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BDX-613 1435 (Rev.)

EVALUATION OF HIGH DENSITY BRAID TERMINATION FATIGUE LIFE AND CONDITION

PDO 6984751, Milestone Report

E. Belarde, Project Leader

Project Team:
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Prepared for the United States Energy Research and Development Administration Under Contract Number E(29-1)-613 USERDA

Bendix Kansas City Division

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Price: Microfiche $2.25
Paper Copy $3.50

BDX-613-1435 (Rev.)
Distribution Category UC-38

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OT E(29-1)-613

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Prepared by E. Belarde, D/862, under PDO 6984751

The fatigue life of high density braid terminations was increased when the braid was impregnated with cellulose nitrate. Preliminary results are promising in a study of a technique to nondestructively determine the quality of solder joints.

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A prime contractor for the United States Energy Research and Development Administration
Contract Number AT(29-1)-613 USERDA

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SUMMARY

A part of the total high-density, braided shield development work was devoted to evaluating electromagnetic radiation (EMR) braided shield solder terminations. Because field handling and excessive flexing of cables lowers the effectiveness of EMR shielding, fatigue failure data is essential for determining the life expectancy and future design of cables.

Cables were bent vertically across a 0.375-inch-diameter (9.5 mm) mandrel (0 to 180 to 0 degrees) for 100 cycles. Wire breakage averaged about 16 percent of the braid. The test was repeated using a 0.50-inch-diameter (12.7 mm) mandrel with breakage averaging about 12 percent. The impregnation of the braid with cellulose nitrate, where practical, creates a more uniform stress distribution and thereby increases the cable fatigue life.

Efforts directed toward developing a technique for nondestructively evaluating the quality of the soldered braid termination proved promising. Initial nondestructive test results on solder joints produced a family of curves which compared directly to the breaking strength of the joints when pull tested. Further development will involve applying the technique to braid-to-EMR hardware terminations.

DISCUSSION

SCOPE AND PURPOSE

This work was performed as part of an overall effort to develop new and improved techniques for terminating electromagnetic radiation EMR shielding to the EMR hardware. Shields terminated by present methods can be damaged when subjected to excessive field handling and usage.

PRIOR WORK

Prior work on this endeavor was devoted primarily to braiding high density EMR shielding and to the nondestructive detection of braid defects on cables having such shields. Reports concerning this work are listed in the References section.[1-5]

ACTIVITY

Bend Test

A fatigue testing program was developed which closely resembled the mode of failure seen on single braided pullout cables during handling and usage. Equipment previously used on a twist test[2] was modified for the program. Figure 1 shows the bend test configuration.

Test cables similar to the pullout cable were fabricated, except that the actual connectors were replaced with brass plugs having the same dimensions. (Brass plugs are both less expensive and reusable.) Figure 2 shows the test cable. The individual wires within the cable were not attached to the brass plug but were attached to a ring and held in place with aluminum-oxide-filled epoxy.

Because of cross conductance between shield wires, resistance measurements could not detect the breakage of individual wires. The solution to this problem was the use of insulated copper magnet wire for the braided shield and for measuring the change in potential (constant current) as the wires broke. With this method, individual wires could not cross-conduct and a change in potential was detected when 1 wire out of 216 broke. The electrical schematic of the system is shown in Figure 3.

Initially, 10 specimens were tested, one at a time, to determine the accuracy of the monitoring equipment. After a given number

