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1 Navy Case No. 77073

2 CABLE INTEGRITY TESTER

3
4 STATEMENT OF GOVERNMENT INTEREST

5 The invention described herein may be manufactured and used
6 by or for the Government of the United States of America for
7 governmental purposes without the payment of any royalties
8 thereon or therefor.

9
10 BACKGROUND OF THE INVENTION

11 (1) Field of the Invention

12 This invention generally relates to the testing of
13 electrical cables and more particularly to methods and apparatus
14 for testing electrical cables designed for underwater use.

15 (2) Description of the Prior Art

16 It is very useful to pretest cables prior to their use,
17 particularly in applications in which the cable will be located
18 in an underwater environment. Such testing would be particularly
19 desirable if it could identify and locate the existence of nicks
20 in armor jackets, porosity in the cable insulation and other
21 defects or faults that could allow seawater to intrude into the
22 cable and destroy its usefulness. It is even more advantageous
23 if such tester identifies the location of the defect and can
24 quantify the defect.

25 Prior art testing methods and apparatus have not provided
26 all the desired information. Some, particularly tests wherein a

1 high potential is applied to the cable, merely provide
2 qualitative results. In some specific applications the tests can
3 even be destructive. Other tests, such as megger tests that
4 measure the resistance over a cable while a high voltage is
5 applied, test bulk properties of cables and therefore can not
6 locate the defect. Other tests, as now described, provide some,
7 but not all of the desired information in a non-destructive
8 fashion.

9 For example, United States Letters Patent No. 5,067,343
10 depicts apparatus for determining the water blocking qualities of
11 a moisture blocking compound applied to the interstitial spaces
12 of a stranded conductor to produce a water impervious cable
13 construction. Basically the ends of a cable are treated with a
14 moisture blocking compound and a sealing and supporting means is
15 attached to the end for receiving a source of colored liquid.
16 The resulting cable end then is monitored at the other end for
17 determining the penetration of the colored liquid through the
18 moisture blocking compound and the cable.

19 High voltage electrical testing, as disclosed in United
20 States Letters Patent No. 2,794,170 to Gooding comprises the use
21 of cable testing apparatus in which a portion of cable under test
22 is led through a tank containing an electrolytic solution. High
23 voltage is applied to an electrode surrounding the cable and
24 faults are indicated when the leakage current produced during the
25 application of the high voltage exceeds a threshold value. This
26 approach incorporates the expense of a high voltage supply and

1 further requires some means of locating the position of any
2 leakage.

3 United States Letters Patent Nos. 3,015,774 and 3,047,800 to
4 Eigen disclose a cable tester that applies a high voltage to a
5 cable and monitors any resulting corona discharge. An entire
6 spool of cable is located in an electrolytic solution in a
7 grounded tank. High voltage applied to a conductor induces
8 corona that is measured to indicate leakage. However, such a
9 system is subject to errors produced by ambient electrical
10 disturbances from other sources. Consequently a high-pass filter
11 generates signals corresponding to radio frequencies including
12 those generated by corona discharge and those ambient
13 disturbances into an amplifier. A separate radio circuit
14 produces signals corresponding only to the ambient disturbances.
15 An amplifier subtracts the two signals to produce a pure corona
16 display.

17 United States Letters Patent No. 4,517,510 to Clinton
18 discloses apparatus for testing the insulation of electric wire
19 or cable in which an insulated wire having one end grounded
20 passes in an unaltered path to an unconfined stream of water to
21 which an electrical potential has been applied. Pin holes,
22 voids, or other faults in the insulation are detected by a
23 current flowing from a variable voltage power supply through the
24 wire to ground. A fault indicator provides a signal response of
25 the current flow. Water remaining on the jacket after passing
26 the stream is removed by a blower.

1 Each of the foregoing patents therefore discloses a cable
2 tester characterized by incorporating a high voltage supply for
3 energizing a conductor in a cable and thereafter measuring
4 leakage from the conductor through the insulation and an
5 electrolytic solution to ground. Each requires a high voltage
6 supply and attendant controls particularly for isolating
7 individuals from the high voltage. Some, such as the Eigen
8 ('774) patent disclose the application of high voltage to an
9 entire cable after it is immersed. Others only immerse
10 successive portions of the cable. The Eigen ('800) patent
11 discloses a magnetic drum structure for recording any corona
12 disturbance twice in an attempt to avoid the influence of any
13 outside interference. This patent also discloses a process for
14 physically marking the insulation in response to the detection of
15 corona. Corona testing has further disadvantages. For example,
16 the voltages necessary to produce corona can sometimes damage a
17 cable. Corona is a form of electrical interference and can
18 disrupt the operations of other nearby equipment particularly
19 communications equipment unless significant effort is made to
20 isolate any radiation from the point of corona discharge.
21 Consequently the various approaches using corona discharge
22 including those disclosed in the foregoing patents, have not been
23 widely accepted.

