

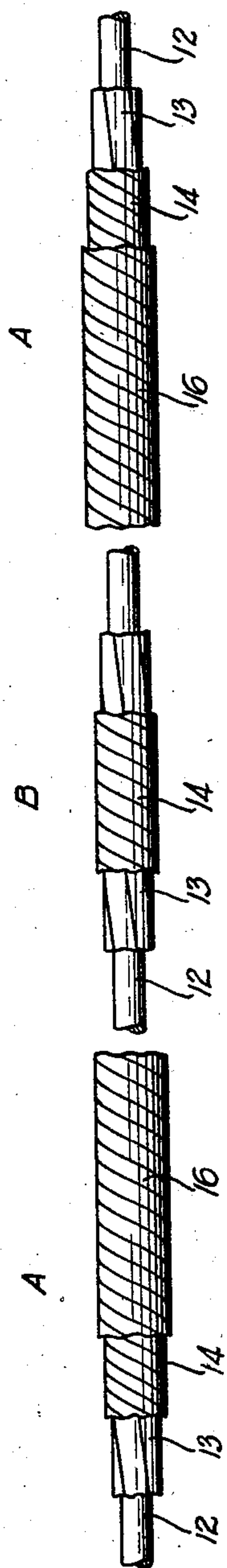
June 10, 1930.

V. E. LEGG

1,762,996

LOADING OF SIGNALING CONDUCTORS

Filed Nov. 8, 1928



INVENTOR  
V. E. LEGG  
BY  
J. W. Schmied  
ATTORNEY



## UNITED STATES PATENT OFFICE

VICTOR E. LEGG, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

## LOADING OF SIGNALING CONDUCTORS

Application filed November 8, 1928. Serial No. 317,931.

This invention relates to long loaded submarine cables.

An object of the invention is to reduce impedance irregularities in taper loaded cables or conductors.

In long submarine cables the overall attenuation is so great that relatively large currents must be applied at one end in order that signals of suitable strength may be received at the distant end. If the conductor is loaded with magnetic material the permeability and hysteresis losses of which vary with the magnetizing force, the large variations in the current and hence the magnetizing force in the terminal sections may cause the inductance and resistance due to the loading material to vary between wide limits during each cycle. As a result of these variations in the inductance and resistance of the conductor it is difficult to construct an artificial line that will simulate such a cable with sufficient exactness for duplex telegraph operation. If the cable is designed for telephone or carrier frequency operation there is the additional objection that the varying impedance produces intermodulation between different telephone and carrier frequencies with resultant distortion. Tapering the loading has been proposed and effects a partial cure for these conditions.

In accordance with this invention the terminal sections are loaded with a greater thickness of loading material than the central sections. The material used for loading the terminal sections has a low hysteresis loss, a lower resistivity than the central sections, and a high constancy of permeability for a wide range of magnetizing forces.

The physical construction of a cable constructed in accordance with this invention and designed to reduce the above mentioned difficulties will now be described in conjunction with the accompanying drawing which is a side view of one embodiment of the invention.

In the drawing, A designates terminal sections and B a central section of a loaded submarine signaling cable. The central

portions of the conductor are loaded in the usual manner with a magnetic material having high permeability and relatively high resistivity. By way of example, the central copper conductor 12 may have a diameter of 0.16 inches (0.406 mm.). It is surrounded by six strands 13 which are shaped to fit the central copper conductor. Upon these strands is wound as shown a helical tape 14 of magnetic loading material having a thickness of about 0.006 inches (0.15 mm.) and a width of 0.14 inches (0.355 mm.). One suitable material for loading the center sections is a composition containing approximately 45% Ni, 23% Fe, 25% Co, 7% Mo and 0.47% Si having after a proper heat treatment an initial permeability of about 87.5, a resistivity of about 82 microhm-cms. and a variation of permeability which, although reasonably small is much greater than that of the material used to load the terminal section as will be described hereinafter. This particular composition and a discussion of the method of selecting a heat treatment needed to give a desired value of initial permeability and other similar compositions which may be advantageously used for loading the central sections are described and claimed in Elmen's U. S. Patent application 220,387, filed September 19, 1927.

The increased thickness of loading material on the terminal sections may be attained by merely applying a loading tape proportionally thicker. A preferred manner, however, is to apply more layers. Thus twice as much material may be applied in two layers. However, it is not necessary that all the layers be of equal thickness. Subdivision of the layers possesses advantages which will be discussed hereinafter. In the drawing, the loading tape 14 is of the same dimensions as that used on the central sections, the composition of this tape, however, being different, as will be described below. At 16 there is shown a second tape of thickness equal to that of the tape 14, helically wound around the underlying layer 14.

