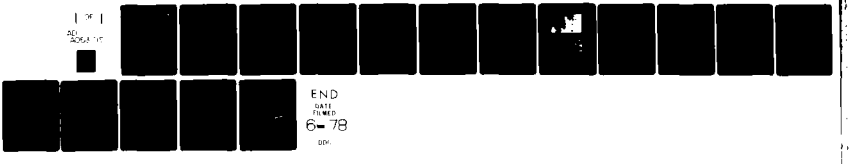
AD-A053 715 IIT RESEARCH INST CHICAGO ILL F/G 9/1
WISCONSIN TEST FACILITY GROUND TERMINAL CORROSION STUDY.(U)
APR 78 M F GENGE, E WOLKOFF N00039-76-C-0141
UNCLASSIFIED IITRI-E-6357-12 NL



END
DATE FILMED
6-78
DDC

Technical Report E6357-12
Contract N00039-76-C-0141

12

IITRI

WISCONSIN TEST FACILITY
GROUND TERMINAL CORROSION STUDY

Michael Genge
Edwin Wolkoff
Paul Bergschneider

April 1978

Prepared for

U. S. Naval Electronic Systems Command
Washington, D. C.

Submitted by
IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

FOREWORD

This report was prepared for the Special Communications Project Office of the U. S. Naval Electronic Systems Command by IIT Research Institute, as part of Contract N00039-76-C-0141.

The technical effort reported herein is intended to support development of the Navy's ELF Submarine Command and Control Communications System. The report provides documentation and discussion of an investigation of the extent to which corrosion is evident in the ground terminals of the Wisconsin Test Facility. The physical investigations were performed by Mr. E. Wolkoff of the Naval Underwater Systems Center and Mr. P. Beraschneider of the Naval Electronic Engineering Office, Clam Lake, Wisconsin. They were assisted by Mr. R. Rice of GTE Sylvania. This report was prepared at the direction of Dr. B. Kruger (PME 117-21).

Respectfully submitted,

IIT RESEARCH INSTITUTE

Michael F. Genge
Michael F. Genge
Research Engineer

APPROVED

R. D. Carlson
R. D. Carlson
Program Manager

A. R. Valentino
A. R. Valentino
Manager, EM Effects

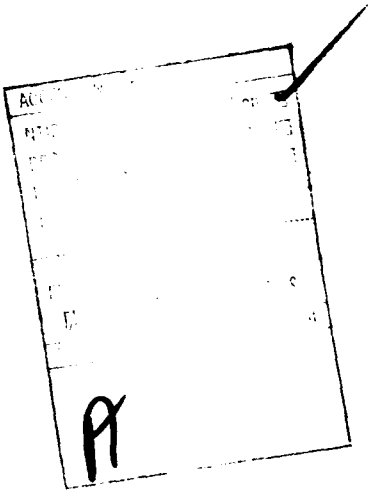


TABLE OF CONTENTS

1. INTRODUCTION AND SUMMARY

Recently, the National Academy of Sciences has expressed concern over the possibility of ELF terminal ground corrosion, and the potential impact of such corrosion on electrical safety in the vicinity of an affected ground structure. This concern is heightened in view of the past experiences of some electrical power companies with corrosion of the concentric neutral wire associated with underground residential distribution (URD) cables.[1-5] As a result of the expressed concerns, an investigation of the Wisconsin Test Facility grounds was recently undertaken, wherein the ground terminals were examined at several locations to characterize their present physical condition.

The study consisted of examining the ground terminals at four separate locations. At each point, the diameter of all accessible strands of the copper cable was measured. A visual inspection of the physical condition of the cable was also performed. The data obtained through these investigations were then compared with the physical characteristics of similar cable which has been in storage since 1969. The findings of this study are that the ground electrodes are not corroding at any perceptible rate and are in good physical condition.

2. WISCONSIN TEST FACILITY GROUND TERMINALS

Each antenna segment at the WTF is connected to the center of a ground terminal as shown in Figure 1. These grounds were located in areas where measurements indicated low near-surface resistivity. This was done to achieve low resistance grounds and to minimize the resulting surface electric fields. Figure 1 also indicates that the north ground partially shares the right-of-way with the North-South antenna segment. The southern half of the north ground terminal was placed in the antenna right-of-way, but the northern half extends beyond the antenna.

The construction of the ground terminals was completed during the fall of 1968. Each ground consists of a single bare 4/0 AWG stranded copper wire buried to a depth of about five feet. The north and south grounds are each about 8400 feet long, while the east and west grounds are 10,800 feet long due to higher local resistivities at their sites.