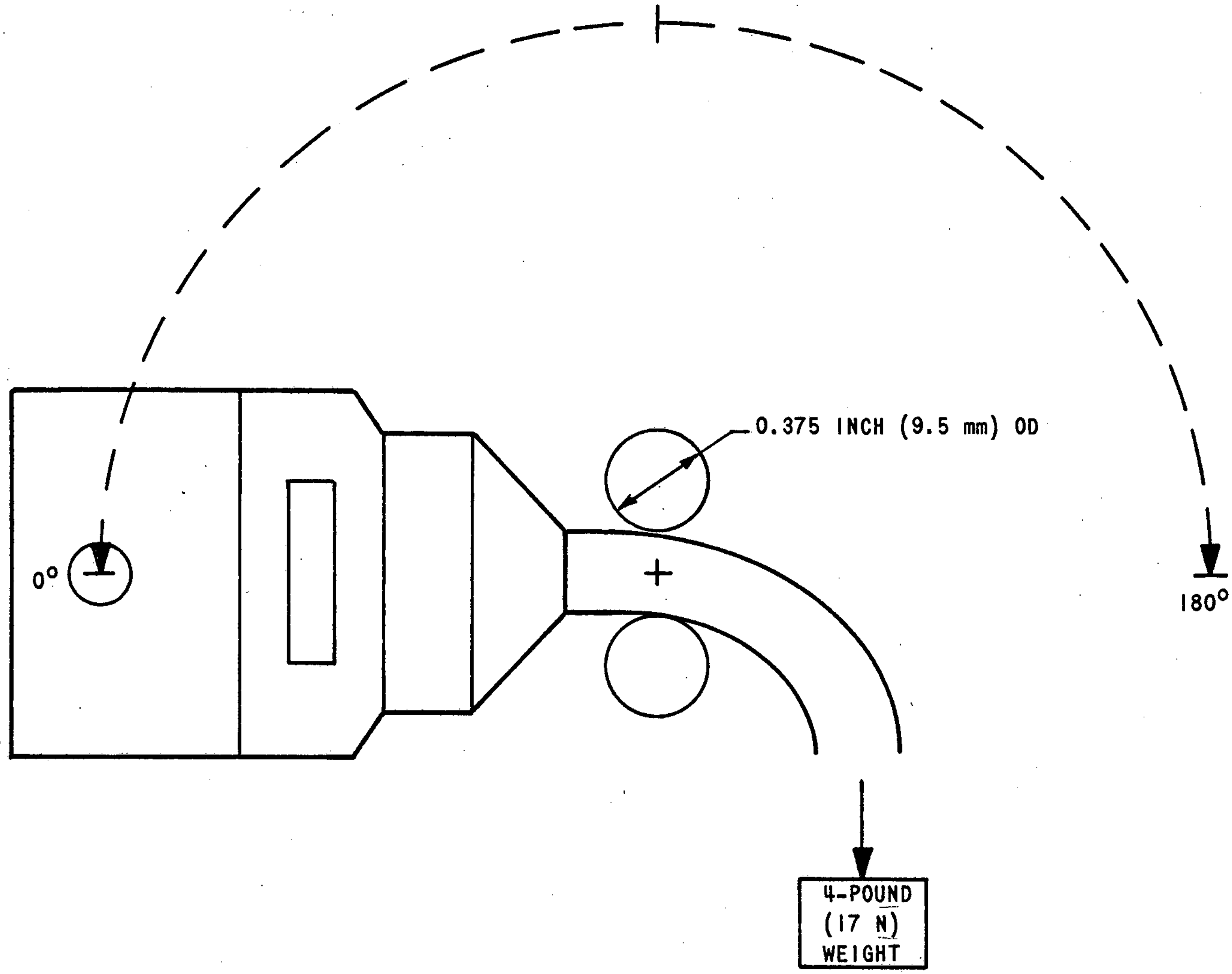

Figure 1. Bend Test Configuration

of fatigue cycles, the unit under test was stripped of the neoprene insulation and visually inspected to verify electrical count of broken wires. One cycle is a bend from 0 to 180 and back to 0 degrees (Figure 1).

Testing was conducted on 30 units in groups of 15. Each unit underwent a total of 100 cycles. The range of data using a 0.375-inch-diameter (9.5 mm) mandrel is shown in Table 1.

The test was repeated using a 0.50-inch-diameter (12.7 mm) mandrel. The range of results is also shown in Table 1. Figure 4 compares the average wire breakage cycles of the two tests.

Although some random breakage occurred, the general rule was that breakage occurred at specific points with all wires in a given carrier breaking as illustrated in Figure 5.

Figure 2. Test Cable

Because braid failure occurred where the cable was flexed, it became apparent that work dealing with improving the braid to EMR hardware terminations should be redirected toward developing techniques which would distribute the stress concentration away from the point of bending.

The effects of using cellulose nitrate (impregnated into the braid) to create a more uniform stress distribution were studied. Among the 10 units bent around the 0.375-inch (9.5 mm) mandrel, there appeared to be no significant difference. The 10 units bent around the 0.50-inch (12.7 mm) mandrel showed an average decrease of approximately one-half in the number of wires broken.

Nondestructive Evaluation Of Solder Joints

Because much RF leakage occurs around cracked solder joints at the shield-to-hardware junction, this interconnection was investigated. Other defects that adversely affect the strength of a solder bond, such as gaps and uneven areas of contact, could also affect EMR characteristics.

Work began with a study of the simplest type of solder joint, overlapped buss wires. Initial efforts were aimed at correlating some type of NDT results with pull-test data.