24 In another approach, described in United States Letters
25 Patent No. 2,942,181, an ac signal is applied to the ends of an
26 uninsulated conductor and a pair of insulated conductors wrapped

1 around the uninsulated conductor. This connection is made to the
2 end of the cable on the inside turn at a supply reel. The other
3 end is directed through an electrolytic tank that fixes the
4 length of the cable in an electrolytic solution and the position
5 of the cable with respect to a grounded electrode in the tank. A
6 take up reel draws the cable through the solution from the supply
7 reel. With this arrangement the insulated conductors form one
8 plate of a condenser and the uninsulated conductor, electrolytic
9 solution and grounded electrode collectively form the other
10 plate. The insulation around the insulated conductors forms a
11 dielectric. When a fault enters the solution, current flows
12 between the insulated and uninsulated conductors causing a
13 detector in a bridge circuit to produce an indication that a
14 fault has occurred. The operator then stops the cable and marks
15 the defective part.

16 In United States Letters Patent No. 5,206,597 to Rivera et
17 al. apparatus including a capacitive test fixture and an
18 electrical impedance analyzer measures the volume of water in a
19 cable based upon cable capacitance. The capacitive test fixture
20 measures the electrical capacitance along the cable as the cable
21 is fed through the test fixture that comprises two spaced,
22 insulated, semi-circular electrodes. While this arrangement can
23 indicate water intrusion, it does not indicate the existence of
24 nicks or other faults that might in the future produce operating
25 problems. Consequently this approach seems useful only for the

1 analysis of cables that have been removed from underwater
2 applications.

3
4 SUMMARY OF THE INVENTION

5 Therefore it is an object of this invention to provide a
6 method and apparatus for testing the integrity of an electrical
7 cable that monitors a wide variety of potential cable defects or
8 faults.

9 Still another object of this invention is to provide a
10 method and apparatus for testing the integrity of an electrical
11 cable that automatically displays the location of any potential
12 fault.

13 Still another object of this invention is to provide a
14 method and apparatus for testing the quality of an electrical
15 cable with minimal equipment that is readily operated in a safe
16 fashion.

17 In accordance with one aspect of this invention, successive
18 portions of an electrical cable with insulated conductors pass
19 into an electrolyte. A position signal and a capacitance signal
20 are generated indicating, at each instant, the portion of the
21 cable passing through the electrolyte solution and the
22 capacitance between an electrode in the electrolytic solution and
23 the conductor. The resulting signals produce a graphical display
24 of capacitance as a function of position thereby to indicate
25 graphically and readily a variety of faults in the cable.

1 In accordance with another aspect of this invention,
2 apparatus for testing the integrity of an electric cable of
3 indeterminate length including an electrical conductor includes a
4 tank for storing an aqueous solution with an electrode disposed
5 in the tank for contacting the aqueous electrolyte. A guide
6 located in the tank and spaced from the electrode passes the
7 cable through the electrolyte in a spatial relationship to the
8 electrode. A capacitance measurement apparatus generates a
9 capacitance signal indicating the capacitance between the
10 electrode and the portion of the conductor located in the guide.
11 A distance measurement circuit generates a position signal
12 indicating the position of the conductor portion in the guide
13 relative to an end. A display connects to the capacitance
14 measurement and distance measurement circuits for displaying the
15 measured capacitance as a function of position.

16 17 BRIEF DESCRIPTION OF THE DRAWINGS

18 The appended claims particularly point out and distinctly
19 claim the subject matter of this invention. The various objects,
20 advantages and novel features of this invention will be more
21 fully apparent from a reading of the following detailed
22 description in conjunction with the accompanying drawings in
23 which like reference numerals refer to like parts, and in which:

24 FIG. 1 is a perspective view of apparatus for testing the
25 integrity of an electrical cable in accordance with this
26 invention;

1 FIGS. 2A through 2C are perspective views depicting the
2 construction of some of the cables that can be tested in the
3 apparatus of FIG. 1;

4 FIGS. 3A through 3D are graphs depicting the various outputs
5 of the apparatus shown in FIG. 1;

6 FIG. 4 is an alternative embodiment of the apparatus in FIG.
7 1; and

8 FIGS. 5A and 5B are graphs that depict the outputs of the
9 apparatus shown in FIG. 4.

10 11 DESCRIPTION OF THE PREFERRED EMBODIMENT

12 The apparatus 10 shown in FIG. 1 can test a variety of cable
13 constructions. FIG. 2A, for example, discloses a conventional
14 coaxial conductor cable 11A with a center conductor 12, an
15 insulating portion 13, a conductive shield layer 14 and an outer
16 insulating jacket 15. FIG. 2B discloses a shielded twisted pair
17 cable 11B including conductors 16 and 17 that are twisted along
18 the length of the cable. Conductor 16 includes a center
19 conductor 20 and insulating jacket 21; the conductor 17, a center
20 conductor 22 and an insulating jacket 23. The conductors 16 and
21 17 are twisted along their length with a shield conductor 24 that
22 can lie inside an optional insulating jacket 25. FIG. 2C depicts
23 an armored cable with a center conductor 26, cable 11C with a
24 center conductor 26, insulating jacket 27 and armored shield 28
25 that forms an outer surface of the conductor. It will be

1 apparent that many variations of these and other cable
2 constructions can be tested by the apparatus 10 in FIG. 1.

