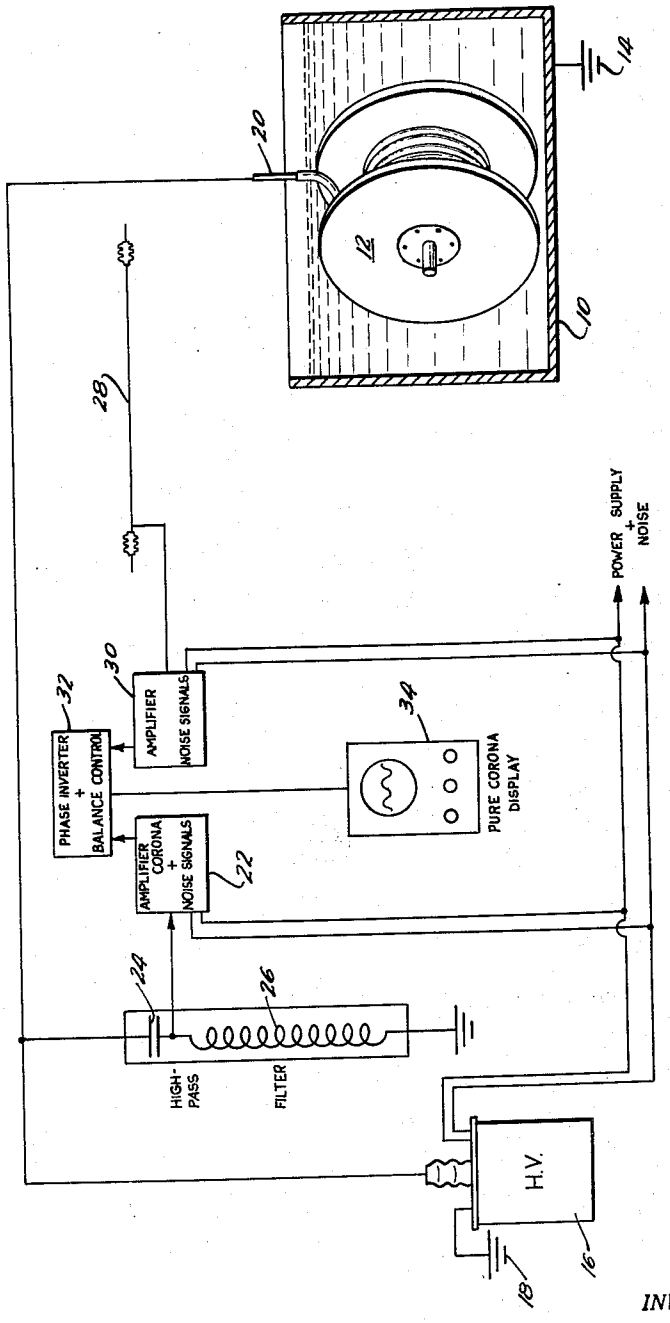
Jan. 2, 1962 D. EIGEN 3,015,774

CORONA-TESTING OF ELECTRIC INSULATION

Filed Dec. 17, 1957 2 Sheets-Sheet 1

FIG. 1



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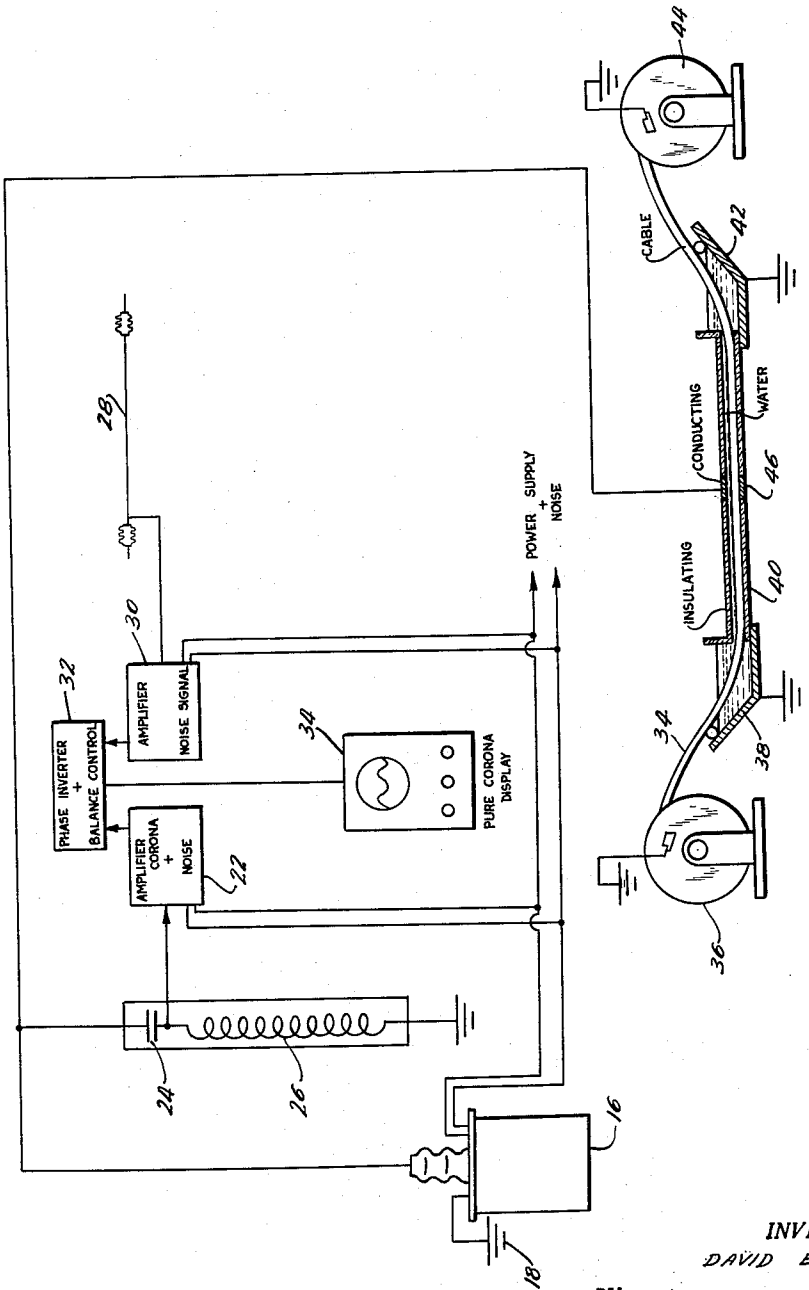


FIG. 2

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3,015,774

CORONA-TESTING OF ELECTRIC INSULATION

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This invention relates to the corona-testing of high-tension cables and more particularly to the detection of voids in the insulation thereof.

When an insulated cable is put into service, a corona discharge will occur under certain conditions wherever there is a gas occlusion within the insulation. Whether or not such a discharge will occur depends upon a number of factors, such as the position, size, and shape of the occlusion; pressure and composition of the gas; presence of solids or liquids in the occlusion; and the conductivity of the walls of the occlusion. The corona discharges are the result of the ionization of the gas within the occlusion.

From a cable manufacturer's point of view the above theoretical considerations serve as considerable guides for fabrication. Despite all precautions, however, occlusions occur, and what appears to be a perfectly insulated cable may contain occlusions which serve as sites for corona discharge while the cable is in service. Such discharges have a very destructive effect.

In view of the above, it has been proposed to subject the cable insulation to electrical stress in the same manner as it would be stressed in service, with a possible overstress as a safety factor, and attempt to detect any corona which may be generated by such electrical stress.

It is known that corona discharges result in the generation of alternating currents of random frequency, extending over a wide portion of the radio and audio bands. Thus, an ordinary amplitude modulated radio can pick up the emanations from corona discharge if directly connected to, or having an antenna in the vicinity of, conductors leading to the vicinity of such discharges. Simply stated, a radio receiver will emit from its speaker a characteristic noise if the receiver is arranged to respond to the electromagnetic radiation from the corona or is connected or coupled to the circuit supplying the voltage which causes the corona. Thus it would appear sufficient for testing purposes to stress the insulating material as it would be stressed in service or such multiple thereof as may be considered a factor of safety.