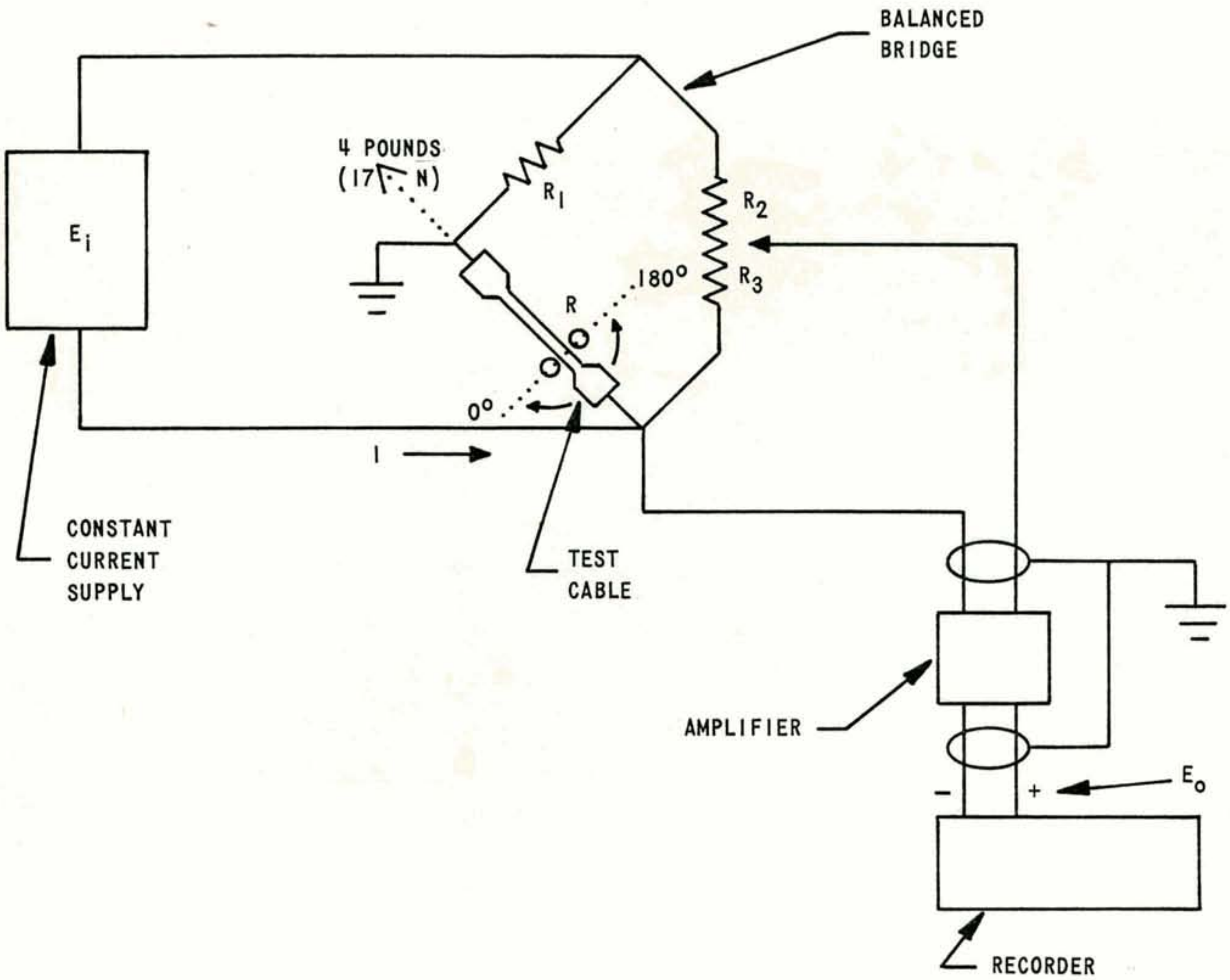

Figure 3. Bridge Circuit

When a joint is formed between two pieces of metal, the contacting surface will be less than 100 percent because of the irregularities of the two surfaces. The resistance of such a joint would be expected to be proportional to the area of the contacting surface. The current density in the points of good contact is higher than in the areas of poor contact. This results in increased heating in the joint which in turn causes the resistance to increase because of the positive temperature coefficient. The increase in resistance with current is higher in bonds where the area of good contact is smaller.

It was felt that nonlinear constriction resistance evaluated at high current densities would give better results than conventional resistance measurements. In both cases, the mass of solder

Table 1. Fatigue Cycles Versus Breakage

Cycles	Breakage On 0.375-Inch-Diameter (9.5 mm) Mandrel	Breakage On 0.50-Inch-Diameter (12.7 mm) Mandrel
10	0-2	0-3
20	0-5	0-3
30	0-15	0-14
40	1-32	0-23
50	2-38	0-31
60	6-40	1-48
70	9-45	4-43
80	11-48	5-48
90	13-53	10-52
100	18-55	11-53

present in a solder joint would affect the cross-sectional area of conductor at the joint. This is not a serious deterrent, however, because most production solder joints do not have excessive solder present.

The use of constriction measurements for evaluating electrical contacts is widely discussed in the literature.[6,7,8] Several methods of measuring these nonlinear characteristics have been reported on, such as third harmonic generation[9] and measurement of a dc component obtained from the demodulation effects of the nonlinearity.[10] No reference, however, has reported any technique supported by any kind of data.

