

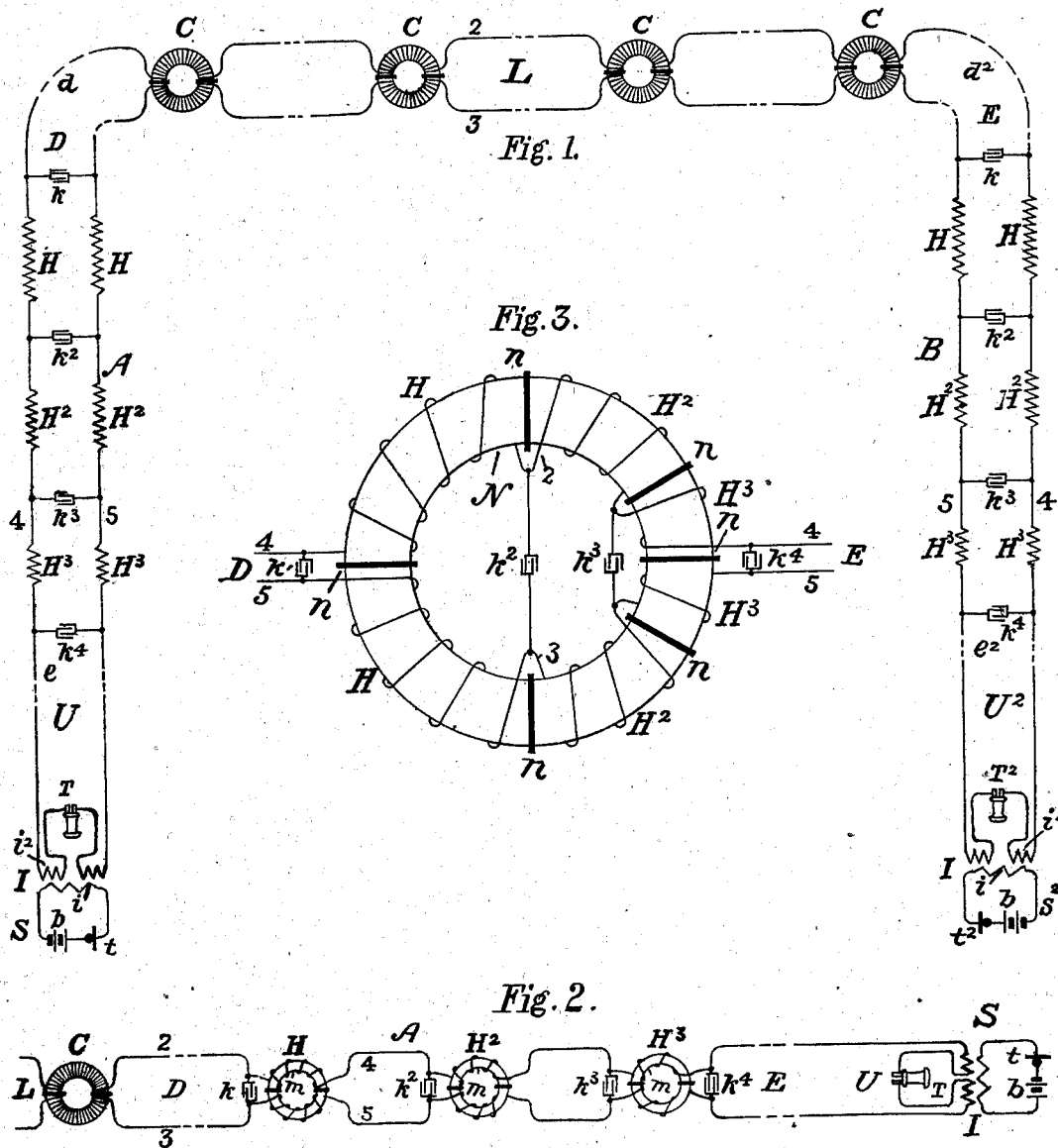
H. S. WARREN & G. A. CAMPBELL.