However, in the practical application of the test for corona, where an alternating current voltage is applied in a manner to stress the insulation as it will be stressed in service, it has been found that a radio or other corona detector of sufficient sensitivity to respond to corona discharge in cable insulation occlusions will also respond to atmospheric or man-made amplitude-modulated disturbances in the vicinity and in the lines supplying the stressing voltage and even in those lines supplying the power necessary to operate the detector. Around an industrial plant there are many motors, generators, switching mechanisms, and the like, like all of which in general create a certain amount of amplitude-modulated ratio frequency disturbance. Suppression of man-made disturbances at their source by proper application of condensers and other arrangements is theoretically possible, but, because of the great power requirements of the plant machinery, such suppression may not be practical. Even if we assume complete suppression of man-made disturbances, the AM radio used as a detection device will still pick up the atmospheric disturbances. The technician conducting the test may have sufficient aural discrimination, imagination, and concentration to listen to the signals from the radio or other corona detector and decide, as a matter of judgment, when corona manifests itself as evidenced by the signal from the radio or other corona detector. Also various visual means have been suggested to permit analysis of the signal, such as recorders and oscillographs. Even such instruments require a high degree of judgment and do not permit increase of amplification to the degree required for positive detection of weak corona signals, since any attempt at such amplification would also amplify the extraneous noise signals. Often the extraneous noise is so great that a valid evaluation of the corona-producing properties of the cable insulation cannot accurately be made.