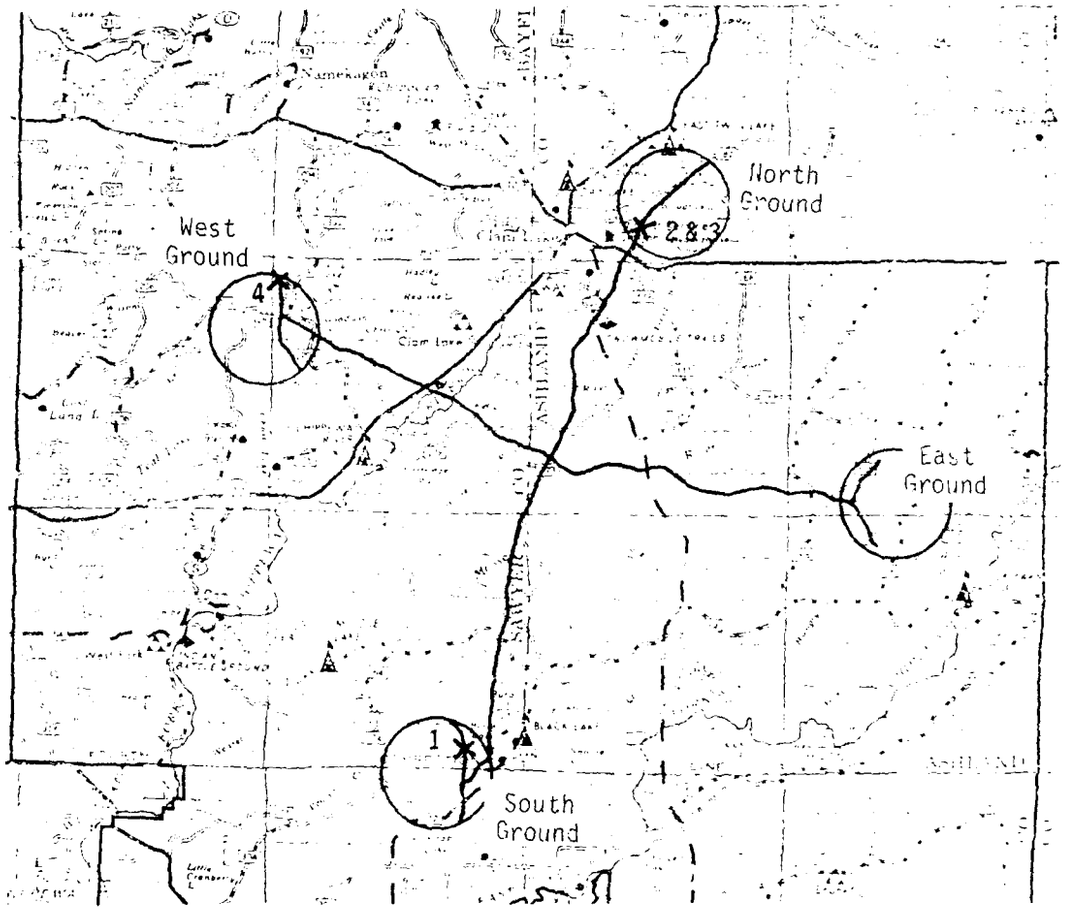


Figure 1 GROUND TERMINAL INSPECTION POINTS AT THE WISCONSIN TEST FACILITY

3. TERMINAL GROUNDS EXAMINATION

During the late summer and early fall of 1977, the Wisconsin Test Facility ground terminals were examined at four different locations, as identified in Figure 1. At each location, after the position of the ground terminal was located using a magnetic field detector, a back-hoe was used to uncover a minimum of eight feet of the ground terminal. A visual inspection of the copper cable was then performed and the diameters of the individual strands of the cable were measured with a vernier caliper. Figures 2 and 3 illustrate typical inspection locations after the ground terminals had been located and exposed.

3.1 Inspection Results

3.1.1 Location No. 1

The first inspection was performed at the south ground. This ground was unearthed at a point 100 feet north of ground pole GP-1S-N9 on 12 September 1977. The soil consisted of two inches of loam over clay and was moist. The ground cable was at a depth of 45 inches. The cable appeared to be slightly oxidized (brown color) but was in excellent physical condition. It was only possible to measure the diameter of the five outer strands of the seven strands forming the copper cable at this point. These results are summarized in Table 1.