3 Apparatus 10 in FIG. 1 includes a conventional supply reel
4 30 from which successive portions of the cable 11 are drawn
5 through a guide 31 to a take-up reel 32. A distance measurement
6 unit 33 engages the cable 11 at some point intermediate the
7 supply reel 30 and take-up reel 32 to generate a POSITION signal
8 that indicates the length of the cable that has transferred from
9 the supply reel 30 to the take-up reel 32. Consequently, the
10 POSITION signal indicates the location of a portion of the cable
11 11 that is coextensive with the guide 31. Such distant
12 measurement units are well-known. In this particular embodiment
13 the distance measurement unit 33 is represented by rollers 33A
14 and 33B that rotate as the cable 11 passes onto the take-up reel
15 32. The distance measurement unit 33 generates a position signal
16 in analog or digital form in response to this rotation.

17 The guide 31 is disposed in a tank 34 containing an aqueous
18 electrolyte 35 that can comprise water or water supplemented with
19 a conductive salt. In a preferred form the dielectric constant
20 of the aqueous electrolyte is about 80. The guide 30 has a
21 finite length and a curved shape with ends 36 and 37 extending
22 above the upper level or surface 38 of the electrolyte 35. A
23 center portion lies below the level 38. Apertures 40 in the
24 guide 31 that admit the electrolyte 35 into the intermediate
25 portion of the guide 31 that acts as a pervious tube.
26 Consequently the electrolyte 35 contacts successive portions of

1 the cable 11 as successive portions of the cable 11 pass through
2 the guide 31. Moreover, the electrolyte 35 contacts the outer
3 surface comprising the insulating jacket 15 in FIG. 2A,
4 insulating jacket 25 in FIG. 2B or the shield 24, if the jacket
5 25 were omitted, and the armored shield 28 in FIG. 2C.

6 The tank 34 additionally includes an electrode 41 that is
7 spaced from the guide 31. Although the relative orientation of
8 the guide tube 31 and electrode 41 is not are critical, in a
9 preferred form the guide tube 31 and electrode 41 lie in parallel
10 planes. The electrode 41 connects to one input of a capacitance
11 measurement unit 42. The other input to the capacitance
12 measurement unit 42 connects to one of the selected ones in the
13 cables such as the conductor 12 or shield 14 in FIG. 2A, and the
14 conductor 20, conductor 22 or shield 24 in FIG. 2B or the
15 conductor 26 or the armor shield 28 in FIG. 2C. Typically this
16 connection will made to the end of the cable at an innermost turn
17 on the supply wheel 30. Such connections are also known. In
18 FIG. 1 the connection is represented by an annular electrode 43
19 on the surface of the supply wheel 30. A contact 44, fixed in
20 space, rides over the electrode 43 as it rotates while the cable
21 11 is transferred to the take-up reel 32. This contact 44
22 provides the second input to the capacitance measurement unit 42
23 that generates a Measured Capacitance (MC) signal.

24 In the embodiment shown in FIG. 1 non-selected conductors
25 such as the conductor 14 in FIG. 2A, need to be electrically
26 isolated from the selected conductor, such as the center

1 conductor 12 in FIG. 2A. Therefore, the capacitance measurement
2 unit 42 connects to a capacitor that includes the electrode 41 as
3 one capacitor electrode and the selected one of the conductors in
4 the cable 11 as the other electrode. The dielectric includes the
5 electrolyte 35 and any insulation on the cable 11 intermediate
6 the electrolyte 35 and the selected conductor. For example, in
7 FIG. 2A if one selects the center conductor 12, the dielectric
8 includes the electrolyte 35, the insulation 13 and the insulating
9 jacket 15.

10 As previously indicated, the dielectric constant for the
11 electrolyte 35 typically is greater than the dielectric constant
12 for any insulating layers. For example, Neoprene rubber used in
13 cables might have a dielectric constant in the range of 6 to 7.
14 If any fault exists in the cable that allows water to intrude,
15 the water intrusion effectively changes the composite dielectric
16 between the electrode 41 and the selected electrode. The
17 capacitance measurement unit 42 detects these changes and
18 produces the MC output signal. Thus the MC signal will vary over
19 time if physical conditions of the cable allow the electrolyte 35
20 to change the composite dielectric strength between the electrode
21 41 and the selected conductor.