In view of all of the above it is a primary object of my invention to provide a corona-indicating arrangement for testing cable insulation which is relatively little influenced by electrical disturbances in the surroundings or in the lines supplying the power necessary to perform the test, so as to permit amplification of the corona signal and, hence, increase the sensitivity of the apparatus.

Referring now to the drawings:

FIG. 1 is a showing of a form of apparatus embodying my invention utilized in one form of testing; and

FIG. 2 is apparatus substituted for part of that shown in FIG. 1 for use in a different form of test.

Both figures of the drawings are diagrammatic in form.

In testing cable insulation for corona-producing voids, the cable may be reeled and have its insulation stressed at one time by applying voltage between the cable conductor and the outer surface of the cable insulation, or the cable may be run through an apparatus which progressively subjects the insulation to a voltage sufficient to result in corona discharge.

Referring first of all to FIG. 1, **10** designates a tank into which a reel **12** of the cable to be tested is inserted. A suitable liquid, for instance water, covers the cable. The tank **10** is grounded at **14** for a reason which will appear. To stress the cable insulation, I employ a high alternating-current voltage. As shown, a transformer **16** has one of its secondary terminals grounded at **18** and its other terminal connected to the cable conductor **20**. This arrangement, it will be seen, stresses the insulation as it would be stressed in service, as the voltage over the entire surface of the cable insulation is susbtantially that of the ground, and the voltage along the conductor is whatever is generated by the transformer **16**. Alternatively, if the cable is of the shielded type, the shield may be connected to ground **14** and the high-voltage lead connected to conductor **20**, to stress the insulation in a manner similar to that above described but without the use of the tank **10**.

For the purpose of detecting corona, an amplifier **22** is provided, which is connected to the cable conductor **20**, as shown. A condenser **24** and a small inductor **26** serve as a filter, permitting only high-frequency corona discharge currents to pass into the amplifier, the 60-cycle high voltage passing through condenser **24** being grounded through the inductor **26**.

It will be appreciated that the output of the amplifier **22** will consist of whatever corona discharge is generated in voids in the cable insulation plus disturbances entering the high-voltage line by capacitance between turns in the transformer and, for that matter, disturbances traveling to the amplifier along its power supply. In addition, however, there are the radio-frequency disturbances traveling through the air and picked up by the reeled cable **12** and/or the leads connecting the various equipments and the equipments themselves shown in FIG. 1, as transformer **16**, condenser **24**, and inductor **26**. The output of the amplifier **22** is one which only great skill and discrimination can interpret in terms of corona, if any worthwhile interpretation at all is possible. Attempts to create and suppress corona by turning the high voltage off and on do not always work, as the turning off and on of the

high voltage disconnects some parts and, therefore, affects the receptivity of the circuit to outside influences. At any rate, quantitative evaluation of corona is scarcely possible if the background disturbance is noticeable.

Accordingly, I propose to provide means which will nullify interference coming in over the lines and through the air. To achieve this, I provide an antenna **28**, which is intended to pick up the interference which travels through the air. As a general matter, by observing the operations in the plant and the location of those mechanisms producing the disturbances, the orientation position, size, and shape of the antenna can be fairly accurately determined, the idea being to install an antenna which receives signals from such disturbances and introduces these signals into amplifier **30**, just as the reel of cable and the rest of the equipment introduce the same signals to amplifier **22**. The antenna must be sufficiently remote from the reel of cable **12** that signals from corona disturbances emanating from the cable are attenuated before reaching the antenna.

The signals picked up by the antenna **28** are amplified in an amplifier **30**, similar in all respects to the amplifier **22**. It is preferable that the two amplifiers be physically close to each other, and that their power leads be connected to the power supply near each other, so that all noise or interference entering amplifier **22** has its counterpart of the same strength also entering the amplifier **30**.