LOADED ELECTRIC CIRCUIT.

APPLICATION FILED MAR. 19, 1902.

NO MODEL.

2 SHEETS—SHEET 1.



WITNESSES:

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Wm. Willis Price

INVENTORS

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By their Attorney Thomas & Lockwood

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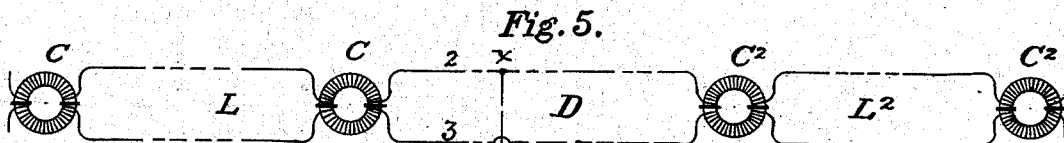
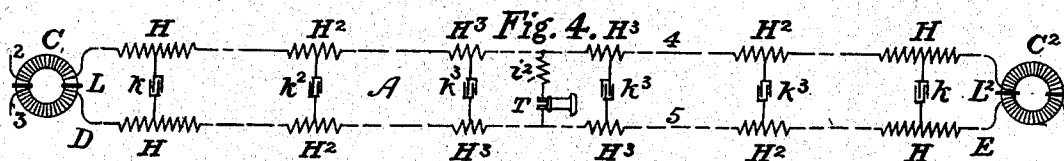
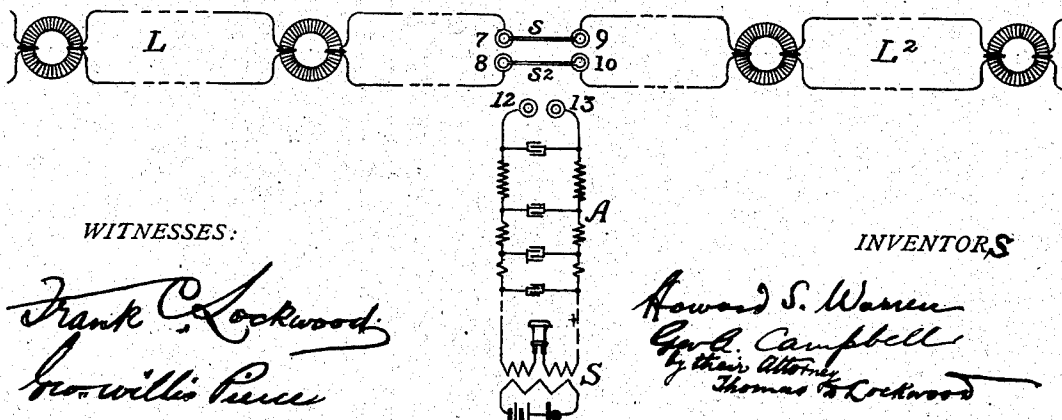


Fig. 6.



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UNITED STATES PATENT OFFICE.

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LOADED ELECTRIC CIRCUIT.

SPECIFICATION forming part of Letters Patent No. 729,709, dated June 2, 1903.

Application filed March 19, 1902. Serial No. 98,983. (No model.)

To all whom it may concern:

Be it known that we, HOWARD S. WARREN, residing at Everett, and GEORGE A. CAMPBELL, residing at Newton, in the county of Middlesex and State of Massachusetts, have invented certain Improvements in Loaded Electric Circuits, of which the following is a specification.

This invention concerns electric circuits loaded with inductance-coils for the prevention or avoidance of adverse capacity effects, and more particularly relates to the diminution or reduction of the effects known as "reflection," which varying currents experience when transmitted in heterogeneous circuits.

