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LOADING SYSTEM FOR LONG SUBMARINE CABLES

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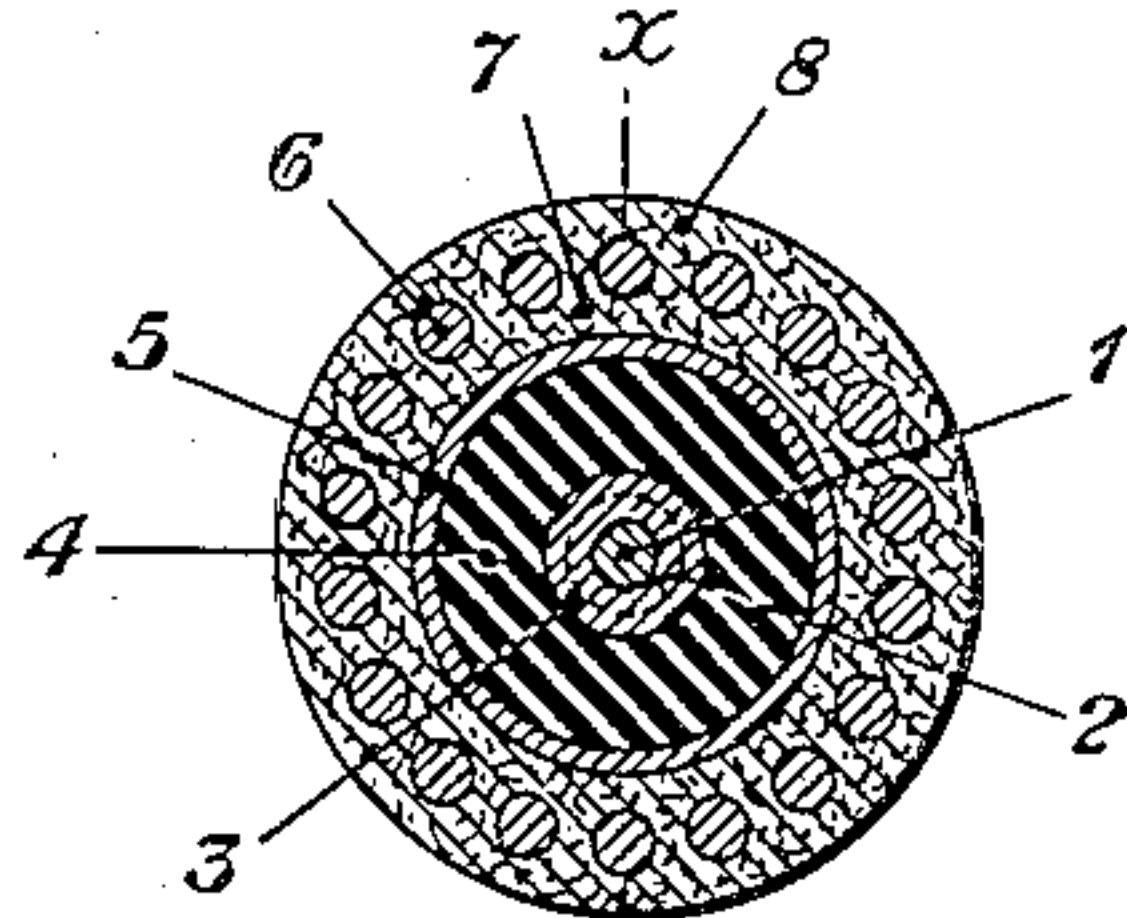