22 There are many ways in which the MC signal from the measured
23 capacitance unit 42 and position signal from the distance
24 measurement unit 33 can be combined. An X-Y plotter 45 forms one
25 such device. In this particular embodiment the POSITION signal
26 energizes an X input 46; the MC signal, the Y input 47.

1 FIG. 3A depicts a graph 50 that shows a substantially
2 constant value of the MC signal over position for the length of a
3 cable 11. Such a constant capacitance signal indicates that the
4 cable is free of any defects that might be caused by a failure in
5 any insulating jacket, or any nicks or other voids in the
6 insulation. FIG. 3B depicts a graph 51 that shows the same basic
7 characteristics. A disturbance 52 represents a nick at a
8 corresponding position on the cable 11 in FIG. 1. FIG. 3C
9 depicts a cable that has a normal capacitance 53 except for a
10 disturbance 54 that represents some kind of fault near the
11 forward termination or the first end of the cable 11 to pass
12 through the guide 31 in FIG. 1. FIG. 3D represents a cable with
13 a general intrusion of water along the entire length of the
14 jacket as represented by the increase of capacitance over a
15 normal level at the terminations of the end portions 56 and 57.

16 It will now also be apparent that the resolution sensitivity
17 of the this apparatus can be easily varied. Sensitivity for
18 example, can be varied by changing the velocity at which the
19 cable 11 passes through the guide tube 31. The spatial
20 resolution can be improved by shortening the length of the guide
21 31 thereby to localize any fault to a greater degree. As will be
22 apparent, however, shortening the guide 31 also tends to decrease
23 sensitivity.

24 The apparatus 10 in FIG. 1 therefore meets all the
25 objectives of this invention. It eliminates any requirement for
26 high voltage sources. It logs the position of any fault without

1 any requirement for stopping the apparatus for making
2 measurements or otherwise physically marking the cable 11. It
3 provides accurate measurements and fault location that can be
4 varied by altering the speed or the length of the guide 31.
5 Finally, the apparatus is readily adapted for automated
6 operation.

7 FIG. 4 depicts an alternative embodiment of this invention
8 that eliminates the guide 31 in FIG. 1. In this particular
9 embodiment the apparatus 60 receives a cable 61 from a supply
10 reel 32 after it passes through a distance measuring unit 63.
11 The cable 61 transfers into a tank 64 containing an electrolyte
12 65 with an electrolyte surface 66. Whereas FIG. 1 depicts take-
13 up reel 32, the apparatus 60 in FIG. 4 merely allows the cable 61
14 to accumulate in a pile 67 at the bottom of the tank 64 within
15 the electrolyte 65. An isolator 68 attaches to the free end of
16 the cable 61 to prevent the conductors in the cable from
17 contacting each other or the electrolyte 65. Such isolators can
18 be readily made. An electrode 71 disposed in the electrolyte 65
19 below the surface 66 provides one input to a capacitance
20 measuring unit 72. An annular electrode and contact 74 connected
21 to the end of the cable remaining on the supply reel 62 provides
22 the other input to the capacitance measuring unit 72. As in FIG.
23 1, the capacitance measuring unit 72 generates a Measured
24 Capacitance (MC) signal. An X-Y plotter 75 receives the POSITION
25 signal at an X input 76 and the MC signal at an Y input 77

1 thereby to display the measured capacitance as a function of the
2 length of cable that has passed into the tank 67.

3 As will be apparent, the measured capacitance will be the
4 capacitance between the electrode 71 and the accumulated cable 61
5 immersed in the electrolyte 65. FIG. 5A depicts the MC signal
6 that results in a good cable producing an increasing capacitance
7 value with a constant slope as additional cable transfers into
8 the electrolyte. FIG. 5B depicts the MC signal that results from
9 a cable with a nick. The cable produces a nominal graph 81 with
10 a constant slope as the cable is introduced into the electrolyte.
11 A nick in the cable produces an increase in capacitance as shown
12 by graph 82. If that were the only fault in the cable, the
13 remainder of the graph 83 would continue to rise at the same
14 slope as the slope in the graph 81.

15 Thus the apparatus in FIG. 4 provides the same information
16 as provided in the apparatus in FIG. 1. However, the graphs
17 somewhat more complicated to interpret given the constant change
18 in capacitance that will occur as a normal event as the cable 61
19 accumulates in the tank. Nevertheless this apparatus meets the
20 remaining objectives of this invention by eliminating the
21 requirement for any high voltage system and by providing an
22 apparatus that produces an indication of a fault and the location
23 of that fault.

24 There have been disclosed two embodiments of a cable
25 integrity tester that will indicate the general fault that could
26 occur by water intrusion along the entire length of the cable or

1 localized faults that might occur as a result of nicks or other
2 faults at defined positions along the cable. The apparatus
3 provides positive indication of the existence of the fault and
4 its location. Moreover, the seriousness of any such fault will
5 control the magnitude of any capacitance change. Those changes
6 therefore can be examined qualitatively and quantitatively to
7 gauge the seriousness of any such fault.

