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LOADING OF CONDUCTORS

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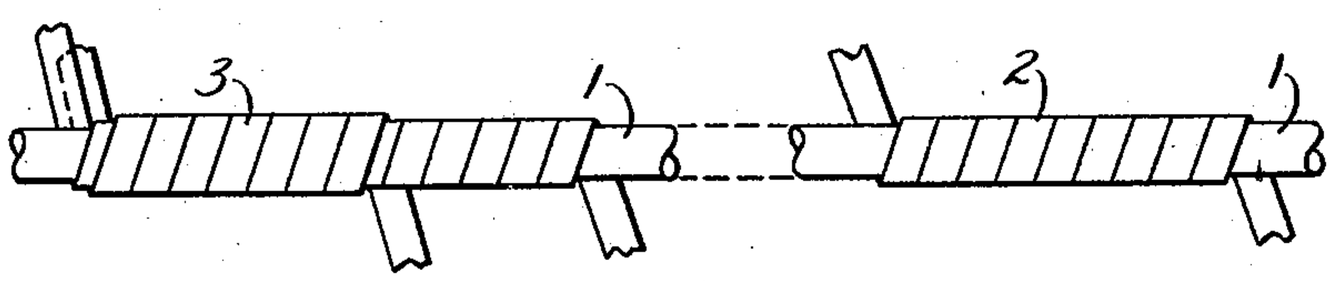

45% Ni
30% Fe
25% Co
$\mu_o = 400$
$\frac{du}{dH} < a$

45% Ni
30% Fe
25% Co
$\mu_o = 800$
$\frac{du}{dH} = a$

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UNITED STATES PATENT OFFICE

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LOADING OF CONDUCTORS

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This invention relates to long loaded submarine cables. This application is a continuation in part of application, Ser. No. 696,981, filed March 5, 1924.

An object of the invention is to reduce impedance irregularities in a loaded cable.

Another object of the invention is to reduce signal distortion which results from variations in the impedance of a signaling conductor with variations in the current flowing therethrough.

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, large variations in the current and hence in the magnetizing force in the terminal sections may cause the inductance and resistance due to the loading material to vary between wide limits. As a result of these variations in the inductance and resistance of the conductor, the attenuation constant of the cable will increase as the current into the cable is increased until a point is reached where further increase in sending current produces a negligible increase in current received at the distant end of the cable. Also 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.

In accordance with this invention the same magnetic composition, within the limits of manufacturing variations, may be employed as loading material upon the entire conductor or upon two or more sections having different degrees of variability of inductance with current. The advantages of having material of more uniform inductance on certain cable sections is therefore attained without the necessity of selecting different material to secure the desired result. This is accomplished by heat treating certain sections in such a manner as to cause the loading material thereon to have more constant permeability and lower hysteresis losses, over a wide range of magnetizing forces, than that on the central sections. When heat treated to have more constant permeability the loading material may have lower initial permeability, which would reduce the effective inductance of the conductor; this, however, may be compensated by increasing the thickness of the loading on the terminal sections.

A cable conductor in accordance with the invention is illustrated in the attached drawing.

By way of describing concrete examples of practicing the present invention we shall first consider its application to a continuously loaded telegraph cable. In accordance with the invention the central portions of said cable may be loaded with a magnetic material containing about 78% nickel and the balance chiefly iron, with or without a material for increasing the resistivity of the loading material, in which a permeability of the order of 4,000 for magnetizing forces of about 0.001 gauss has been developed by suitable heat treatments such as are described in U. S. Patents 1,586,883 and 1,586,884, both granted June 1, 1926 to G. W. Elmen. The terminal sections, extending over a length of about 100 miles from both cable ends, in accordance with the invention, are loaded with the same magnetic material in which, however, a permeability of about 2,000 to 4,000 has been developed by giving it a heat treatment at a lower temperature.

For example the conductor with the loading tapes wrapped thereabout may be drawn in the direction of its longitudinal axis through an annealing furnace such as described in the patents referred to above or such as described in U. S. Patent 1,586,887, granted June 1, 1926, to G. W. Elmen, the annealing temperature being only about 600° C. In this manner there will be developed in the loading material a lower but more constant permeability.

Consider now the application of the present invention to a continuously loaded tele-

phone cable. In accordance with one embodiment of this invention the central sections of the cable may be loaded with a magnetic material comprising about 45% nickel, 30% iron and 25% cobalt, with or without a fourth substance such as 1 to 10% of molybdenum or chromium, replacing equal amounts of iron, for increasing the resistivity. When this particular composition without the fourth element is heat treated at about 1100° C. for one hour and cooled in such a fashion that it reaches room temperature after about seven hours, it has an initial permeability of about 900, and a relatively low constancy of permeability. However, by giving it a different heat treatment, such as for instance reheating it after the first exposure of about 1100° C. at about 400° C. for several hours, although the initial permeability may be reduced from about 900 to 400, its constancy of permeability is much improved. Whereas the percentage variation of permeability for a change of magnetic induction in passing from a very small value to 100 gauss was 5% in the first case it was only 1% in the second case. Furthermore, the hysteresis loss of the sample thus treated was almost negligible for a flux density up to about 370 gauss. In accordance with the principles of the invention the constancy of permeability possessed by this material, together with its low hysteresis loss, reduce the variations of inductance and effective impedance of the terminal sections of the loaded conductor.

In the accompanying drawings is illustrated a specific embodiment of this invention in which all the sections of a continuously loaded submarine signaling conductor 1 are loaded to have the same inductance. For example, the central sections may be loaded with one layer 2 of the above-mentioned composition (45% nickel, 30% iron, 25% cobalt), heat treated to have an initial permeability of 800; this permeability can be developed by using a cooling rate a little faster than the first one above specified. The terminal sections, however, are loaded with two equally thick layers 3 of the same composition, but heat treated, as specified above, to have an initial permeability of 400.

However, it is not essential that the sections have the same inductance but the heat treatment may be varied so as to obtain different constancies of permeability on different sections while the thickness of the loading may not be correlated to give the same inductance on all the sections.

The constancy of permeability may be varied in more than two steps along the loaded conductor, and the thickness of loading and the permeability do not have to have inverse integral ratios. Any desired permeability and any desired total thickness of loading divided into any desired number of equal or unequal layers may be employed.

The invention is not limited to the particular combinations of magnetic properties and heat treatments or embodiments disclosed herein; it is understood that various other combinations may be employed by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. The method of improving the transmission characteristics of a long signaling conductor loaded with a material of substantially identical composition throughout, which method comprises heat treating the terminal sections of said conductor to have greater constancy of permeability than the center sections.

2. Method in accordance with claim 1, characterized in this that in loading the terminal sections a greater thickness of loading material is applied than in loading the center sections.

3. A long submarine signaling conductor loaded with magnetic material of substantially identical composition throughout its length, in which the loading material on a terminal section has a materially greater constancy of permeability than the loading on a center section for a given induction.

4. Conductor as defined in claim 3, characterized in this that the loading material on a terminal section has a greater thickness than the loading on a center section.

5. A long signaling conductor having sections loaded with magnetic material of substantially uniform composition, said sections having substantially equal effective inductance for small signaling currents but having a materially different rate of variation of inductance with variation of current over the range of current values traversing the sending terminal of said conductor.

In witness whereof, I hereunto subscribe my name this 3rd day of November, 1928.

JOHN J. GILBERT.