Fig. 1

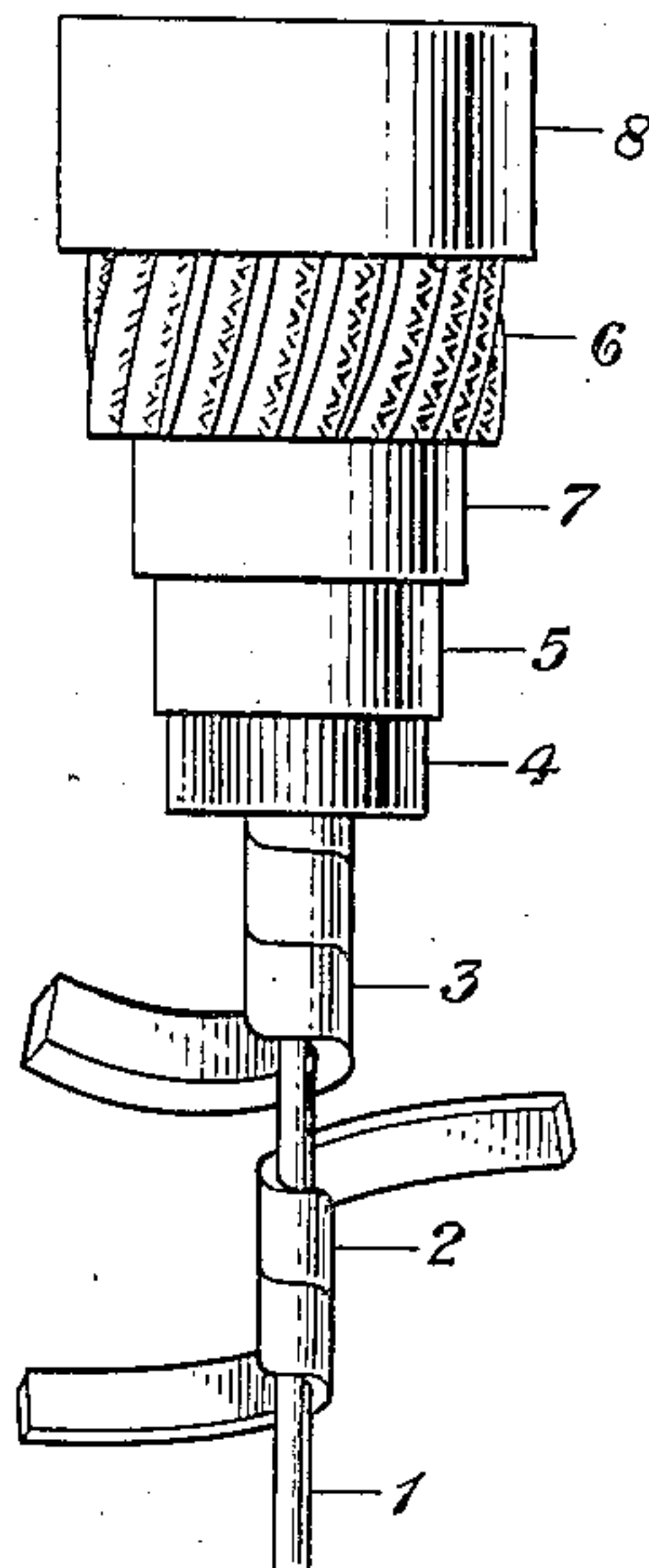


Fig. 2

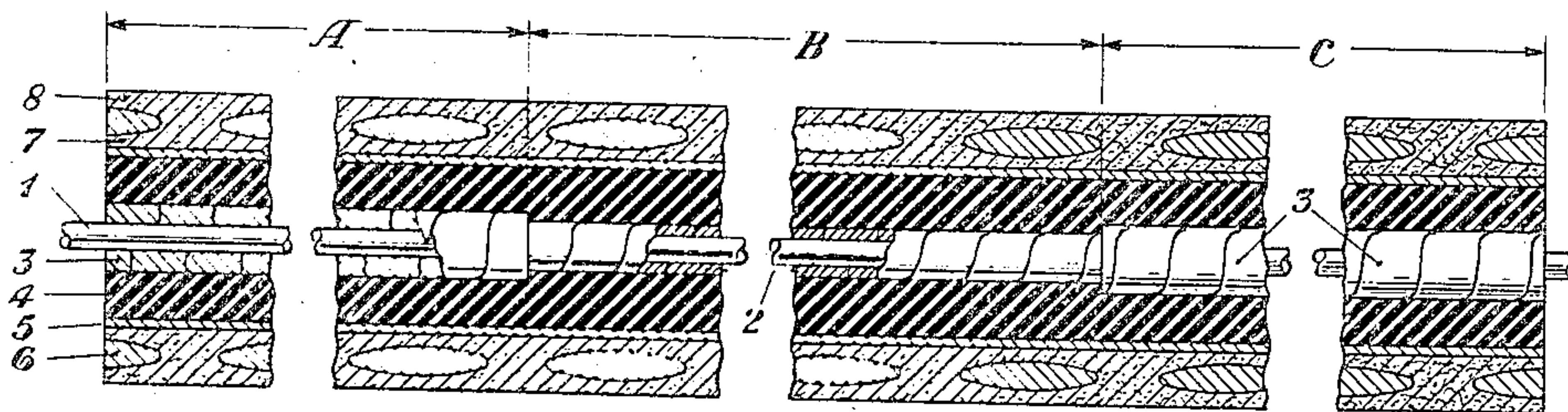


Fig. 3

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LOADING SYSTEM FOR LONG SUBMARINE CABLES

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This invention relates to the art of communication over wires, and more particularly to an improved method for continuously loading a long submarine ocean cable designed for communication purposes. According to this invention, the terminal portion of the cable is loaded to have the same inductance per unit length as the central portion, using a greater amount of lower permeability material in order to reduce distortion effects and impedance irregularities which otherwise tend to result from the use of high energy levels at the sending end of the cable.

In the drawing, Figure 1 shows a cross-section of a typical deep sea submarine cable. Fig. 2 shows a section of cable of the type shown in Fig. 1. In Fig. 2 portions of the cable are cut away to show the various layers of material involved in building up the cable from the central conductor to its outer covering. Fig. 3 discloses a cable sectioned along the line $x-x$ of Fig. 1. The cable of Fig. 3 discloses the improved loading system of the present invention.

Owing to the impossibility of amplifying signaling currents transmitted over a long submarine ocean cable at intermediate points along such cable, it is desirable to employ a high energy level at the sending end to insure a level at the receiving end sufficiently great that the signals will not be rendered unintelligible in the presence of interfering currents introduced into the cable circuit from extraneous sources. If such a cable is continuously loaded at the ends in the same manner as is most economical for the principal portion, the high energy level used at the sending end may cause objectionable magnetic effects in the initial portion of the cable. These effects would be detrimental to signal transmission in several ways, namely, (1) by causing an increased attenuation in the cable, (2) by increasing the signal distortion, and (3) by the introduction of impedance irregularities. These effects will be discussed in the order named.