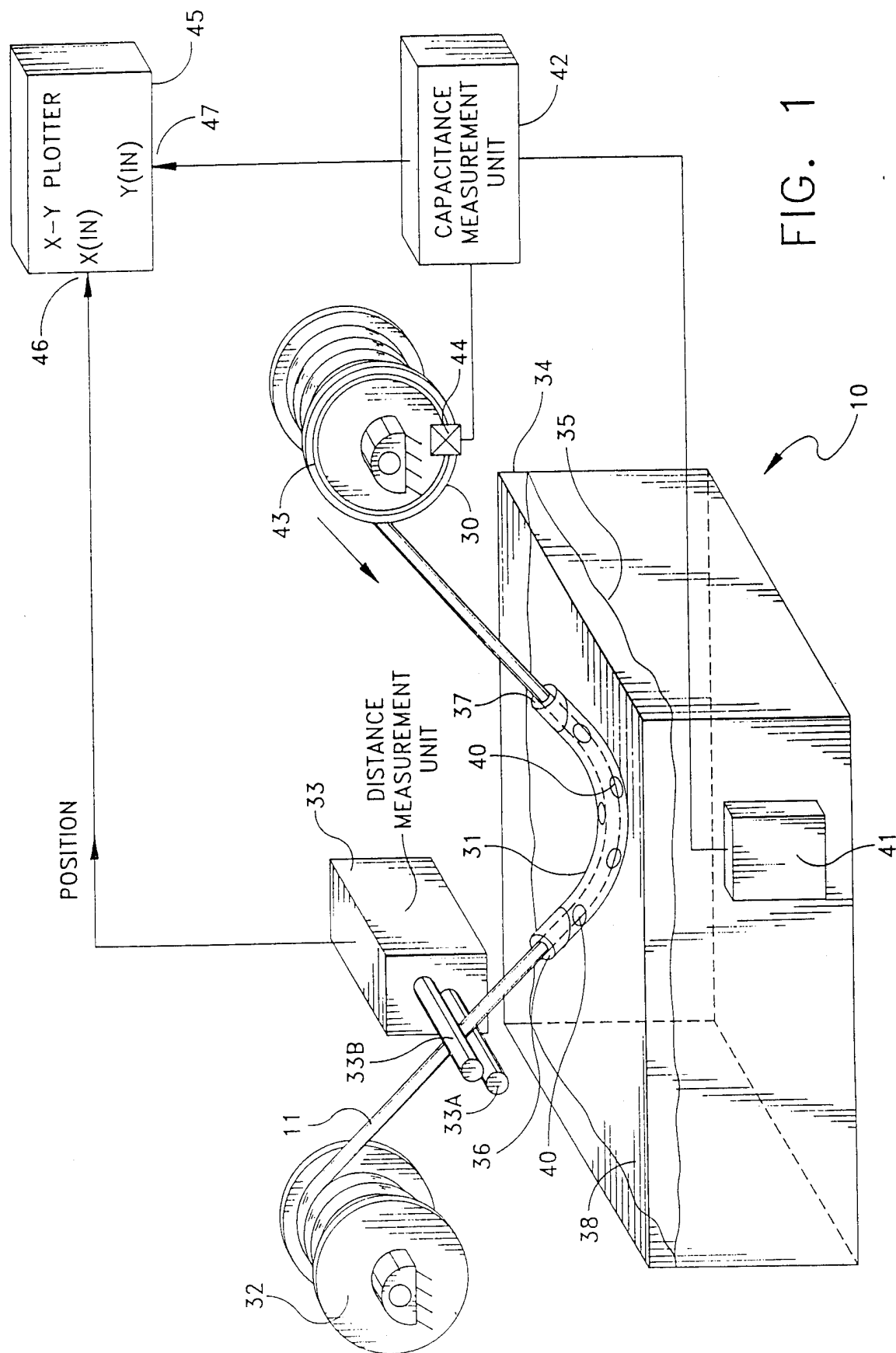
8 It will be apparent that many modifications can be made to
9 the disclosed apparatus without departing from the invention.
10 Therefore, it is the intent to cover all
11 such variations and modifications as come within the true spirit
12 and scope of this invention.

1 Navy Case No. 77073

2
3 CABLE INTEGRITY TESTER

4
5 ABSTRACT OF THE DISCLOSURE

6 A testing apparatus for determining the integrity of an
7 electrical cable. Successive portions of electrical cable pass
8 through an aqueous electrolyte with a distance measurement unit
9 providing an indication of the position of a portion of the cable
10 located in the electrolyte. A capacitance measurement unit
11 connects to a selected conductor in the cable and to an electrode
12 in the electrolyte to continuously generate a measured
13 capacitance signal. An X-Y plotter produces an output that
14 displays the measured capacitance as a function of the length of
15 the cable passing through the electrolyte.