An equal number of good and bad solder joints were fabricated by an experienced production operator. Each joint was to have the same mass of solder showing. All joints were of overlapped 24-gage cold drawn copper wire (Figure 6). Twenty of these joints were subjected to both destructive and nondestructive evaluation.

Initial effort was to pump the bonds with an ac constant current source, amplify the voltage drop across the bond, and perform a real time power spectral density analysis on this voltage. Any nonlinearities with respect to current should produce a measurable harmonic content. According to Homes,[6] this nonlinear relationship is

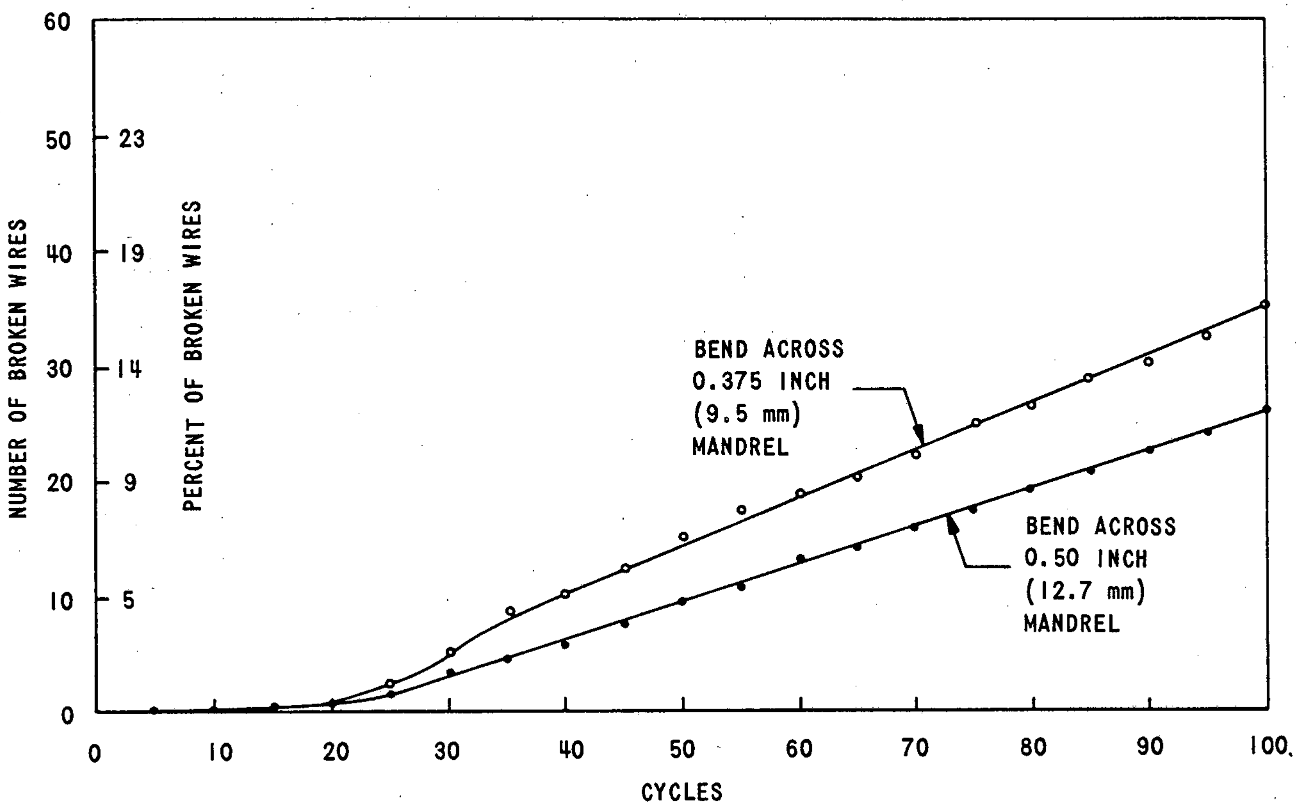

Figure 4. Average Wire Breakage Versus 180 Degree Bend Cycles

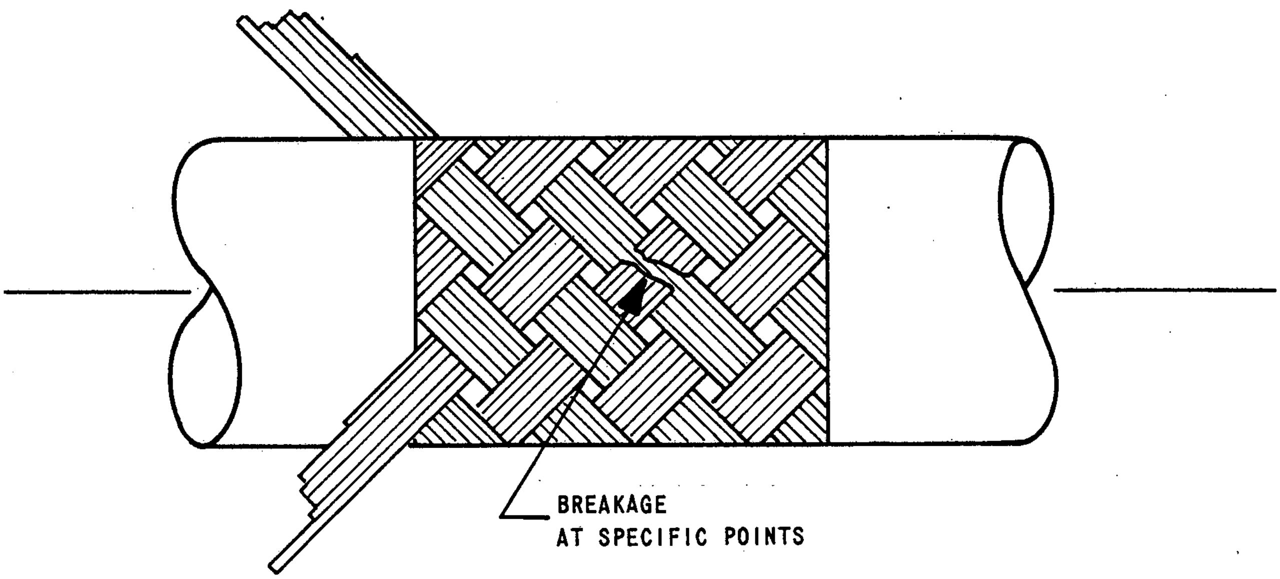

Figure 5. Fatigue Wire Breakage

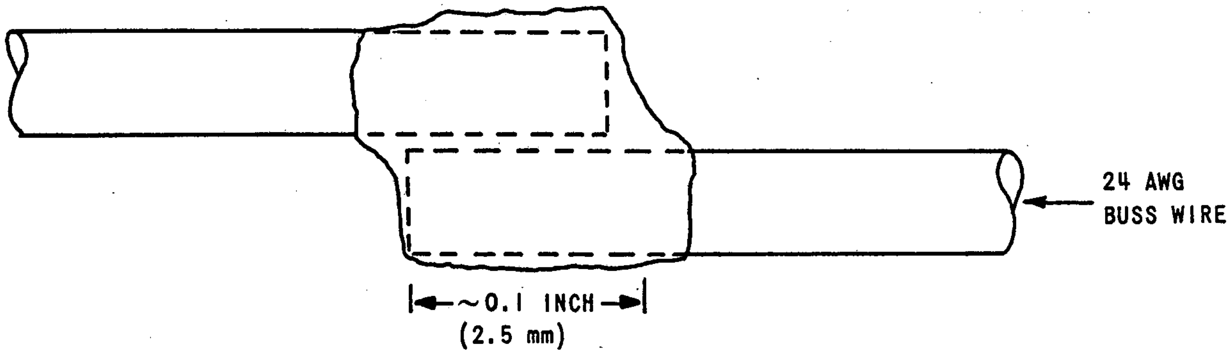

Figure 6. Overlapped Solder Joint

$R_u = \frac{VL}{I} T_o$ across (T/T_o)

where

R_u is constriction resistance,

I is current,

T is temperature,

T_o is room temperature, and

L is a constant.

This method of measuring constriction resistance was not successful because the thermal response time of the bond was much longer than the lowest operating period of available ac current sources.

The next effort was to make dc resistance measurements as a function of current. These data yielded the family of curves shown in Figure 7. Resistance measurements were taken in the Bendix Metrology Laboratory using a Leeds & Northrup Model 7556-1 guarded nulling potentiometer and a precision current source designed and built by the Metrology Laboratory. The accuracy of this combination for measuring resistance is certified to be ±0.025 percent.

Figure 7 shows that the increase in resistance with respect to current is greater with the bonds having lower breaking strength. Figure 8 shows the difference between the resistance across the bond and the resistance across an adjacent piece of wire on the Y axis and the pull test breaking strength on the X axis at a current level of 1 ampere. Figure 9 shows the same information