The principal cause for increased attenuation is due to hysteresis effects in the magnetic material. The hysteresis effects increase with the maximum flux density in the mag-

netic material, and the losses due to them become excessive for large values of signaling current. For extremely high sending levels, the increased attenuation due to hysteresis effects may become so great as to very nearly offset an increase in amplification of energy at the sending end, with the result that the receiving level will remain approximately constant thereafter, irrespective of an increase in the sending level. Another source of increased attenuation in the cable is that due to the reflection losses caused by variations in inductance resulting from the magnetic effects of large currents in the initial portions of the cable.

Large magnetic saturation effects cause signal distortion and other objectionable effects to be introduced in several ways. As a result of non-linearity between magnetizing current and resultant flux, which becomes greater for the larger field intensities, extraneous voltages are generated and as a result, frequencies are transmitted to the receiving apparatus which were not present in the original signal current, and also the original signal current may be altered in its relative magnitude. This effect is generally termed asymmetric distortion. Besides resulting in asymmetric distortion the large non-linearity effect in the magnetic material would result in considerable intermodulation of transmitted currents of different frequencies which would be detrimental to the simultaneous operation of a multiple of transmission channels over a loaded cable circuit. Distortion may result from the variation in inductance per unit length throughout the cable caused in the manner discussed above. Large magnetic effects would also increase the difficulty of equalizing the cable characteristics from the attenuation and velocity standpoints.

The variation in impedance in the initial portion of the cable, in addition to causing reflection losses, would tend to reduce the balance which could be maintained between the cable and balancing networks which might be used in the terminal apparatus. Such reduction in balance would decrease the efficiency with which the cable could be operated if the use of amplifiers were necessary.