TABLE 1

DIAMETER OF INDIVIDUAL STRANDS
OF COPPER CABLE AT INSPECTION POINT NO. 1

Strand No.	Diameter (inches)
1	0.1765
2	0.176
3	0.174
4	0.176
5	0.176
mean	0.1757
standard deviation	0.00097

3.1.2 Location No. 2

The second inspection point was at the south end of the north ground as shown in Figure 1. The exact location of this point was 120 feet north

Figure 2 EXPOSED SECTION OF WTF GROUND TERMINAL

Figure 3 SECTION OF WTF GROUND TERMINAL BURIED IN CLAY

of antenna Pole P1N-122. This ground location was examined on 14 September 1977. The soil in the area was sandy and damp; the ground cable was at a depth of about 59 inches, but the burial depth was not uniform. Part of the cable was completely submerged in ground water while other sections were above the water table. Those portions in the water looked new, with no apparent oxidation, while those sections above the water table appeared dull and slightly oxidized. Again, it was only possible to measure five of the seven strands of this cable. These results are presented in Table 2, and correspond to that portion of the cable which lay above the water table.

TABLE 2

DIAMETER OF INDIVIDUAL STRANDS
OF COPPER CABLE AT INSPECTION POINT NO. 2

Strand No.	Diameter (inches)
1	0.172
2	0.1745
3	0.1745
4	0.175
5	0.173
mean	0.1738
standard deviation	0.00125

3.1.3 Location No. 3

The third location was also located at the south end of the north ground terminal. This ground was excavated at a point approximately 50 feet south of antenna pole P1N-123 on 15 September 1977. The soil in this area was sandy and dry. The ground cable was located at a depth of 59 inches. In this region the copper cable was in water. The cable appeared bright and clean. There again was no evidence of corrosion. Table 3 provides a summary of the measured diameter of the five accessible cable strands.

TABLE 3

DIAMETER OF INDIVIDUAL STRANDS
OF COPPER CABLE AT INSPECTION POINT NO. 3

Strand No.	Diameter (inches)
1	0.1735
2	0.1745
3	0.175
4	0.175
5	0.176
mean	0.1748
standard deviation	0.00091

3.1.4 Location No. 4

The final ground terminal inspection was performed at the west ground on 11 November 1977. The cable was exposed at a point about 320 feet north of ground pole GP-4W-S16. In this area the ground cable was buried to a nominal depth of 54 inches. The soil in this region consisted of damp sand. The copper cable in this area also appeared in good physical condition. At this location it was possible to measure the diameter of all seven strands of the cable; these results are presented in Table 4.

TABLE 4

DIAMETER OF INDIVIDUAL STRANDS
OF COPPER CABLE AT INSPECTION POINT NO. 4

Strand No.	Diameter (inches)
1	0.176
2	0.175
3	0.174
4	0.174
5	0.175
6	0.174
7	0.175
mean	0.1747
standard deviation	0.00076

3.2 Comparison with Similar Unused Cable

A reel of unused cable identical to that employed in the construction of the ground terminals has been stored outdoors behind the transmitter building at the Wisconsin Test Facility since 1968. Although this cable has been exposed to the environment for over nine years, it is felt that its present physical characteristics can be used as a benchmark for making comparisons with the buried copper cable. Specifically, a comparison of strand diameters of this cable with the measurements made at the four inspection points should provide an indication as to whether or not the ground terminals are indeed corroding and at what specific rate.

Table 5 provides a complete set of strand diameters for this "control" cable. Comparison of these measurements to those presented in Tables 1-4 indicates that the individual strand diameters at the inspection points are nominally equal or slightly larger than those of the control sample.

TABLE 5

DIAMETER OF INDIVIDUAL STRANDS OF UNBURIED COPPER CABLE

Strand No.	Diameter (inches)
1	0.173
2	0.174
3	0.174
4	0.174
5	0.1735
6	0.1745
7	0.174
mean	0.1739
standard deviation	0.00048

This comparison is shown graphically in Figure 4, which presents both the mean and standard deivation for the ground cable strand diameters at each of the test points and for the control sample. These results indicate that the mean strand diameter of the cable at three of the four test points was slightly greater than that of the control sample.

To quantify the importance of these differences, a "Student's" t test was applied. This is a statistical technique useful for studying small samples