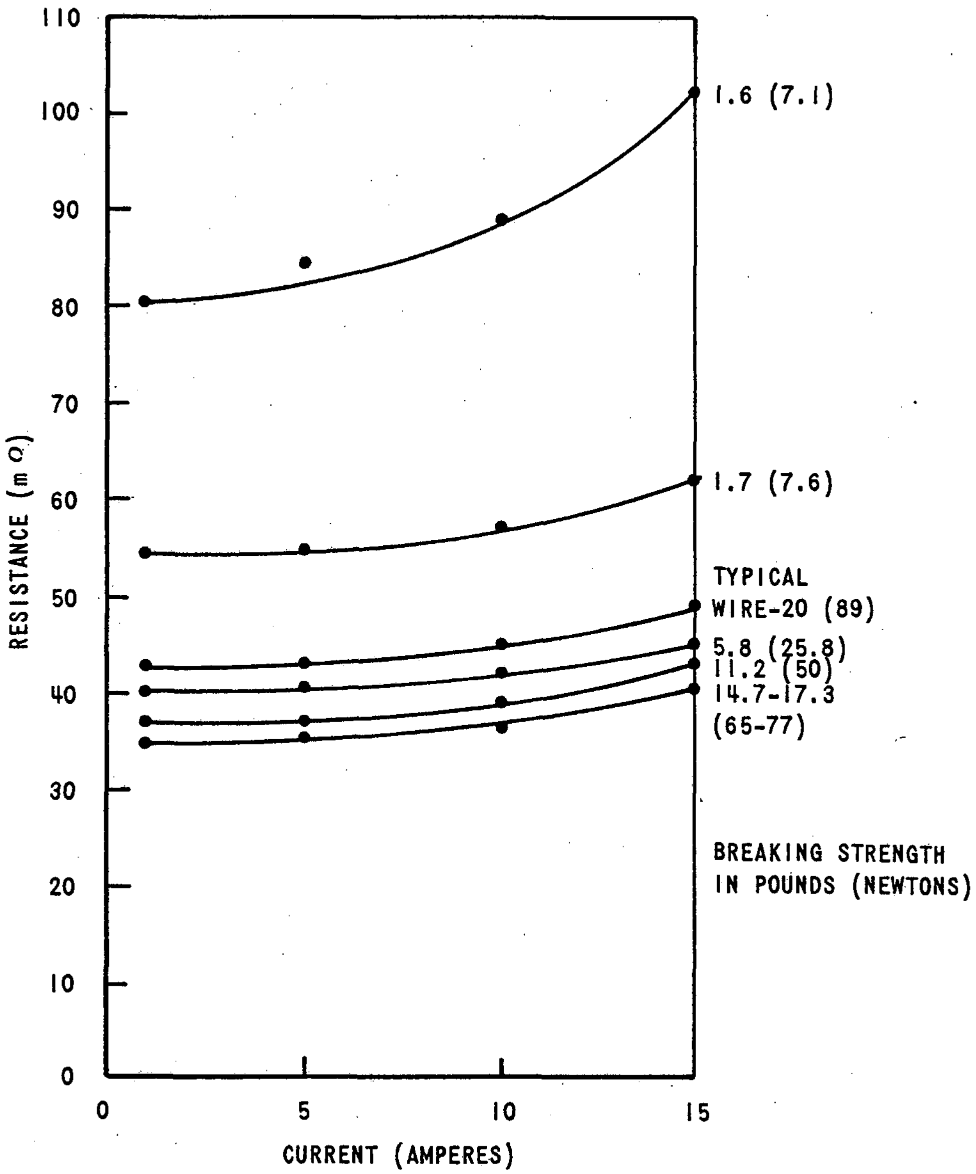

Figure 7. Resistance Versus Current

at a current level of 15 amperes. The spread in the difference between the two resistance values has increased because of the preferential heating of the weaker bonds.

These results are preliminary but encouraging. While the graph of resistance versus pull test force shows a definite relationship, the group of good joints shows a spread of about 30 micro-ohms while the difference between the mean value of good and poor bonds is about 50 micro-ohms. Fortunately, the really bad bonds show dramatic differences.