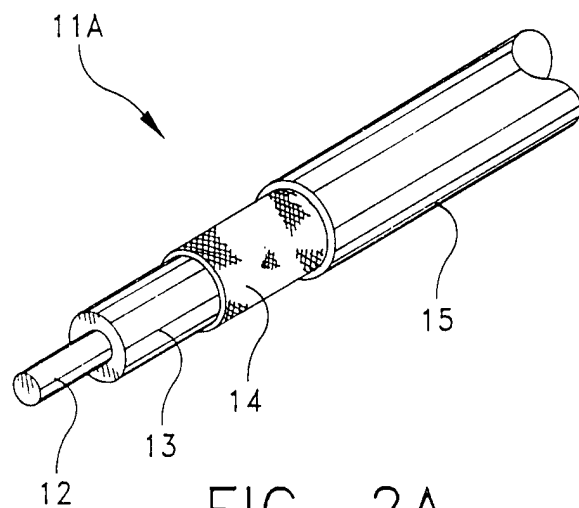


FIG. 2A

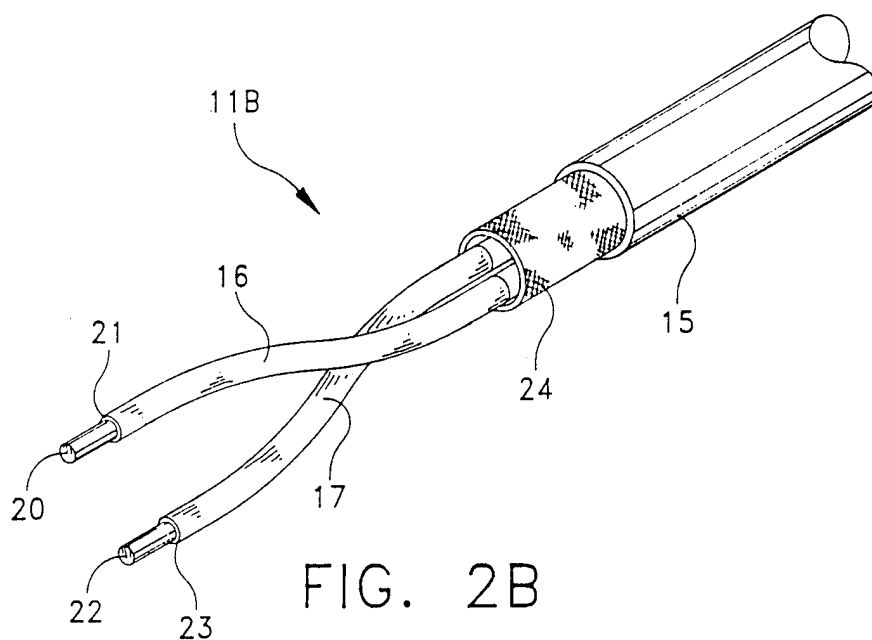


FIG. 2B

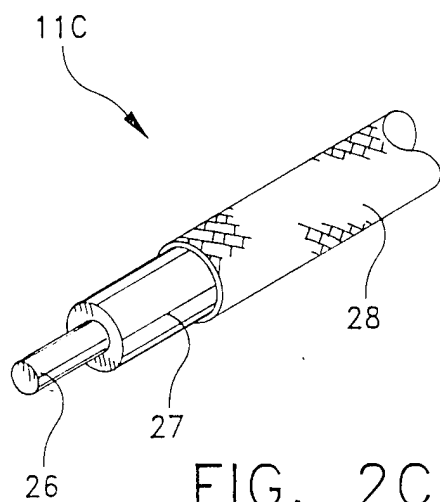


FIG. 2C

