

June 6, 1933.

J. J. GILBERT

1,912,442

LOADED CABLE

Filed Oct. 30, 1930

2 Sheets-Sheet 1

FIG. 1.

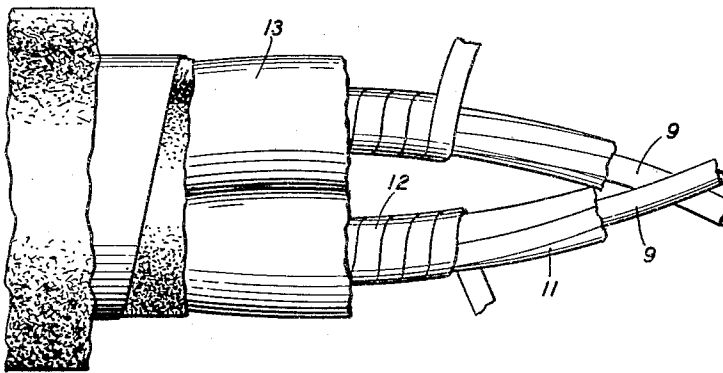
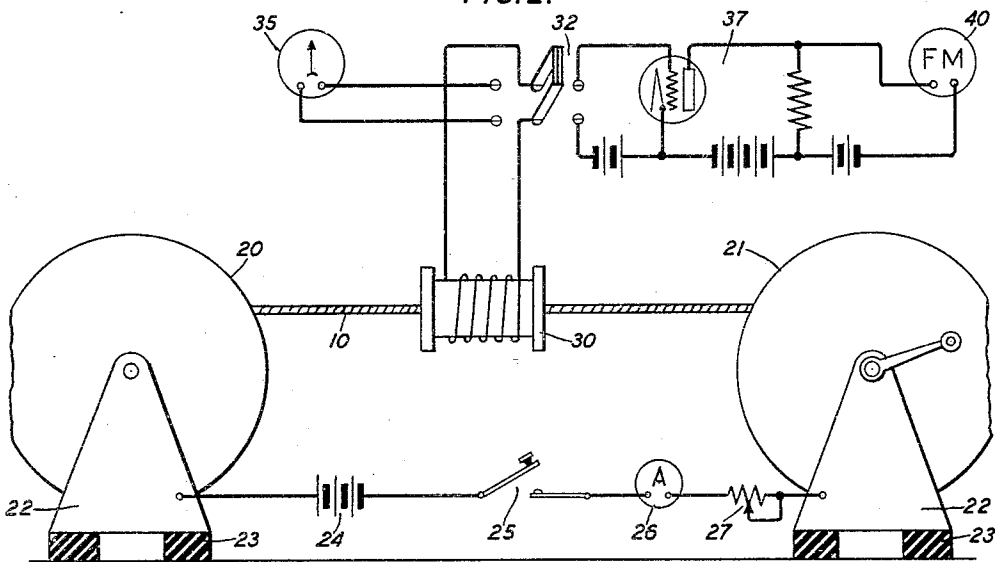


FIG. 2.



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FIG. 3.