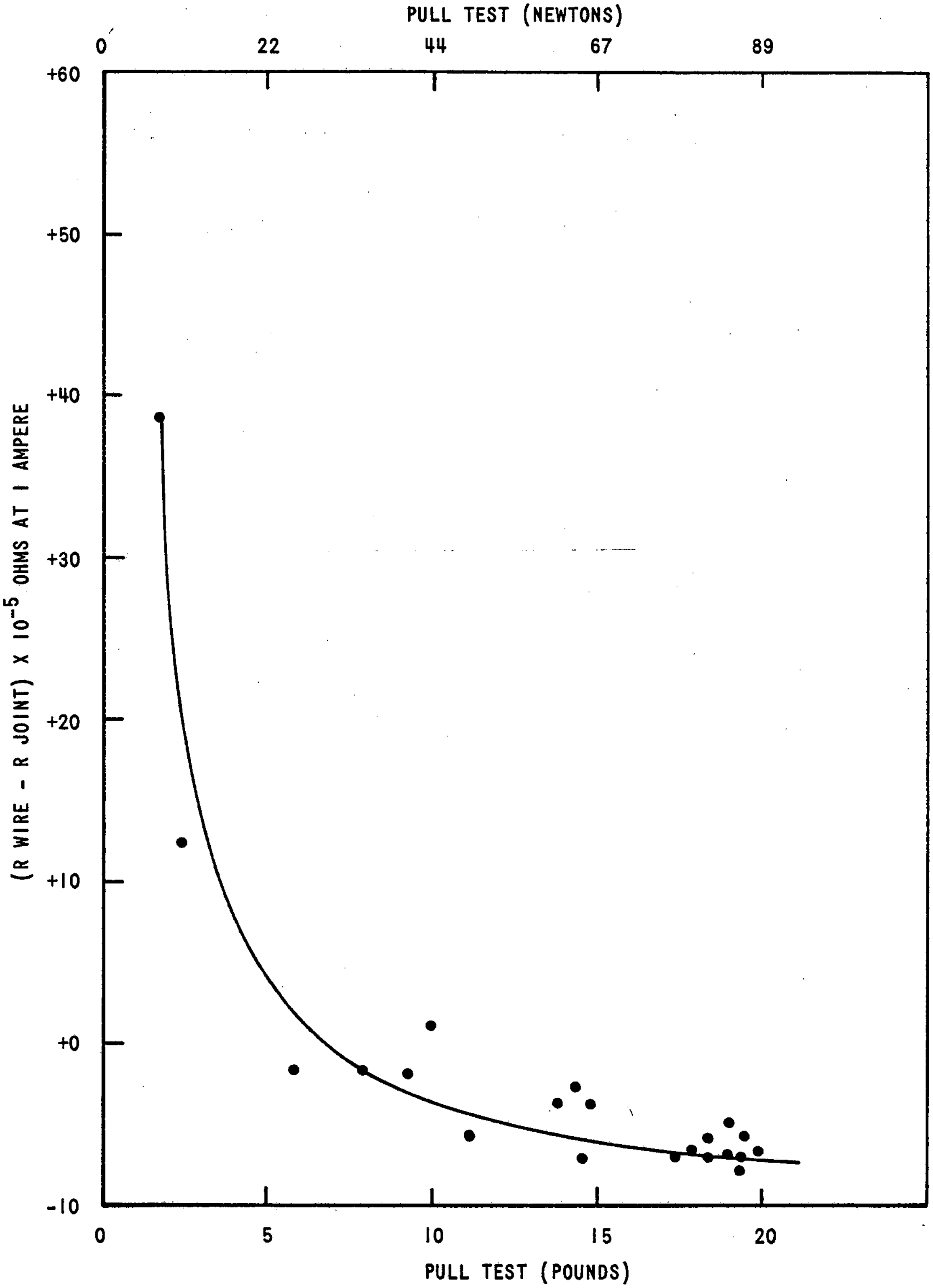

Figure 8. Current Versus Pull Strength at 1 Ampere

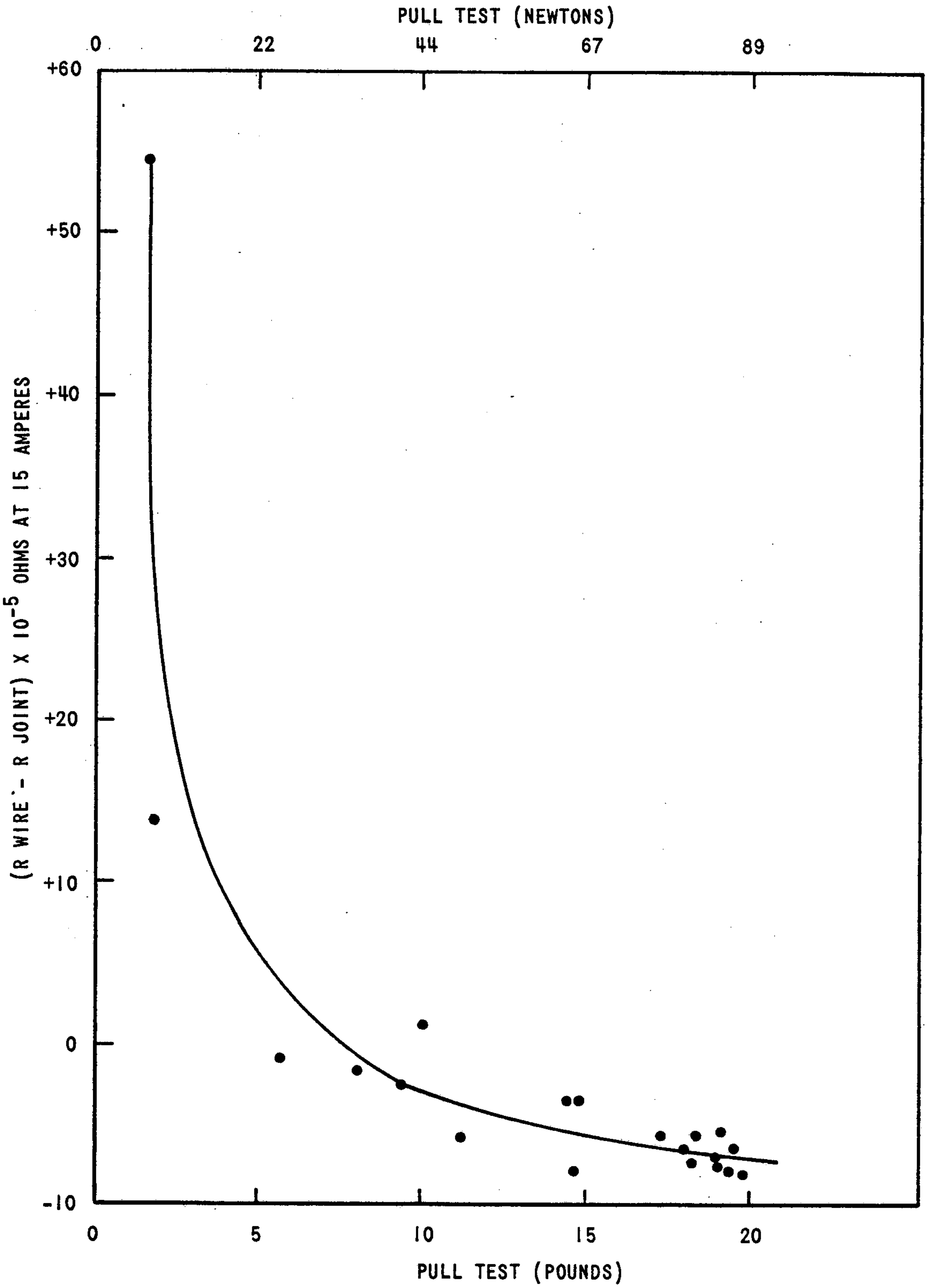

Figure 9. Current Versus Pull Strength at 15 Amperes

ACCOMPLISHMENTS

Results of a bend testing program simulating the fatigue failure of single braided pullout cables during handling and use will serve as guidelines for future design of cables having a similar configuration. It was found that the fatigue life of the braid on some cables can be increased by impregnation with cellulose nitrate.

The investigations also led to a nondestructive technique for evaluating the quality of solder joints. Although more testing and development work is necessary for application on braid terminations, the results are promising.

FUTURE WORK

Future work will be directed toward improving the resolution between good and poor solder bonds and using the techniques developed to evaluate braid terminations.

Specifically, the work will include the investigation of thermoelectric effects and data reduction techniques to relate the slope of the constriction resistance characteristic to destructive testing. The investigation will attempt to relate nondestructive test data to the probability of breakage of the braid-to-ferrule bond under flexural tests and the consequent increase in leakage.

REFERENCES

[1]H. J. Edwards, *Fatigue Failure in Braided Electromagnetic-Radiation Shielding*. UNCLASSIFIED. Bendix Kansas City: BDX-613-1192, February 1975.