In order to reduce the above detrimental effects to a satisfactory degree the terminal portions of the cable may be loaded in a different manner from that employed for the intermediate portion of the cable. It is proposed to do this and at the same time obtain the same inductance per unit length for the terminal portions as for the intermediate portion of the cable by the use of a greater amount of loading material of such permeability as to give the same loading effect as is obtained by the loading material of the intermediate portion. The application of a different amount of loading material at the terminals might, of course, involve a graduation of several steps. In each portion, however, the relation between the permeability and the amount of loading material used would be adjusted so as to obtain the same cable inductance throughout.

Referring now to the drawing, the same elements are numbered alike in Figs. 1, 2 and 3. In Fig. 1, which shows in cross-section a typical submarine cable embodying the improvements of the present invention, the central conductor, usually of copper, is indicated at 1. The loading material for the intermediate portion of the cable is indicated within the dashed circle 2. The loading material for the terminal portions of the cable is shown by the magnetic material 3. Surrounding the magnetic material is a layer of insulating material 4 which usually consists of gutta-percha. A return conductor 5, comprising a thin copper sheath, uniformly surrounds the insulating material 4. In order to protect the copper sheath 5 a layer of jute 7 is served about the outer coating of the sheath 5. In order to protect the cable from injury due to the rubbing action of the waves and the like a plurality of equally spaced steel armor wires 6 are served helically about the cable throughout its entire length; and the steel armor wires 6 are covered by another layer of jute 8, with the net result that the armor wires become embedded in the jute, as indicated in Fig. 1.

Referring now to Fig. 2 which shows a section of cable with various portions cut away to show the different layers involved, the central conductor, usually of copper, is indicated again at 1. The loading material used for the principal and intermediate portion of the cable is shown at 2. This loading material as indicated in Fig. 2 consists of a ribbon of magnetic material wound helically about the central conductor 1 so that it forms a continuous coating for the same. Any type of magnetic material might be adapted in a certain instance, but it is probable that for any cable constructed at the present date permalloy would be used. In Fig. 2 a single layer of magnetic material 2 is shown, but it is to be understood, of course, that the loading may be accomplished by winding a plurality

of thin ribbons over the conductor in such manner that a first ribbon would be wound about the conductor and a second ribbon would be wound about the first ribbon, and so on. This latter procedure would have the advantage of reducing the hysteresis and eddy current losses in the magnetic material.

The magnetic material for the terminal portions of the cable is indicated at 3, and again is shown to consist of a ribbon of magnetic material wound helically about the conductor. Here again, a plurality of layers of magnetic material might be used, each layer comprising a thin ribbon of magnetic material wound as indicated. The gutta-percha insulating material surrounding the loading material is indicated at 4, the copper sheath at 5, the first serving of jute at 7, the steel armor wires at 6 and the last serving of jute at 8.

Referring now to Fig. 3, an entire cable is shown loaded in accordance with the ideas set forth in the present invention. The cable is divided into three lengths A, B and C. In general, length A would equal length C. The numbering of the various elements in Fig. 3 is the same as for Figs. 1 and 2. In Fig. 3 it will be observed that the principal and centrally located portion of the cable B is loaded to a given inductance per unit length by uniformly distributing along the central conductor 1 a given amount per unit length of magnetic material 2 of a predetermined permeability. The terminal portions of the cable A and C are loaded to the same inductance per unit length as the central portion by uniformly distributing along the same about the central conductor a greater amount per unit length of magnetic material 3, having a lower permeability than the material 2 used for the central portion of the cable.

With a cable design such as suggested above, insuring approximately the same inductance per unit length for the terminal and for the intermediate portions of the cable, the detrimental effects due to using a high energy level at the sending end of the cable can be reduced without introducing the impedance irregularities. The use of an increased amount of loading material in the terminal portions of the cable will result in increasing slightly the external cable diameter. The effect of the increased size of the conductor on the electrostatic capacity of the circuit can be offset by a compensating increase in the thickness of the insulation. As in general the thickness of the loading material is small compared to the diameter of the conductor, the diameters of the loaded conductors and the amount of insulating material will, however, be approximately the same throughout the cable.