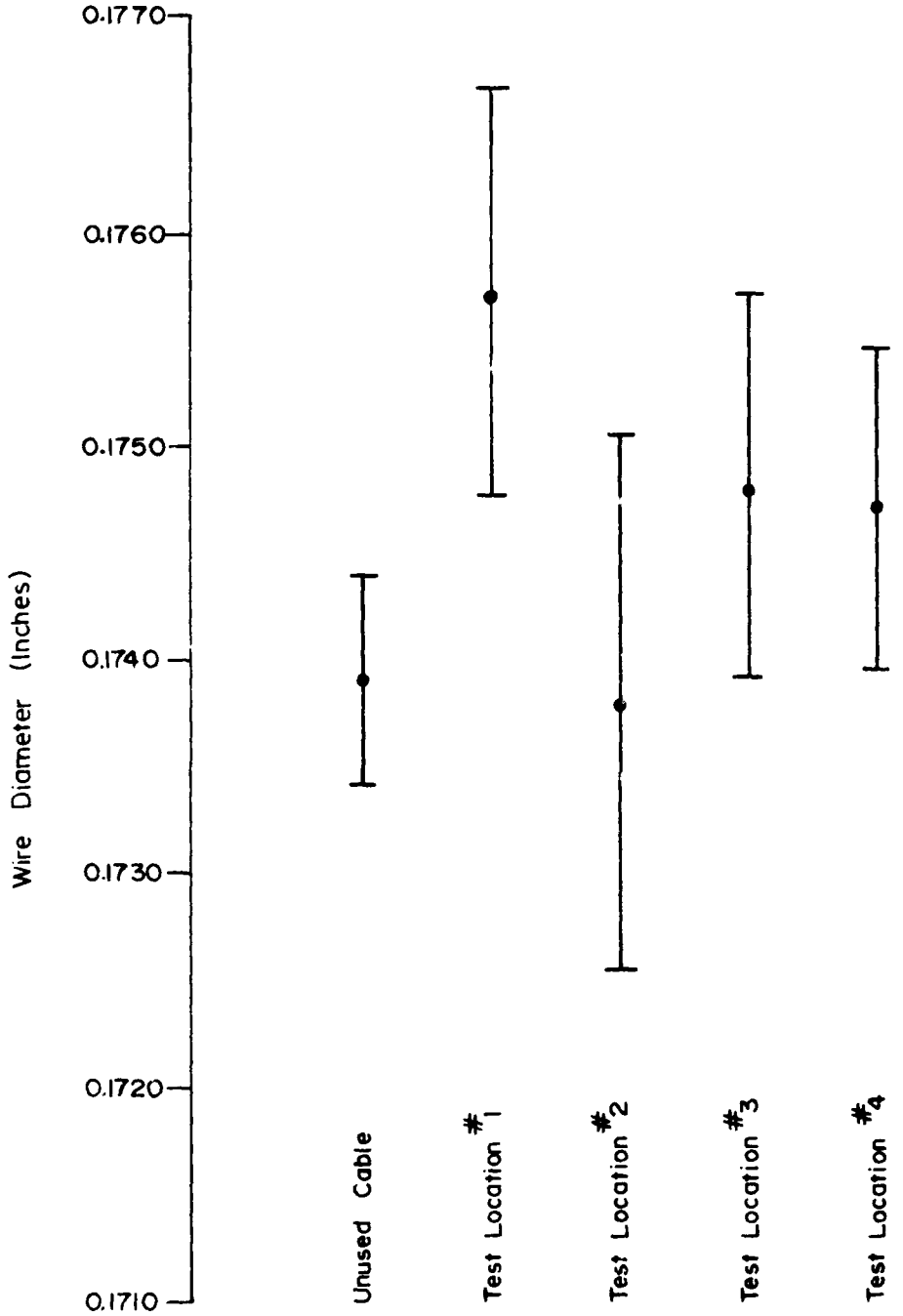


Fig. 4 MEAN AND STANDARD DEVIATION OF GROUND CABLE SAMPLE DIAMETERS

to determine whether the differences in the sample means are significant. Table 6 summarizes the results of these calculations.

TABLE 6

RESULTS OF ANALYSIS
TO DETERMINE SIGNIFICANCE OF MEAN DIFFERENCES
OF BURIED GROUND CABLE SAMPLES VS. CONTROL SAMPLE

Test Location	$p < 0.01$ (99% confidence level)
1	Significant
2	Not Significant
3	Not Significant
4	Not Significant

At the 99% level of confidence, the t-test shows the difference in mean diameter between Test and Control samples to be statistically significant only at Test Location 1. At the other locations, the sample mean diameters are not different from that of the control sample by a significant amount, according to this statistical test.

The difference in diameter between the control and the sample at Test Location 1 cannot be attributed to corrosion with any confidence, however, since a number of other variables could have produced the observed effect. Some of the factors which could influence the measured wire diameters include: (1) the manufacturing tolerance of the wire ($\pm$ 1%), (2) deformation due to the physical stress of burial and/or excavation, (3) additional deformation due to the separating of the cable to allow measurement of individual strands, (4) the presence of foreign matter on the cable and/or the measurement instrument, and (5) the basic measurement accuracy ($\pm$ 0.001 inch).