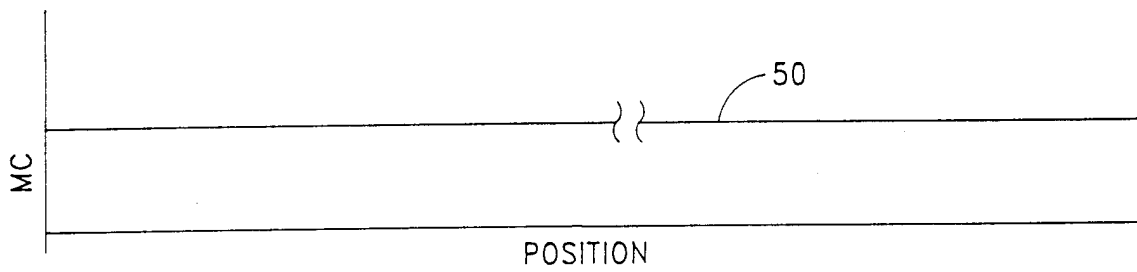


FIG. 3A

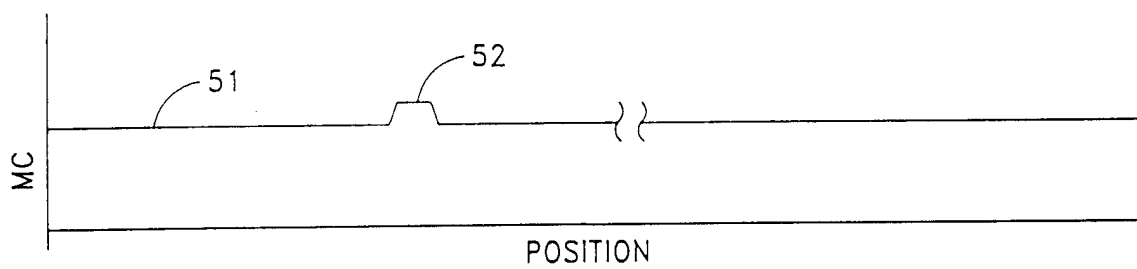


FIG. 3B

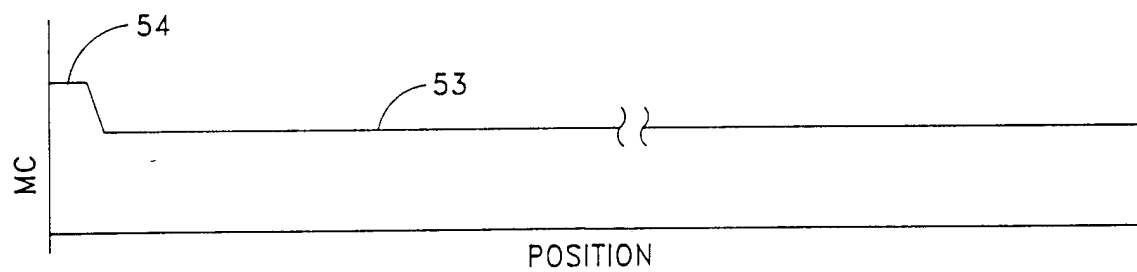


FIG. 3C

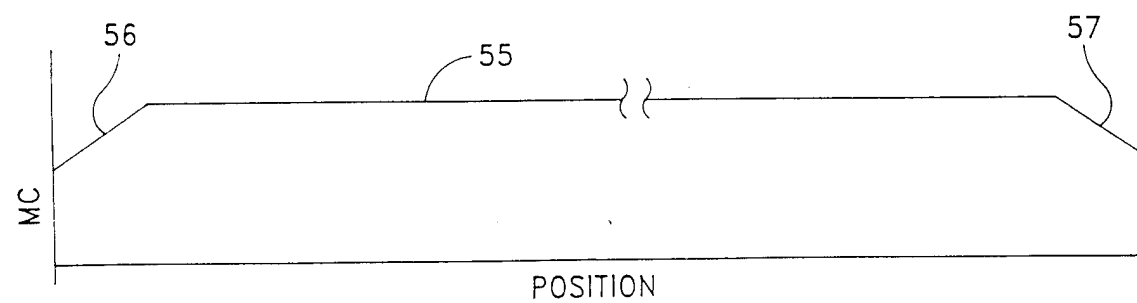