The loading material of the terminal sections is characterized by a reduced resistivity



ity and by a more constant although lower permeability, hence the compositions used on these sections are different from those used on the central sections. Fortunately, materials are known which have the desired increased constancy of permeability, lower permeability, and reduced resistivity. For a full discussion see Elmen's U. S. application, Serial No. 220,387, filed September 19, 1927, and the Journal of the Franklin Institute for September 1928. For instance, a composition may be used which contains about 27% iron, 45% nickel, 25% cobalt, 2.5% molybdenum and 0.35% manganese and has, after a suitable heat treatment an initial permeability of about 480 which is constant up to magnetizing forces of about two gauss. This material, when so heat treated exhibits a hysteresis loss of only about 8.6 ergs per cubic centimeter per cycle for a maximum induction of about 1070 gauss, its resistivity is about 43 microhm-cms. The rather low resistivity of about 43 microhm-cms. of this material is approximately one-half that of the material used to load the central section and this property is advantageously correlated with the further fact that its initial permeability is one-half as great. The decreased resistivity increases the component of effective resistance of the conductor due to eddy current losses. This invention involves application of the principle that the eddy current loss is reduced in proportion to the decrease of permeability, for a given inductance. The net effect is to maintain the eddy current loss in the central and terminal sections constant. Furthermore the eddy current loss in the terminal sections is normally small as compared to the losses due to hysteresis.

In the above described embodiment of the invention a single layer of loading material is used in the central section and two layers are used in the terminal sections, the resistivity of the terminal sections being  $\frac{1}{2}$  of that of the central section, the permeability and permeability variation with flux density being also about  $\frac{1}{2}$  of that of the central section; consequently the inductance per mile will be approximately equal for the two sections. The component of the conductor resistance due to eddy-current losses will for the same frequency be the same per mile in the two layers of the terminal sections taken together as in one layer of the central section. This equality of the eddy-current component of the resistance tends to equalize the impedance of the central and terminal sections. These conclusions are based upon the known formula for the resistance component due to eddy-current losses.

$$R_e = \frac{n\mu^2 t^3}{\rho} x C$$

wherein

" $\mu$ " is the permeability of the magnetic material

" $t$ " thickness of each layer

" $\rho$ " resistivity

" $n$ " number of layers of magnetic material

" $C$ " a constant which depends on the form of the loading material. The increase of inductance caused by a signal of given current strength will be only  $\frac{1}{4}$  as great as in the central sections and the hysteresis resistance will be approximately  $\frac{1}{4}$  as great for the same frequency and the same current flowing. Due to attenuation the current in the central section is considerably lower than that in the terminal sections so that the hysteresis component of the effective resistance will be made more uniform by this method. Moreover, the eddy current losses may be kept at a relatively small value by applying the loading material in a plurality of thinly laminated layers. The important point in connection with the terminal sections is that the permeability variation with flux density must be as low as possible, thus keeping inductance variations small, and keeping hysteresis losses at a minimum. However, other materials may be employed for loading the central sections, such for instance as one of those described in Elmen's Patent 1,586,883, June 1, 1926, containing approximately 55% Ni, 34% Fe and 11% Cr, and having a resistivity of 100 microhm-cms. and a permeability at magnetizing forces approaching zero of about 1000. In such case other appropriately selected materials will be used for the terminal sections.

In the example given an integral ratio between total thickness of loading material is given but this ratio may have any value and the effective permeability may be selected to suit. The thickness may be determined by the permeabilities and resistivities of such materials as are available. The total thickness of loading material may consist of layers of different thickness as well as the same thickness. The word "thickness" is used in a generic sense to include variations in quantity of loading or effective value thereof by varying the lay or tape width as well as by actual variation of physical thickness. Loading material in the form of layers, tapes or wires are equivalents for the purposes of the present invention.

Three or more types of sections each loaded with magnetic materials of progressively different permeability constancy of permeability, resistivity and thickness of material may be employed and the number of layers may also be changed progressively, if desired.

What is claimed is:

1. A conductor surrounded with magnetic material, the material on different portions of the conductor being of different effective



permeability and the lower permeability material having the lower resistivity.

2. A conductor in accordance with claim 1 in which the resistivities are proportional to the permeabilities of the two magnetic materials.

3. A magnetically loaded conductor in which magnetic material of decreased resistivity on one portion of the conductor is more subdivided than magnetic material of greater resistivity on another portion.

4. A long, loaded cable having the terminal sections loaded with a greater thickness of loading material than the central section, the loading material on the terminal section having lower but more constant permeability and lower resistivity than that on the central section.

5. A cable in accordance with claim 4 characterized in this that the loading material of the terminal sections consists of a greater number of layers than that on a central section.

6. A long submarine signaling conductor having great over-all attenuation, comprising cable sections loaded with a magnetic composition the essential constituents of which are nickel, iron and cobalt, the different cable sections having different constancies of permeability and different resistivities, characterized in this that the sections of greater constancy of permeability and lower resistivity are closer to the terminals of said conductor than the section of greater resistivity and lower constancy of permeability.

7. A submarine cable continuously loaded differently in different portions of its length in such manner that the product of the permeability squared of the loading material by the number of layers thereof by the cube of the thickness per layer divided by the resistivity of the material for one section is approximately equal to the corresponding product for another section.

In witness whereof, I hereunto subscribe my name this 31st day of October, 1928.

VICTOR E. LEGG.