The physical appearance of the cable at all the test points would instead suggest that corrosion is not responsible for the apparent differences in the mean strand diameters. Furthermore, those mean diameters which were determined to be different were always larger than the control sample. It is believed that any corrosive effect would produce a loss of ground cable material and a consequent diameter reduction, rather than the deposition of new material to enlarge the wire. Therefore, although only a limited sampling of ground

terminal locations has been studied, it is believed that corrosion is not occurring at any perceptible level along the ground terminals at the Wisconsin Test Facility.

3.3 Operating History and Experience

No operational problems related to corrosion of the grounds have been experienced at the Wisconsin Test Facility and no indications of deterioration of the terminal grounds have been observed since their installation in 1968. During this period the grounds have been maintenance free, with no corrosion problems observed or even suspected.

Table 7 presents a summary of the antenna current history of the ground terminals. As this table illustrates, each ground has provided over four million ampere-hours of service since 1969. Over this period, no obvious corrosion has occurred.

TABLE 7

SUMMARY OF WISCONSIN TEST FACILITY ANTENNA CURRENT LEVELS
(November 1969 - June 1977)

Antenna Current (amperes)	Ampere-Hours of Operation (40-80 Hz)	
	E/W Grounds	N/S Grounds
0-50	19,982	20,432
51-100	1,840	4,530
101-150	69,490	76,626
151-200	8,212	5,332
201-250	3,835	3,835
251-300	4,030,455	3,906,820
TOTAL	4,133,814	4,017,575

4. CONCLUSIONS

Inspection of the Wisconsin Test Facility ground terminals has not produced any evidence of corrosion in the buried cables, despite eight years of use during which the facility has provided over four million ampere-hours of operational experience. While the number of inspection points and data samples were small, the physical condition of those portions examined, coupled with the absence of any corrosion-related operational problems during this extensive period of use, allows the conclusion that no significant corrosion of ELF ground cables should be expected over the life of the system.

Because the corrosion issue has importance relative to both public safety and system operations, it is nevertheless advisable that any new ELF ground structures be constructed in such a way as to permit simple periodic inspection and accurate measurement of the extent of any corrosion effects. This should be done using sample weight and/or resistance measurement techniques commonly employed in the electrical and pipeline industries.

REFERENCES

1. O. W. Zastrow, Copper Corrosion in Moderate and High Resistivity Soils, Materials Performance, August 1974.

2. K. G. Compton, Corrosion of Bare Concentric Neutrals in URD Systems: A Review, Materials Performance, August 1975.

3. D. H. Kroon, Corrosion Evaluation and Cathodic Protection of URD Cable, Materials Performance, August 1976.

4. O. W. Zastrow, Galvanic Behavior of Underground Cable Neutral Wires and Jacketing Material, Materials Performance, November 1977.

5. K. G. Compton, Corrosion of Concentric Neutrals, Materials Performance, December 1977.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

REPORT NUMBER (14) IITRI-E6357-12

3 RECIPIENT'S CATALOG NUMBER

(6) TITLE (and Subtitle)
Wisconsin Test Facility Ground Terminal Corrosion Study.

(9) TYPE OF REPORT & PERIOD COVERED
Technical Report

6 PERFORMING ORG. REPORT NUMBER
E6357-12

(10) AUTHOR(s)
M. F. Genge, Michael F. Genge
E. Wolkoff, Edwin Wolkoff
P. V. Bergschneider, Paul V. Bergschneider

(15) CONTRACT OR GRANT NUMBER(s)
N00039-76-C-0141

9 PERFORMING ORGANIZATION NAME AND ADDRESS
IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

10 PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11 CONTROLLING OFFICE NAME AND ADDRESS
U. S. Naval Electronic Systems Command
Washington, D. C.

12 REPORT DATE
April 1978

(12) 47 P.

13 NUMBER OF PAGES
16

14 MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15 SECURITY CLASS (of this report)
Unclassified

15a DECLASSIFICATION/DOWNGRADING SCHEDULE

16 DISTRIBUTION STATEMENT (of this Report)

Distribution Unlimited

This document has been approved for public release and sale; its distribution is unlimited.

17 DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18 SUPPLEMENTARY NOTES

19 KEY WORDS (Continue on reverse side if necessary and identify by block number)

ELF
Extremely Low Frequency
Ground System
Corrosion

20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

Investigations of ELF ground system corrosion at the Navy's Wisconsin Test Facility were undertaken in response to concerns expressed by the National Academy of Sciences. Ground areas were excavated in several locations and the cable strand diameters measured for comparison with an unused cable. No evidence of corrosion in the ground system was observed.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

175 350