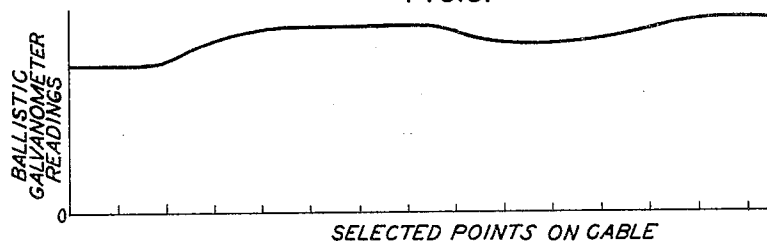


FIG. 4

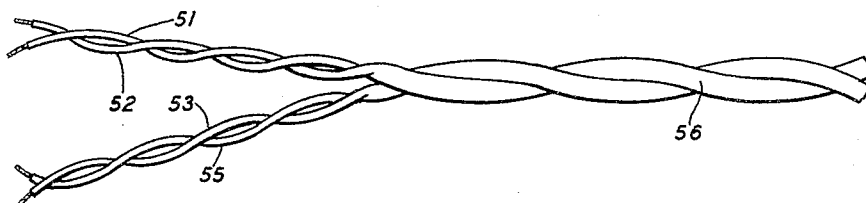
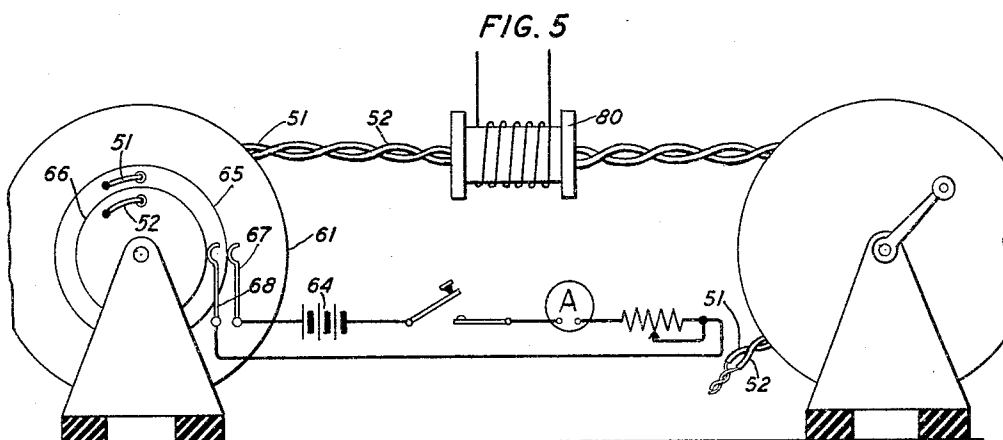


FIG. 5



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LOADED CABLE

Application filed October 30, 1930. Serial No. 492,134.

This invention relates to signaling conductors and more particularly to continuously loaded conductors for the transmission of telephone and telegraph currents.

5 This invention is applicable to the usual type of continuously loaded conductors in which the loading is effected by wrapping a wire or tape of magnetic material around a central conductor. The tape forms a thin
10 layer through which runs a helical air-gap.

The lines of magnetic induction set up in the loading material by a conductor of the type described follow a helical path through the loading material. Owing to the presence
15 of the air-gap, the magnetic flux due to currents in the central conductor may be resolved into two components, one parallel to the length of the tape and the other parallel to the plane of the tape but perpendicular to its length. The latter component is
20 longitudinal with respect to the axis of the conductor and will hereinafter be referred to as the longitudinal component of magnetic flux. It should be noted that this
25 theory is not in agreement with the commonly accepted and widespread idea that the lines of magnetic induction around the conductor form closed loops. For a more theoretical discussion of the magnetic induction in a loaded cable of this character,
30 reference is made to Patent 1,586,962 issued June 1, 1926 to O. E. Buckley.

The longitudinal component of magnetic induction of a loaded conductor creates a
35 number of undesirable results, among them being to impair the efficiency of the conductor for signaling purposes. The usual submarine cable, in addition to a surrounding layer of insulation, is further surrounded by
40 conducting material composed of the sea water and armor wire. This conducting material forms a path for eddy currents which are set up by the longitudinal flux in the loading material. The eddy currents en-
45 counter resistance in the conducting mate-

rial and thus energy is dissipated. The effect of the wasted energy manifests itself in an increase in the attenuation of the signaling circuit.

A longitudinal component of magnetic
50 flux may be objectionable in the case of a multi-conductor telegraph or telephone cable in which each pair of conductors forms an individual circuit, as well as in the case of
55 a cable in which the pairs are grouped to form quads for the well known phantom circuit arrangement. The longitudinal components of flux resulting from two conductors in the same circuit, unless neutralized
60 by each other, produce a resultant flux which may cause cross-talk in adjacent circuits in the same cable.