It is now well known that when an electric wave or a train of electric waves traveling along a heterogeneous circuit passes from one portion of the circuit having a well-defined character to another of diverse characterization a reflection of the waves occurs at the point of heterogeneity and the reflected waves tend to travel back to their place of origin instead of proceeding to the farther end of the circuit. Experience has demonstrated that when a comparatively short portion of unloaded extension or continuation circuit conductor is attached to the end of a long loaded circuit or line a decided loss of efficiency in transmission over the said loaded line occurs. In the operation, for instance, of telephone-circuits the telephone instruments of a user or of a subscriber's station are not usually united directly to a loaded long-distance circuit conductor, the connection with such loaded-circuit conductor being generally established through the unloaded conductors of the subscriber's line-circuit and frequently also through the conductors of a trunk-line or other intervening circuit connection. Under such conditions a depreciation of transmission efficiency is clearly manifested and is due to the reflection losses accruing from the abrupt transition between the high impedance of the loaded line and the low impedance of the unloaded portion of the circuit extending from the loaded line to the said station instruments.

The object of this invention is to prevent these reflection losses by providing effectual and easily-applied means for the avoidance of such abrupt changes in the character of the circuit.

Accordingly the invention consists in a localized and artificial impedance taper or tapering system adapted to be interposed between the regularly-loaded main-line conductor and any such extension or continuation circuit conductor as may at or through a terminal or way station extend to the operating instruments of a substation, or, to state the matter otherwise, between such loaded line portion and the station instruments regardless of the presence, absence, or length of any such continuation-conductor and comprising a series of gradually-varying impedance elements or sections diminishing or tapering by gradations or successive and progressive steps from the impedance of the first element, which may approximate that of the loaded portion of the line, to that of the last, which may be that of the said continuation-conductor.

It consists also in such a localized taper constituted of a plurality of self-induction coils connected in series in a circuit-conductor adapted to be placed in a combined circuit between the regularly-loaded portion and the station or continuation circuit and a group of associated condensers in parallel branches of said circuit-conductor, the inductances of said coils and the capacities of said condensers being so arranged and relatively proportioned as to provide a succession of sections or elements of gradually or progressively changing impedance, the different values of said impedance-sections of course increasing as they progress toward the loaded portion of the line and diminishing as respects transmission from such loaded portion of the circuit and toward the unloaded portion thereof. The condenser branches extend from points between the self-induction coils or, if desired, from the center of the coils to the return-conductor of the circuit, and the coils themselves may be wound over separate iron

cores or over different sections of the same core.

The invention consists, further, in combining the localized artificial load or impedance tapering apparatus or system with a loaded electric circuit in such manner that when the said apparatus is placed between said loaded circuit and an unloaded continuation thereof there shall be a graded fall or a fall in progressive relatively short steps from the impedance of the loaded circuit to that of its unloaded continuation, and this whether the said unloaded continuation be located at a terminal station or at a way-station.

In the drawings which accompany and illustrate this specification, Figure 1 is a diagram conventionally representing a long loaded circuit connecting at each end with an unloaded portion of a circuit and telephone instruments through our localized and artificial tapering apparatus. Fig. 2 represents one end of such a circuit connected with terminal telephone instruments through such a concentrated terminal taper wherein the inducto-resistance elements are wound on separate and independent cores. Fig. 3 represents an example of a localized tapering apparatus in which the inductance-coils of the graduated impedance are wound over separate sections of the same iron core, and Figs. 4, 5, and 6 are diagrams representing different plans for utilizing the localized tapering appliances or apparatus at way-stations.

In Fig. 1, L is the main line or portion of the circuit having main conductors 2 and 3 and loading inductance-coils C, S S² the instruments of stations (usually substations) connected therewith at the two ends thereof, and U U² intermediate unloaded portions of the circuit as completed between the two sets of telephone or other instruments, such portions consisting, as the case may be, of a substation-circuit or of a station-circuit and an intervening trunk-line. The station instruments may, as shown, comprise the receivers T T², the transmitters t t², the batteries b for said transmitters, and the induction-coils I, having each a primary winding i in a local circuit with the transmitter electrodes and battery, and a secondary winding i² in the main line, together with the receiver. A and B at the two ends, respectively, of the loaded line are the localized load-tapering appliances placed at suitable stations at the ends of said line and interposed between the regularly-loaded permanent portion L of the circuit and the unloaded extension or continuation portions thereof, U U², leading ultimately to the station instruments S S². Being thus placed, they are properly described as being between the loaded portion of the circuit and the said instruments S S². The broken lines at d d² indicate that at these points the loaded long-distance lines terminate, and the broken lines e e² afford a similar indication as regards the circuit continuations U U², leading