The output of amplifier **30**, which is solely noise and interference, is utilized to buck the signals from amplifier **22**. For this purpose I provide a phase inverter **32**, which may also include the necessary equipment to balance the two outputs.

The resulting signal will be that produced by corona in the cable the insulation of which is being tested. This signal may be amplified for operating indicating means, for example a speaker, or a cathode-ray oscilloscope such as shown at **34**, or it may be amplified and/or rectified for operating more elaborate means, as, for example, a pen recorder.

It can be appreciated that with the above described arrangement the high-frequency wide band signals originating from whatever source enter amplifier **22** and amplifier **30** with the following relative intensities:

Type signal	How entering amplifier	Amplifier 22	Amplifier 30
Noise	Through line	Same	Same.
Do	Through air (Equipment picked up).	do	Do.
Corona	From cable by close coupling of condenser etc.	High	Nil.
	From cable by remote coupling of antenna.	Nil	Nil.

With an arrangement such as this, regardless of the degree of amplification by amplifier **22**, the noise can be obliterated by amplifier **30**, and therefore the amplification employed in amplifier **22** can be as high as desired, except for limitations engendered by noises generated by the tubes of the amplifier itself, thus promoting the sensitivity of my arrangement to corona in the cable.

The above described arrangement does not, of course, locate the defect or void in the reeled cable. For the purpose of locating the voids, the arrangement above described can be modified as illustrated in FIG. 2, wherein like parts have been given like reference characteristics.

In the arrangement shown in FIG. 2 the cable is extended, as distinguished from being reeled, during testing, the cable, designated **34**, passing from a reel **36** through grounded tank **38**, tube **40** of insulating material, and grounded tank **42** to take-up reel **44**. The insulating tube **40** and the tanks **38** and **42** contain a semi-conducting fluid, such as water, and the tube **40** intermediate its ends is provided with a conducting section or electrode **46**. As in the construction illustrated in FIG. 1, one terminal of the secondary of the transformer **16** is grounded. The other terminal of the secondary of this transformer is connected to the electrode **46** of the tube **40**, instead of being connected directly to the conductor of the cable, as in FIG. 1.

As set out in Francis H. Gooding Patent No. 2,794,-168, dated May 28, 1957, corona-producing stresses are built up in the insulation of the cable as the cable passes from reel **36** to take-up reel **44** through the semi-conducting liquid in the tanks **38** and **42** and tube **40**.

Antenna **28** is provided, as in FIG. 1, for the purpose of picking up interference, exactly as described in connection with FIG. 1. The antenna **28** and the lead to the electrode **46** are connected as shown to the apparatus described in connection with FIG. 1, and the operation of this equipment will be obvious from the foregoing description and that of the Gooding Patent 2,794,168.

As earlier stated, it is important that the two amplifiers **22** and **30** of FIGS. 1 and 2 be identical in characteristics. Also it is important that the phase inverter balance the outputs of the two amplifiers.

From all of the foregoing it will appear that I have provided for corona-testing of the insulation of electric cables, one embodiment of the invention providing for testing a full reel of cable, the other embodiment providing for the progressive testing of the cable, i.e., while the cable is extended as distinguished from being reeled. In both embodiments of the invention it will be seen that I have provided for eliminating outside interference from atmospheric disturbances as well as from motors, generators, switching mechanisms, etc.

It is to be understood that changes may be made in the details of construction and arrangement of parts hereinabove described within the purview of my invention.

What I claim is:

1. Apparatus for the corona-testing of electric insulation, said apparatus comprising, in combination, means for subjecting the insulation to a sufficiently high electrical stress to cause corona discharge in defective portions of the insulation; a radio-frequency receiver, including an amplifier, responsive to high-frequency emanations resulting from said corona discharge; a second radio-frequency receiver, including an amplifier; an antenna, connected to said second receiver, for receiving high-frequency electrical disturbances from the surrounding area, said antenna being positioned sufficiently remote from the stressed insulation so that the high-frequency emanations resulting from said corona discharge will be attenuated before reaching the antenna; a phase inverter to which the output of each amplifier is connected so as to transpose the high-frequency electrical disturbances picked up by the second receiver to one hundred and eighty degrees phase displacement relative to any high-frequency electrical disturbances picked up by the first receiver, thereby to nullify the same; and an indicating device connected to the output of the said phase inverter.