An object of this invention is to reduce cross-talk due to longitudinal magnetic induction in a multi-conductor cable.
65

Another object of this invention is to reduce eddy current losses due to longitudinal magnetic induction in a cable in which there is one or more circuits formed by pairs of
70 conductors.

The above objects are obtained by pairing the conductors so that the longitudinal component of induction of one conductor balances or neutralizes that of the other. If
75 the loading tapes on the two conductors have exactly the same permeability, thickness, width and lay, and the currents are equal and opposite, the longitudinal induction components of the two conductors are balanced and the cross-talk and eddy current
80 effects are eliminated.

A further object of this invention is to provide a practical and economical method of matching cable sections to neutralize their longitudinal induction components. A long
85 deep sea signaling cable is usually manufactured in a number of sections of about one mile in length which are joined before the laying operation. Owing to inherent manufacturing conditions the electrical proper-
90

ties of the individual sections will not be identical. In accordance with this invention, the longitudinal flux component of each section for a given current is separately measured and sections having nearly identical longitudinal flux components are paired or twinned.

It has been hitherto proposed to eliminate the longitudinal induction component of a loaded conductor by constructing the cable exactly in accordance with an accurate design. See Patent 1,674,912, issued June 26, 1926 to U. Meyer. As contrasted with this method, the present invention obviates the necessity of painstaking care in the manufacture of the cables. The difference between the permeability of the loading material of one cable section and that of another section is compensated in the process of matching the cable sections after they have been manufactured and tested.

Fig. 1 of the accompanying drawings show a twin core submarine cable constructed in accordance with this invention;

Fig. 2 shows an arrangement for testing the loaded conductors before they are matched with each other;

Fig. 3 is a curve plotted from readings taken by the ballistic galvanometer shown in Fig. 2;

Fig. 4 shows a number of loaded conductors arranged to form a multiple twin quad; and

Fig. 5 shows a device similar to that of Fig. 2 for testing a pair of conductors intended for use in forming a multiple twin quad.

Referring to the submarine cable shown in Fig. 1, the central copper conductors 9 are surrounded by a number of segments 11, say six, shaped to fit the central conductors 10. Upon the segments 11 is applied a helix of loading material 12. Suitable loading materials and suitable methods of applying loading materials are known and need not be discussed herein. The conductor is heat treated after the loading material is applied thereto. Suitable heat treating methods such as are well known may be employed. The loading material is surrounded by a pressure equalizing fluid, such as liquid bitumen or depolymerized rubber. Surrounding the loading material is a sheath of insulating material 13 such as gutta percha or gutta percha substitute. The entire structure thus far described constitutes a unit hereinafter referred to as a core. Two such cores are twinned together in a twinning machine and given a spiral lay or pitch. The pitch is preferably of the order of several feet. The cores 13 are surrounded by the usual jute, teredo tape and armor wire, not shown.

In the process of manufacture of the cores, the loading tapes on the two conductors are

constructed to have, as nearly as possible, the same permeability, thickness, width and lay. Two cores are arranged to form a two-wire circuit, with the loading tapes of the two cores having the same direction of lay as illustrated in Fig. 1. Assuming that the two cores are matched perfectly, the longitudinal component of magnetic induction set up by one conductor will be neutralized by the corresponding component set up by the other conductor.

In practice, the dimensions, permeability and lay of the loading tape vary slightly, and to compensate for corresponding variations in the magnetic field, a number of sections of loaded conductors of about a mile in length, and approximately similar in construction, are separately measured and from the measurements taken, two conductor sections are selected which when paired together will most nearly neutralize each other's longitudinal flux component.

Fig. 2 shows an arrangement for recording the longitudinal component of magnetic induction at different points along the length of a loaded conductor. The conductor 10 after being wrapped with loading material is wound upon a paying-out reel 20 and is adapted to pass from that reel to another reel 21. The cable is connected electrically with the reels and with the supports 22 for the same. The supports 22 are insulated from each other by insulating blocks 23, and are connected to form a series circuit with the conductor 10, a battery 24, a key 25, an ammeter 26 and a rheostat 27. A solenoid or exploring coil 30 surrounds the conductor 10 and is supported by suitable means, not shown. A two-pole double-throw switch 32 is connected to the terminals of the solenoid 30, and is adapted, when thrown in one position, to connect the solenoid to a ballistic galvanometer 35. In its other position the switch 32 connects the terminals of the solenoid through an amplifier 37, preferably of the thermionic vacuum tube type, to a flux meter 40.