to the station instruments S S². The said localized load-tapering apparatus may otherwise be described as an artificial loaded and graduated reflection-reducing extension of the loaded portion of the circuit and comprises the circuit-conductors 4 5, which end at D and E, respectively, the diverse inductance and resistance coils H H² H³, &c., united serially by said conductors with one another, (and with the loaded line L and instruments S S²), and the condensers k k² k³ k⁴, &c., placed, as shown, in parallel branches or bridges between the two main circuit-conductors, or, as a matter of course, in the case of a grounded main circuit extending from the main conductor to its earth return. It will be thus seen that the localized taper apparatus of this invention is practically an artificial intermediary connection forming a portion of the completed circuit, which being located at a suitable station between the otherwise immediately adjacent loaded and unloaded portions of the said circuit may be always concentrated and always under control and supervision and which is formed of and provided with successive graduated impedance sections or elements stepping gradually down or tapering from the section nearest the loaded line, the impedance value of which approximates that of a like section of loaded line to the section nearest the unloaded portion of the circuit or instrument continuation, which section has an impedance value in like manner closely approaching that of such terminal or continuation. The drawings show three such graded impedance-sections; but it is of course to be understood that the invention is not limited or restricted to any particular number thereof and that the number and value of the said steps or sections may be varied within a wide range, depending largely upon the peculiar conditions of any particular case. Assuming, for example, that the impedance of a given length (corresponding to a section of the taper) of the loaded main-line portion of the circuit is three thousand ohms and that the tapering apparatus or system is to comprise, say, six sections, the impedance values progressively diminishing toward the unloaded portion of the circuit will then preferably be two thousand four hundred, eighteen hundred and fifty, fourteen hundred and twenty-five, eleven hundred, eight hundred and fifty, and six hundred and fifty ohms, respectively, thus following a substantially geometrical ratio between successive sections. It is to be observed that in such a tapering apparatus it is the property or characteristic of impedance which requires to be gradually changed or varied, and that consequently it is not essential that the inductance of the several self-induction coils shall regularly diminish in one direction, or, what is the same thing, increase in the other, or that there shall be any corresponding regular change in the capacity value of the condensers, care being

taken, however, to maintain the balanced condition of the circuit by providing that the inductance and resistance of each coil on one side of said circuit shall be the same as or closely similar to that of the corresponding coil on the other side. The inductances and capacities of the said coils and condensers, respectively, are, however, to be so relatively arranged and proportioned that the impedance of successive sections will be progressively modified, diminishing or falling regularly from maximum impedance in one end section—viz., that which is adapted to connect with the loaded-circuit conductor—to minimum impedance in the other end section, where connection may be made with the unloaded continuation-circuit conductor.

Fig. 2 illustrates a construction of the tapering apparatus wherein the inductance-coils H H^2 H^3 of the several impedance-sections of gradually-changing value are each provided with a separate iron core m , two similar windings being wound over each core for inclusion in the two sides 2 3 of the circuit, respectively. C is the final loading-coil of the regularly-loaded long-distance circuit L , and A the localized tapering apparatus as a whole, having its first impedance-section D united to the said loaded conductors and its last section E connected with the unloaded extension-circuit U . The gradually-lowering values of the several impedance-sections as their distance from the loaded portion increases, which in Fig. 1 are indicated by different lengths, are here indicated by different numbers of turns. Thus the two windings of coil H are each indicated by five turns, those of H^2 by four turns, and those of H^3 by three turns. The number of turns in each case thus shown has, however, no significance, except as such an indication that the impedance of each following section in the direction of the instruments S is less than that of its predecessor. The condensers k , k^2 , k^3 , and k^4 are here shown as being bridged between the two circuit-conductors, on which are strung the inductance-coils in such manner that one of them is bridged on both sides of each coil.

