	0.59	0.60	0.69	0.67	0.63	0.68	0.86
	15	0.38	0.77	0.80	0.84	0.70	0.62	0.63	1.44
	16	0.62	0.89	0.65	0.63	0.59	0.52	0.49	1.04
	17	0.61	0.52	0.59	0.47	0.54	0.56	0.57	0.54
	18	0.61	0.63	0.53	0.50	0.65	0.70	0.64	0.57
Average		0.73	0.64	0.62	0.61	0.57	0.59	0.57	0.75

TABLE 2. DATA SHEET FOR SPECIMEN NUMBER 2 — NICKEL PLATED, CLEANED

Condition		Room Atmosphere		Outside Weather					Room Atmos.
		Initial Insertion	One Week	First Week	Second Week	Third Week	Fourth Week	Fifth Week	After 500 Cycles
Date of Reading		(12/9/69)	(12/17/69)	(1/5/70)	(1/12/70)	(1/19/70)	(1/26/70)	(2/2/70)	(2/16/70)
Resistance (milliohm) for each of the 18 contacts	1	0.63	0.41	0.68	0.56	0.51	0.52	0.48	0.56
	2	0.56	0.77	0.82	0.85	0.88	0.97	0.94	0.87
	3	0.69	0.76	0.62	0.75	0.75	0.89	0.84	0.85
	4	0.97	0.47	0.57	0.58	0.76	0.81	0.63	0.58
	5	0.45	0.82	0.75	0.83	0.78	1.06	0.82	0.78
	6	0.71	0.74	0.97	0.89	0.82	1.13	0.78	0.83
	7	0.90	0.42	0.55	0.85	0.68	0.85	0.77	0.88
	8	0.93	0.70	0.78	0.91	0.89	1.01	0.87	0.64
	9	0.70	0.87	1.16	1.32	1.29	1.55	1.38	0.80
	10	0.89	0.35	1.11	0.82	0.98	1.32	1.25	1.02
	11	0.42	0.76	0.89	0.97	0.81	1.24	0.85	0.93
	12	0.75	0.72	0.79	1.08	1.20	1.13	0.86	0.87
	13	0.72	0.84	0.88	1.05	0.80	0.85	0.99	0.93
	14	0.89	0.86	0.91	0.88	0.91	1.18	1.01	0.88
	15	0.86	0.52	0.79	1.00	0.94	0.98	1.02	1.01
	16	0.62	0.68	0.73	0.99	1.00	1.16	1.14	1.07
	17	0.61	0.56	0.78	0.57	0.78	1.01	0.99	1.06
	18	0.74	0.64	0.82	0.93	0.92	1.09	1.02	0.99
Average		0.73	0.66	0.81	0.87	0.87	1.05	0.93	0.87

TABLE 3. DATA SHEET FOR SPECIMEN NUMBER 3 — NICKEL PLATED, UNCLEANED

Condition		Room Atmosphere		Outside Weather					Room Atmos.
		Initial Insertion	One Week	First Week	Second Week	Third Week	Fourth Week	Fifth Week	After 500 Cycles
Date of Reading		(12/9/69)	(12/16/69)	(1/5/70)	(1/12/70)	(1/19/70)	(1/26/70)	(2/2/70)	(2/16/70)
Resistance (milliohm) for each of the 18 contacts	1	2.14	1.38	1.22	1.18	1.21	1.11	0.81	0.71
	2	1.30	0.99	1.37	1.42	1.39	1.56	1.49	2.01
	3	1.05	0.67	0.84	1.16	1.26	1.16	1.14	0.74
	4	1.26	1.15	1.26	1.11	0.93	0.96	0.84	0.78
	5	1.83	2.13	1.98	2.17	2.11	2.03	1.53	0.87
	6	1.15	1.10	0.87	1.06	1.37	1.39	1.15	1.63
	7	1.52	1.06	2.21	1.61	1.79	1.61	1.16	1.52
	8	1.18	0.85	1.03	0.75	1.12	1.40	1.14	1.02
	9	1.86	0.60	1.37	2.15	1.41	1.42	1.17	0.75
	10	1.26	2.09	1.27	1.42	1.16	1.09	0.95	0.93
	11	1.26	0.58	0.63	0.49	0.84	2.32	1.90	0.87
	12	1.27	1.04	1.03	0.87	1.15	2.84	1.10	0.64
	13	1.68	1.43	1.45	1.42	1.13	0.87	0.91	0.92
	14	1.84	1.15	1.16	1.01	1.01	1.32	1.12	1.03
	15	2.24	0.58	0.51	0.43	0.59	0.83	0.73	0.64
	16	1.79	1.60	1.08	1.14	1.23	1.59	1.22	0.73
	17	1.40	0.71	0.70	1.25	1.45	1.44	1.12	1.03
	18	1.14	1.42	1.76	1.24	1.18	1.14	1.05	1.08
Average		1.51	1.14	1.21	1.21	1.24	1.45	1.14	1.0

TABLE 4. AVERAGE CONTACT RESISTANCE OF SPECIMEN NUMBERS 1, 2, AND 3

Condition	Specimen No. 1 Gold-Over-Nickel Plated (milliohm)	Specimen No. 2 Nickel Plated, Cleaned (milliohm)	Specimen No. 3 Nickel Plated, Uncleaned (milliohm)
Initial Insertion	0.73	0.73	1.51
Room Atmosphere (One Week)	0.64	0.66	1.14
Outside Weather			
First Week	0.62	0.81	1.21
Second Week	0.61	0.87	1.21
Third Week	0.57	0.87	1.24
Fourth Week	0.59	1.05	1.45
Fifth Week	0.57	0.93	1.14
After 500 Mating Cycles	0.75	0.87	1.00

CONCLUSION

Test data showed that the contact resistance of gold-over-nickel-plated conductors was the lowest, but that cleaned nickel-plated conductors were within acceptable limits for functional operation. For a typical connector, the total connector resistance (which includes all joints, internal circuit hardware, and the contact) may be 10 to 15 milliohms; this total connector resistance corresponds to a 30 to 45 millivolt voltage drop at 3 amperes of current flow. From Table 4, it is noted that the difference between maximum resistances of gold-over-nickel-plated and nickel-plated contacts did not exceed 0.76 milliohm. In most cases, this very small contact resistance change (0.76 milliohm) becomes inconsequential when compared to a total connector resistance of 10 to 15 milliohms. The results of these test conclusively prove that, for relatively short durations (less than 6 weeks), nickel-plated conductors (without additional gold plating) can, in many cases, be used without sacrificing reliability or functional requirement.

APPROVAL

CONTACT RESISTANCE OF ELECTROPLATED FLAT CONDUCTOR CABLE CONDUCTORS

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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