What is claimed is:

1. A submarine cable for communication purposes, the intermediate portion of which

is continuously loaded to a given inductance per unit length with a magnetic material of predetermined permeability and the terminal portions of which are continuously loaded to the same inductance per unit length with a magnetic material of sufficiently lower permeability than that first mentioned to maintain the energy losses and frequency distortion due to the cable within predetermined limits based on the larger current flowing in the initial portion as compared to that flowing in the remainder of the cable.

2. A submarine cable for communication purposes, the intermediate portion of which is continuously loaded to a given inductance per unit length utilizing therefor a magnetic material of predetermined permeability, and the terminal portions of which are continuously loaded to the same inductance per unit length utilizing therefor a magnetic material of permeability lower than that first mentioned.

3. A submarine cable for communication purposes, comprising a central conductor, loading material uniformly surrounding said conductor, consisting, for the intermediate portion of said cable, of a given amount per unit length of magnetic material of a predetermined permeability, said magnetic material being sufficient in amount to load said portion of the cable continuously to a given inductance per unit length, said loading material for the terminal portions of said cable consisting of a sufficiently greater amount per unit length of magnetic material of permeability lower than that first mentioned to load the terminal portions continuously to the same inductance per unit length as that of the intermediate portion and also to reduce the energy losses and frequency distortion within said cable to a desired value based on the larger current flowing in the initial portion as compared to that in the remainder of the cable, a layer of insulating material uniformly surrounding said loading material, a sheath of conductive material placed about said insulating material, protective layers of jute served about said conductive sheath, a plurality of steel armor wires served helically about said jute, and a final layer of jute served about said armor wires.

4. In the art of electrical communication over wires, the method of reducing attenuation and distortion effects in a long submarine cable which consists in increasing the inductance of the terminal portions of the cable to a given value per unit length by uniformly distributing along the same magnetic material of a predetermined permeability, and increasing the inductance of the principal and intermediate portion of the cable to the same inductance per unit length by uniformly distributing along the same, magnetic material of a permeability greater than that used for the terminal portions.

5. In the art of electrical communication over wires, the method of reducing attenuation and distortion effects in a long submarine cable which consists in increasing the inductance of the terminal portions of the cable to a given value per unit length by uniformly distributing along the same magnetic material of a predetermined permeability, and increasing the inductance of the principal and intermediate portion of the cable to the same inductance per unit length by uniformly distributing along the same, magnetic material of a permeability greater than that used for the terminal portions, the permeabilities of the two materials being so selected with reference to the increased signaling current flowing in the terminal cable portions compared to that flowing in the intermediate portion that the distortion and attenuation effects are maintained within predetermined limits.

6. A long inductively loaded signaling conductor having a great overall attenuation in which the quantity per unit length and the permeability of the loading material are different on different sections but such that the effective inductance per unit length of conductor is the same for all sections.

7. A long inductively loaded signaling conductor having a great overall attenuation in which the thickness and permeability of the loading material are different in different sections but such that the effective inductances of all sections are substantially the same.

8. A long signaling conductor having great overall attenuation and substantially uniform diameter throughout, surrounded by magnetic loading material, the magnetic characteristics of which vary with the density of the magnetic flux induced therein, characterized in this, that the quantity of magnetic material per unit length of conductor is greater, but its permeability and variation of permeability with magnetizing force are less on a section adjacent a terminal of the conductor than on a section more remote from the terminal, and further characterized in that the product of the quantity of loading material per unit length of conductor and the permeability of the loading material in each section of the conductor is the same as for every other section.

9. A submarine cable conductor surrounded by one or more layers of loading material characterized in that at least two of the three parameters of the loading, namely the permeability, the number of layers and the thickness per layer are different in different portions of the conductor but in that the product of the number of layers, the thickness per layer and the permeability is approximately constant for all portions of the conductor.

In testimony whereof, I have signed my name to this specification this 12th day of April, 1928.

BENJAMIN F. LEWIS.