As shown in Fig. 3, the several inductance-coils of the artificial taper apparatus may all be wound over a single iron core to form a highly-condensed structure. In this appliance N is an iron ring core of well-known character divided on each semicircular side into three subdivisions of diverse size by partitions n . On each side of the said core the coils H H^2 H^3 occupy the largest, medium, and smallest subdivisions, respectively, and are strung along their respective conductors 4 and 5, which unite them serially, in such manner that from the end D of the appliance the impedances of the several sections regularly and gradually diminish toward the end E . The condenser k is bridged between the

said conductors at a point before the first induction-coil is reached, condensers k^2 and k^3 at successive points between the coils H H^2 and H^2 H^3 , respectively, and condenser k^4 at a point posterior to the final coils H^3 . In practice, however, the partitions n may be disregarded or, in fact, dispensed with, and the windings of each section may and preferably will be distributed over a considerable portion of the core and over one another, care being taken to bring out loops between the sections for the attachment of the condenser-terminals. By this arrangement leakage losses which are liable to occur near the partitions where it is difficult to uniformly distribute the windings are avoided. With a taper appliance of such form any practical number of subdivisions or impedance-sections may be formed upon the same core, a fact which promises distinct advantage, since the working current losses where the total required inductance is wound over a single core are substantially less than they would be were the sectional inductance-coils wound on separate cores.

In Figs. 4, 5, and 6, which diagrammatically represent plans for utilizing the tapering appliance or apparatus at a way-station, Fig. 4 illustrates a double-graduated or impedance tapering apparatus introduced into the main circuit between two regularly-loaded portions L L^2 thereof, C indicating the last loading-coil of division L , and C^2 the final loading-coil of division L^2 . The impedance taper A has its highest impedance-sections, comprising the inductance-coils H and capacities k , at the ends D E , and from both of the said ends the successive sections H^2 k^2 , H^3 k^3 , &c., diminish, the lowest impedance being at the center, where the station instruments—in this instance a telephone-receiver T and a high-resistance secondary winding i^2 of a transmitter induction-coil—are bridged between the conductors 4 5 of the localized taper apparatus, which conductors are joined at their ends D E with the corresponding conductors 2 3 of the loaded portions L L^2 of the circuit. The condensers in this case are shown as being bridged between the two circuit-conductors 4 5 of the system at points within the inductance-coil windings, which in the said two conductors correspond, the said points being at or near the centers of the said windings. Such an alternative arrangement may in any particular case be adopted, if preferred. Fig. 5 represents a slightly-different plan, wherein the localized impedance or taper appliance forms a series connection at one end E with the unloaded continuation circuit or instrument loop U , extending therefrom to the station instruments S , and a bridge connection at points x y between any two of the regular loading-coils C C^2 with the main line or regularly-loaded portion of the circuit. In this case not merely the station

instruments but also the entire system of tapering impedance is bridged and the way-station communicates in either direction with equal facility. In Fig. 6 the two divisions L
 5 L² of the loaded line portion are shown as being normally connected through by switch-board devices, (represented as switch-cord conductors $s s^2$), which have their terminal
 10 plugs placed in switch-sockets 7 9 and 8 10, respectively. Obviously the plugs at either end of the said cords may be withdrawn from their sockets and inserted instead in the switch-sockets 12 13 of the impedance tapering apparatus. By this plan when the station
 15 instruments S are connected through the taper to the loaded division L or L² on either hand the other of said divisions will be for the time disconnected.

In the practice of this invention the total
 20 reflection loss in the entire localized tapering apparatus or system, or, in other words, the sum of the several reflection losses of the several progressive steps, is small in comparison with the loss occurring when no such tapering
 25 system or when no competent substitute, such as a terminal transformer, is provided and when therefore the transition from the loaded to the unloaded portions of the circuit, or vice versa, is precipitous.