FIG. 3D

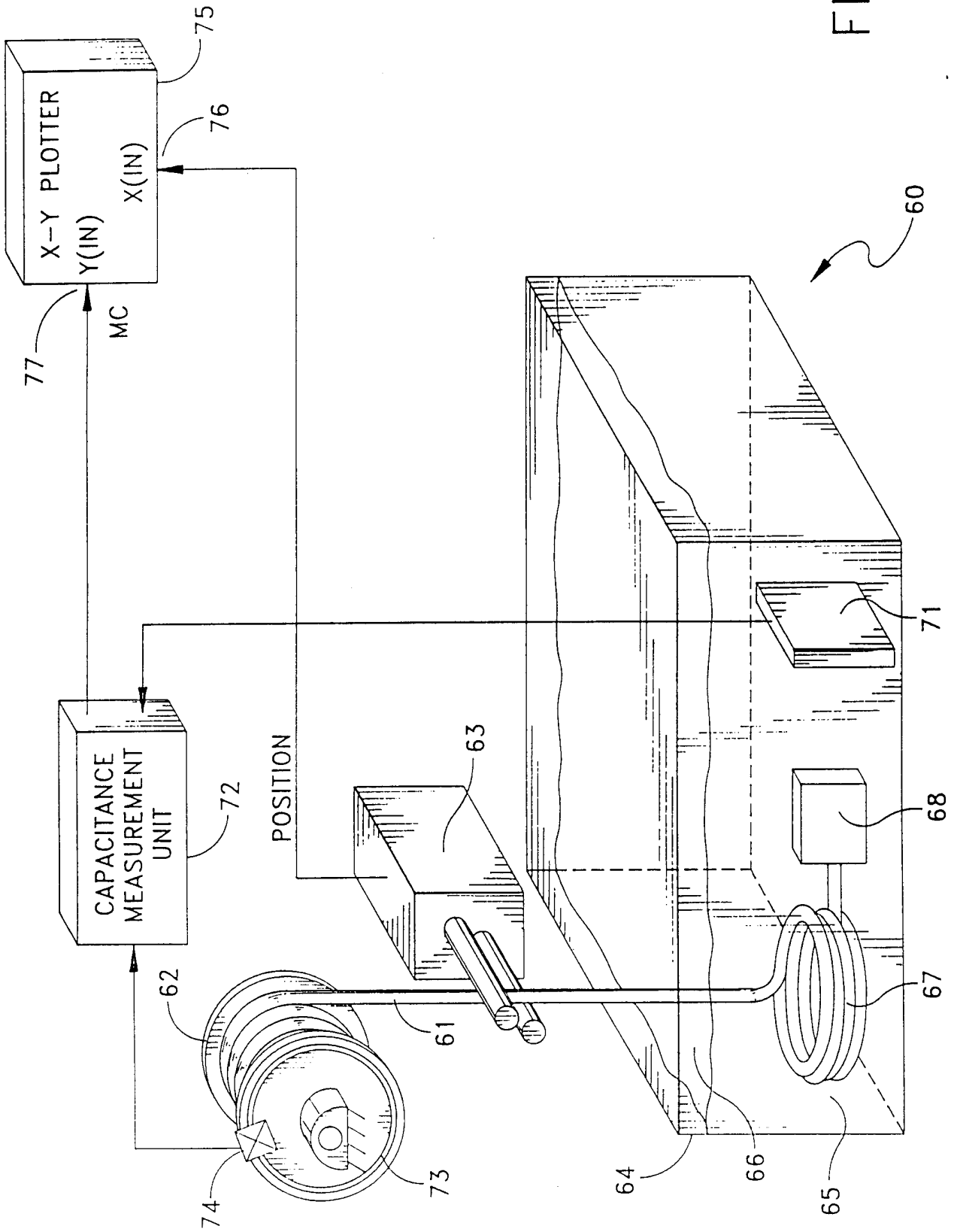


FIG. 4

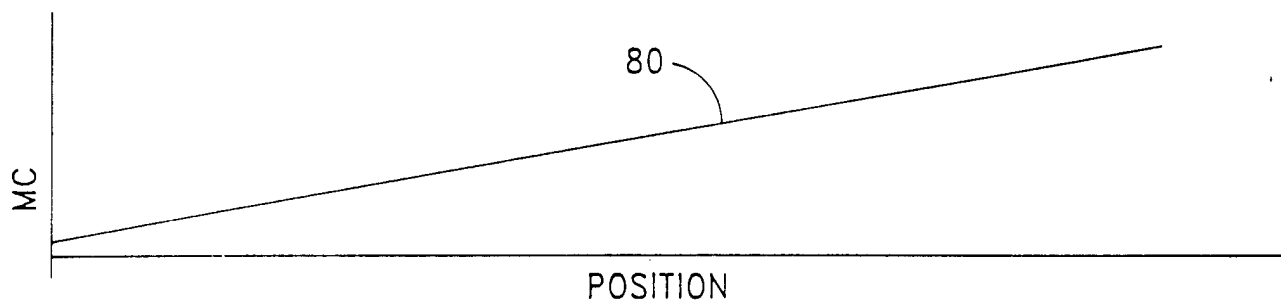


FIG. 5A

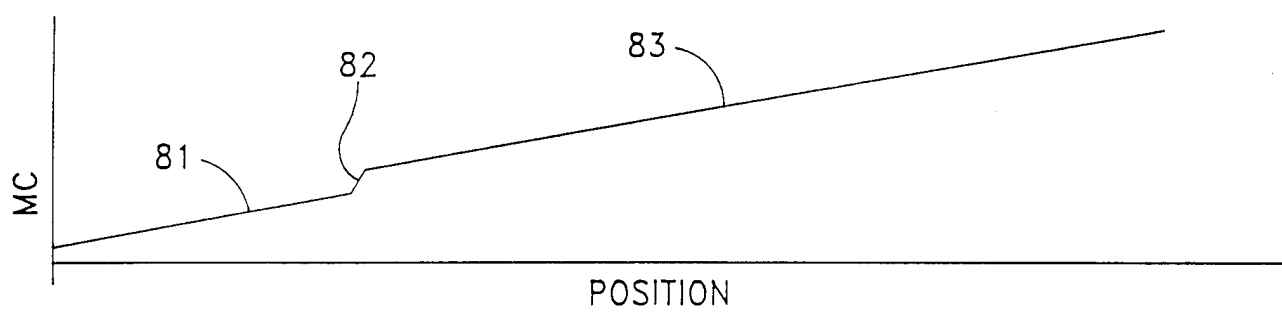


FIG. 5B