2. Apparatus for the corona-testing of electric insulation, said apparatus comprising, in combination, means for subjecting a reel of insulation to a sufficiently high electrical stress to cause corona discharge in defective portions of the insulation; a radio-frequency receiver, including an amplifier, responsive to high-frequency emanations resulting from said corona discharge; a second radio-frequency receiver, including an amplifier; an antenna, connected to said second receiver, for receiving high-frequency electrical disturbances from the surrounding area, said antenna being positioned sufficiently remote from the stressed insulation that the high-frequency emanations from said corona discharge will be attenuated before reaching the antenna; a phase inverter to which the output of each amplifier is connected so as to transpose the high-frequency electrical disturbances picked up by the second receiver to one hundred and eighty degrees phase displacement relative to any high-frequency electrical disturbances picked up by the first receiver, thereby

to nullify the same; and an indicating device connected to the output of the said phase inverter.

3. Apparatus for the corona-testing of electric insulation, said apparatus comprising, in combination, means for subjecting the insulation progressively to a sufficiently high electrical stress to cause corona discharge in defective portions of the insulation; a radio-frequency receiver, including an amplifier, responsive to high-frequency emanations resulting from said corona discharge; a second radio-frequency receiver, including an amplifier; an antenna for said second receiver for receiving high-frequency electrical disturbances from the surrounding area, said antenna being positioned sufficiently remote from the stressed insulation that the high-frequency emanations from said corona discharge will be attenuated before reaching the antenna; a phase inverter to which the output of each amplifier is connected so as to transpose the high-frequency electrical disturbances picked up by the second receiver to one hundred and eighty degrees phase displacement relative to any high-frequency electrical disturbances picked up by the first receiver, thereby to nullify the same; and an indicating device connected to the output of the said phase inverter.

4. A device for detecting voids in electric insulation, said device comprising means for applying alternating-current voltage to the insulation under test to induce corona discharge in the voids in the insulation; means detecting and responsive to said corona discharge and to similar high-frequency disturbances in the area surrounding the insulation under test; means detecting and responsive to said similar high-frequency disturbances and comprising an antenna positioned sufficiently remote from the stressed insulation that the high-frequency emanations resulting from said corona discharge will be attenuated before reaching the antenna so that said second detecting means is relatively insensitive to the said corona discharge in the insulation; and means superimposing the response of the second detecting means on the response of the first detecting means in a manner to suppress the response of the first detecting means to high-frequency disturbances in the area surrounding the insulation.

5. A device for detecting voids in the insulation of an electric cable comprising a bath of semi-conducting liquid in which the cable is immersed; a source of high voltage between the liquid and the conductor of the cable, stressing the insulation to produce corona in the voids therein; a high-frequency detector closely coupled to the cable and responsive to high-frequency emanations resulting from said corona discharge and responsive to electrical disturbances in the surrounding area; a second high-frequency detector; an antenna connected to said second detector for receiving high-frequency electrical disturbances from the surrounding area, said antenna being positioned sufficiently remote from the stressed insulation that the high-frequency emanations resulting from said corona discharge will be attenuated before reaching the antenna; and means superimposing the response of the second detector on the response of the first detector in such a manner that the combined output of the two detectors is a result of substantially only corona discharge in the cable voids.

6. A device for testing the insulation of an electric cable comprising a tank containing a semi-conducting liquid; means for passing the cable to be tested through the tank; means maintaining the cable conductor and the tank ends at the same potential; means, including an electrode intermediate the ends of the tank, generating an electrical stress in the cable insulation; a high-frequency detector and amplifier electrically coupled to the stressed cable insulation and responsive to high-frequency energy emanating therefrom generated by corona discharge in the insulation and responsive to electrical disturbances in the area; an antenna, high-frequency detector, and amplifier responsive to high-frequency energy emanations, said antenna being positioned so as to be responsive to electrical disturbances in the area and relatively insensitive to energy emanating from said corona discharge; and a phase inverter coupling the output of the two amplifiers with a resultant combined output relatively free of electrical disturbances.

7. Equipment for testing the insulation of a length of electric cable of the shielded type comprising, in combination, means for grounding the cable shield; a grounded high-tension source connected to the cable conductor; an antenna positioned for receiving electrical disturbances reaching the vicinity of the test leads and equipment and the cable conductor but relatively insensitive to corona discharge in voids in the insulation; detecting and amplifying means responsive to high-frequency energy emanating from corona discharge in the cable insulation; detecting and amplifying means responsive to energy emanations received by said antenna; and means for so superimposing the output of the second amplifier upon the output of the first amplifier that the combined output of the two amplifiers is substantially confined to the emanations resulting from corona discharge in the cable insulation.

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