30 It has been experimentally ascertained that the practical advantage attending the employment of the taper is perceptibly greater than that obtained from the use of the best terminal transformer thus far designed.
 35 Since the employment of such terminal transformers has to some extent been found to hamper the simultaneous use of telephone-circuits for other purposes (such as telegraphy) by reason of the solution of conductive
 40 continuity introduced by them, an added (albeit incidental) advantage attending the present invention in association with loaded lines is that by its use the said transformers may be altogether dispensed with. Furthermore, it
 45 has also been found that such attenuation of the working current as occurs in and by reason of the impedance tapering apparatus itself is so slight as to be practically negligible.

Having thus described our invention, we
 50 claim—

1. A localized or station taper for loaded electric circuits, comprising a series of gradually-varying impedance elements composed of inductance-coils and condensers adapted
 55 to be interposed in the circuit between the loaded line portion thereof and the station instruments, and constituting an artificial loaded and graduated reflection reducing extension of said line-section, the magnitude or
 60 value of the said impedance elements respectively, being greatest toward the said loaded line-section, and diminishing by successive steps toward the said instruments, substantially as described.

65 2. A localized and artificial tapering appa-

ratus or system for a loaded electric circuit adapted to be interposed in said circuit between the regularly-loaded portion thereof and an unloaded continuation or instrument extension, and consisting as described, of a
 70 series of impedance sections or elements constituted each of resistance, inductance, and capacity so combined in each section, that the nearest section to the said loaded portion of the circuit shall have a high impedance
 75 approximating that of a corresponding section of loaded line, and that the following sections shall have impedances each smaller than its predecessor and diminishing in substantially geometrically progressive steps to
 80 the section nearest to the said unloaded circuit continuation, substantially as described.

3. The combination in a concentrated artificial taper extension for a loaded electric circuit, of a plurality of self-induction coils, a
 85 circuit-conductor electrically uniting the said coils in series and adapted to be interposed between the regularly-loaded line portion of such loaded electric circuit and a station or
 90 continuation circuit, and a group of associated condensers in parallel branches of said circuit-conductor, the inductances and capacities of said coils and condensers respectively being so relatively arranged and proportioned as to constitute a succession of
 95 balanced sections or elements of gradually or progressively changing impedance, substantially as described.

4. A graduated impedance appliance forming an artificial and localized taper for loaded
 100 electric circuits, and comprising a succession of balanced self-inductive windings wound over a single iron core and connected in series to constitute a through-conductor, and a
 105 group of associated condensers in parallel branches of said conductor extending from points in or between said windings, the said windings and condensers being so arranged and proportioned as to constitute a series of
 110 separate successive sections varying gradually or by regular or progressive steps from maximum impedance in one end section, to minimum impedance in the other, substantially as described.

5. The combination with an electric circuit
 115 loaded with inductance-coils connected in the main conductor or conductors in series and at short intervals, of a localized and concentrated artificial load taper placed at a station of said circuit between the regularly-loaded
 120 or main portion thereof and a continuation circuit or instrument extension, and comprising a series of sections or divisions gradually or progressively diminishing or tapering in impedance from the impedance value of said
 125 regularly-loaded portion to that of said continuation or extension, substantially as and for the purposes set forth.

6. The combination with an electric circuit loaded with inductance-coils connected in the
 130

main conductor or conductors in series and at short intervals, of a localized load tapering system at a way-station of said circuit adapted to be connected between the regularly-loaded or main portions of such circuit leading in both directions or either of them and a continuation circuit or instrument extension, and comprising a series of impedance-sections gradually or progressively diminishing in value from both directions of said regularly-loaded circuit portions toward the said continuation circuit or extension, substantially as described.

In testimony whereof I have signed my name to this specification, in the presence of

two subscribing witnesses, this 4th day of March, 1902.

HOWARD S. WARREN.

Witnesses:

GEO. WILLIS PIERCE,
JOSEPH A. GATELY.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 14th day of March, 1902.

GEORGE A. CAMPBELL.

Witnesses:

GEO. WILLIS PIERCE,
JOSEPH A. GATELY.