Upon opening and closing the key 25 an electromotive force will be induced in the solenoid having a value which depends upon the longitudinal flux component of the conductor 10. A reading is taken on the ballistic galvanometer at the instant that the key is closed or opened. The conductor 10 is then moved to a different position relative to the solenoid 30, and another reading taken on the ballistic galvanometer. A series of readings thus taken may be plotted, as shown in Fig. 3. The ordinates of the curve in Fig. 3 represent the values of longitudinal flux component at different points along the conductor 10. A similar set of readings is taken for another cable section, and another curve similar to Fig. 3 is plot-

ted. The curves for the different cable sections are compared, and those sections whose curves approximately coincide are paired with each other. In taking these
 5 measurements it is necessary that the steady direct current through the conductor 10 following each closing or preceding each opening of the key 25 be kept at approximately the same value. This current can be regulated conveniently by the rheostat 27.

A more expeditious method of obtaining flux readings for the purposes of comparison may be employed by using the flux meter 40 in conjunction with the ballistic
 15 galvanometer 35.

The flux meter 40 should be of the type which integrates changes in magnetic field over a long period of time before the indicating element of the flux meter creeps appreciably toward the zero position. The
 20 flux meter readings are taken while the conductor 10 is moved, at an approximately uniform rate, through the solenoid 30. During the time the readings are taken, a steady direct current flows through the conductor. The initial reading of the flux meter may be taken by closing the key 25 after the conductor 10 has started moving. The
 25 flux meter indicating element moves from its zero position to a position representing the longitudinal flux component at one point on the conductor 10. As the longitudinal flux within the solenoid 30 increases or decreases, the deflection of the indicating
 30 element increases or decreases correspondingly.

The readings of the flux meter may be observed at regular intervals while the conductor 10 is moving and may be plotted to
 40 obtain a curve similar to the one shown in Fig. 3. A more convenient method, however, is to provide the flux meter with an arrangement for recording the deflections automatically.

The satisfactory operation of the flux meter method of measuring longitudinal flux as described above, is dependent to a large extent upon the property of the indicating element to remain in the same position when the longitudinal flux is distributed evenly along the conductor 10, and there is hence no electromotive force induced in the solenoid 30. If the indicating element of the flux meter, under these conditions
 50 creeps toward the zero position, errors in the readings will cumulate. As a check upon the flux meter readings the switch 32 may be thrown occasionally to the opposite position and one or more readings may be taken
 60 with the ballistic galvanometer 35.

While two methods have been described for measuring and recording the longitudinal flux component of a conductor, it is to be understood that there are other methods,
 65 whereby these same readings may be recorded.

For example, the arrangement shown in the patent issued to O. E. Buckley No. 1,586,962, June 1, 1926 is suitable for the purpose mentioned.

Fig. 4 shows a multi-conductor cable comprising two conductors 51 and 52 twisted upon each other to form one pair, and two other conductors 53 and 54, respectively, which are similarly twisted to form a second pair. Each pair of conductors forms a two
 70 wire circuit. The two pairs of conductors are twisted upon each other to form a quad. Each conductor is separately loaded by a helical tape and insulated preferably by paper. Each conductor, being loaded, sets up
 75 a magnetic field which has a component longitudinal with respect to the conductor. If the two conductors of a pair are properly matched in accordance with the method described above, the resultant longitudinal
 80 component of magnetic induction will be zero. However, if no attempt has been made to match the conductors of each pair, or if the conductors have been matched imperfectly, an arrangement may be employed for
 85 neutralizing the resultant longitudinal flux component of one pair of conductors with the resultant component from another pair of conductors, of which the two pairs form a quad.