[2]E. Belarde, *Defect Detection in High-Density Braided Shields*. UNCLASSIFIED. Bendix Kansas City: BDX-613-1122, June 1974.

[3]H. J. Edwards, *High-Density Cable Shields, FY72-4*. UNCLASSIFIED. Bendix Kansas City: BDX-613-776, February 1973.

[4]J. F. Galbraith, *High-Density Cable Shields, FY72-3*. UNCLASSIFIED. Bendix Kansas City: BDX-613-690, June 1972.

[5]J. F. Galbraith, *High-Density Shields, FY72-1*. UNCLASSIFIED. Bendix Kansas City: BDX-613-543, February 1972.

[6]Holmes Ragnar, *Electrical Contacts*. Berlin: Springer Verlag, 1967.

[7]Bernard F. Hueber, "Joule Heating and Development of Temperature in a Symmetric Metallic Current Constriction," *Proceedings of the VI International Conference on Electrical Contacts Phenomena*. Chicago: 1972.

[8]J. B. P. Williamson, "Thermal Effects in Electrical Connectors," *Proceedings of the VI International Conference on Electrical Contacts Phenomena*. Chicago: 1972.

[9]Jerzy Kaczmarek and others, "Constriction Resistance Measurements Based on the Method of Third Harmonic," *Proceedings of the VI International Conference on Electrical Contact Phenomena*. Chicago: 1972.

[10]Charles E. Sksov and others, "Sensitive Method for the Measurement of Nonlinearity of Electrical Conduction," *The Review of Scientific Instruments*, Vol. 35, Number 8, pp 292-294.

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