An arrangement for measuring the resultant longitudinal flux component of a pair of conductors 51 and 52 is shown in Fig. 5. A device similar to that shown in Fig. 2 is provided, but in the device of Fig. 5 it is necessary to provide a slip ring arrangement so that the ends of the conductors 51 and 52 may be connected to the battery
 90 64. The conductors 51 and 52 are connected to each other electrically at one end whereby the two conductors carry the same current in opposite directions. The slip rings 65 and 66, respectively, are connected to the free ends of the conductors 51 and 52 and cooperate with brushes 67 and 68 to
 95 connect the conductors 51 and 52 serially with the battery 64 and an arrangement which consists of a key, ammeter and rheostat similar to those shown in Fig. 2. The solenoid 80 may be connected in the same
 100 manner as the solenoid 30 of Fig. 2.

As an alternative to the arrangement of Fig. 5 the resultant longitudinal flux component at any point along a pair of loaded conductors may be computed by plotting
 105 two curves, similar to the curve of Fig. 3 and adding the ordinates at each point to obtain the resultant flux component. By balancing the resultant longitudinal flux of one pair with that of another pair of
 110 conductors, cross-talk between the two pairs may be avoided.

What is claimed is:

1. A continuously loaded multi-conductor cable for communication purposes, comprising
 120

ing two adjacent conductors each surrounded with helically arranged loading material and matched by having the loading materials arranged with the same permeability, thickness, width, and lay in corresponding portions so that in each section the longitudinal component of magnetic induction due to one conductor is balanced by the longitudinal component due to the other conductor.

2. A signalling cable, each section of which comprises a group of conductors matched so that the longitudinal component of magnetic induction due to one conductor is balanced by the longitudinal component due to another conductor.

3. A continuously loaded communication cable of twin core type characterized in this, that two core lengths selected from a number of sections and constituting a twin core section are more nearly equal to each other in respect to their inductance in a longitudinal direction than they are equal to the cores of other sections of the number from which the sections were selected, said core lengths being arranged so that said inductance components are opposite in direction.

4. The method of constructing a continuously loaded communication cable which comprises selecting from a number of core lengths, pairs of core lengths having as nearly as possible equality of induction longitudinally of the cores to form a twin core section, and arranging the cores so that their longitudinal inductance components are opposite in direction.

5. In a multi-conductor cable, the method of neutralizing the component of magnetic induction longitudinally of the cable, which method comprises selecting a number of conductor lengths, subjecting each length to the same current condition, measuring the longitudinal induction component at corresponding points on the respective conductor lengths and pairing conductor lengths having nearly equal measurements.

6. A method of determining two conductors most nearly matched as to their longitudinal component of magnetic induction, which method comprises measuring the longitudinal induction component at a corresponding point on each one of a number of such conductors when the conductors are subjected to similar current conditions, and comparing the measurements thus taken.

7. A method of constructing a two conductor cable with conductors most nearly matched as to their longitudinal component of magnetic induction, which method comprises measuring the longitudinal induction component at a plurality of corresponding points on each one of a number of lengths of conductors, comparing curves plotted with the measurements thus taken,

and pairing lengths of conductors whose curves approximately coincide.

8. A multi-conductor communication cable comprising a plurality of pairs of continuously loaded conductors, said conductors being so selected that the resultant longitudinal component of magnetic induction due to one pair of conductors is opposite and approximately equal to the longitudinal induction component resulting from a second pair of conductors by which the first pair is closely paralleled.

9. In a communication cable comprising a number of pairs of continuously loaded conductors, the method of neutralizing the component of magnetic induction longitudinally of the cable, which method comprises selecting a number of pairs of conductors, subjecting each pair to the same current condition, measuring the resultant longitudinal induction component of each pair, at corresponding points on the several pairs, and grouping two pairs having nearly equal measurements to form a quad.

In witness whereof, I herunto subscribe my name this 20 day of October, 1930.

JOHN J. GILBERT.