E. GRISSINGER.

TELEPHONE REPEATER.

APPLICATION FILED FEB. 24, 1902.

1,198,212.

Patented Sept. 12, 1916.

3 SHEETS—SHEET 1.

Fig. 1.

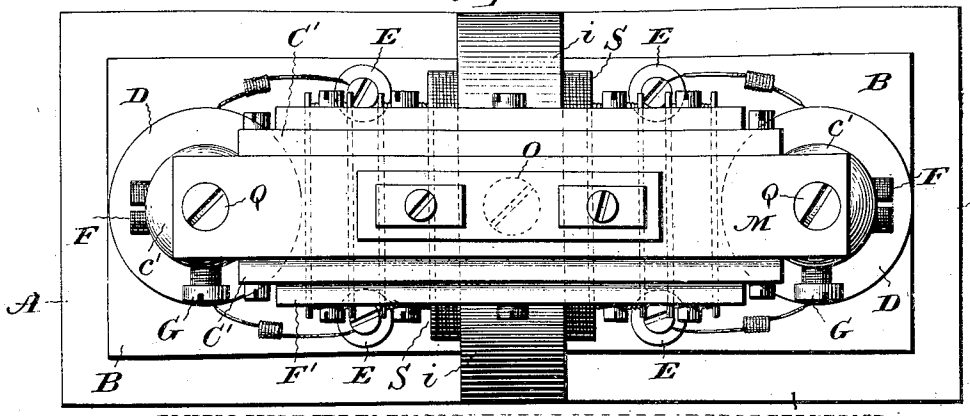
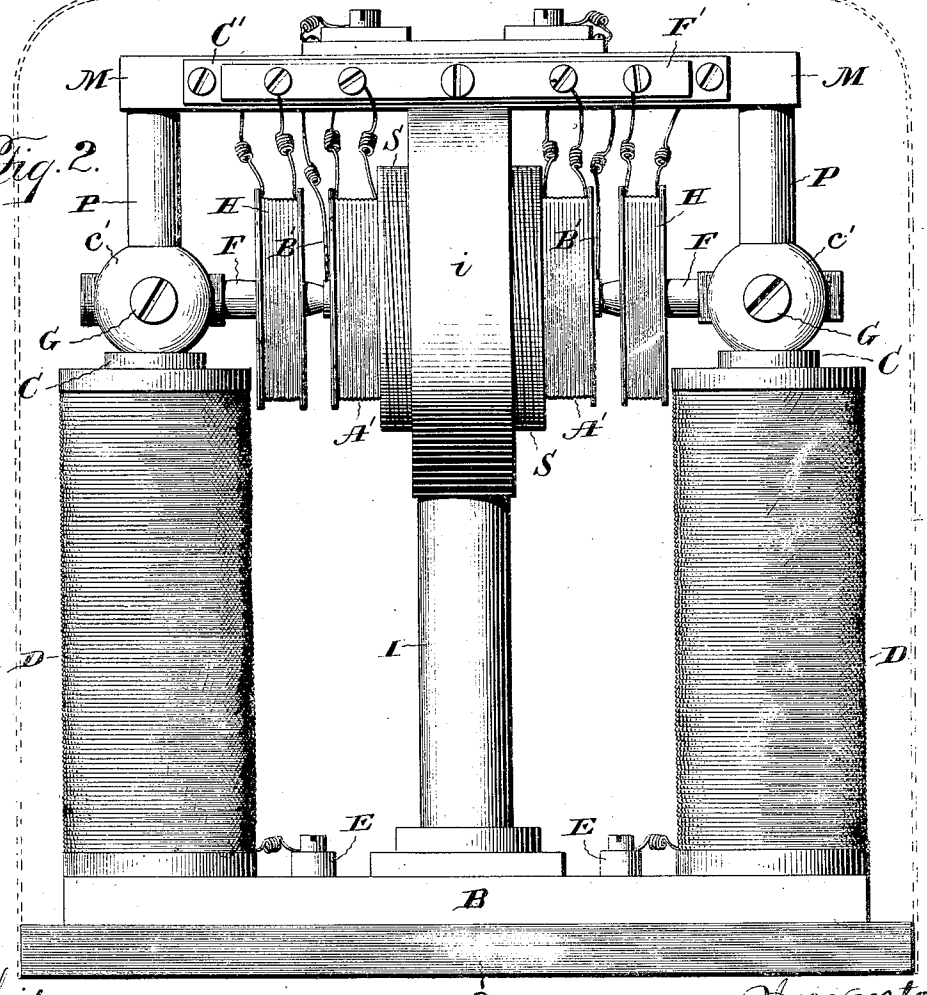


Fig. 2.



Witnesses.
Jas. E. Hutchinson
Henry C. Hazard.

Inventor
Elwood Grissinger,
by Edwin J. Prindle,
his Attorney.

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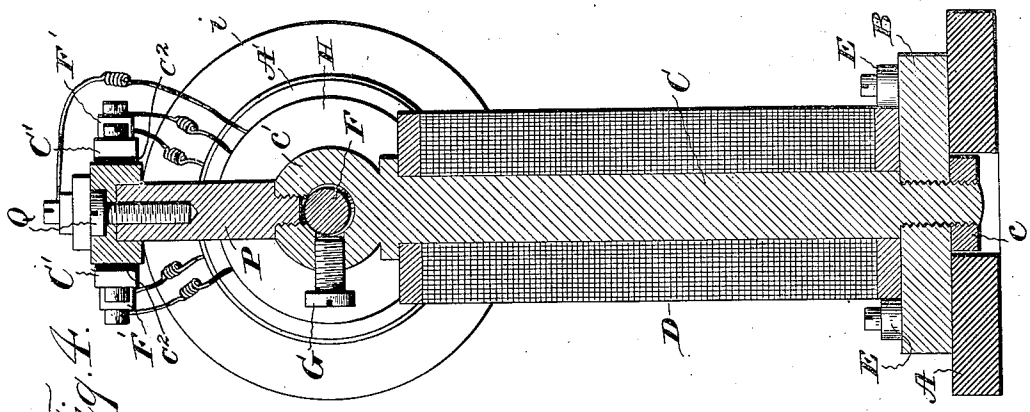

Fig. 4.

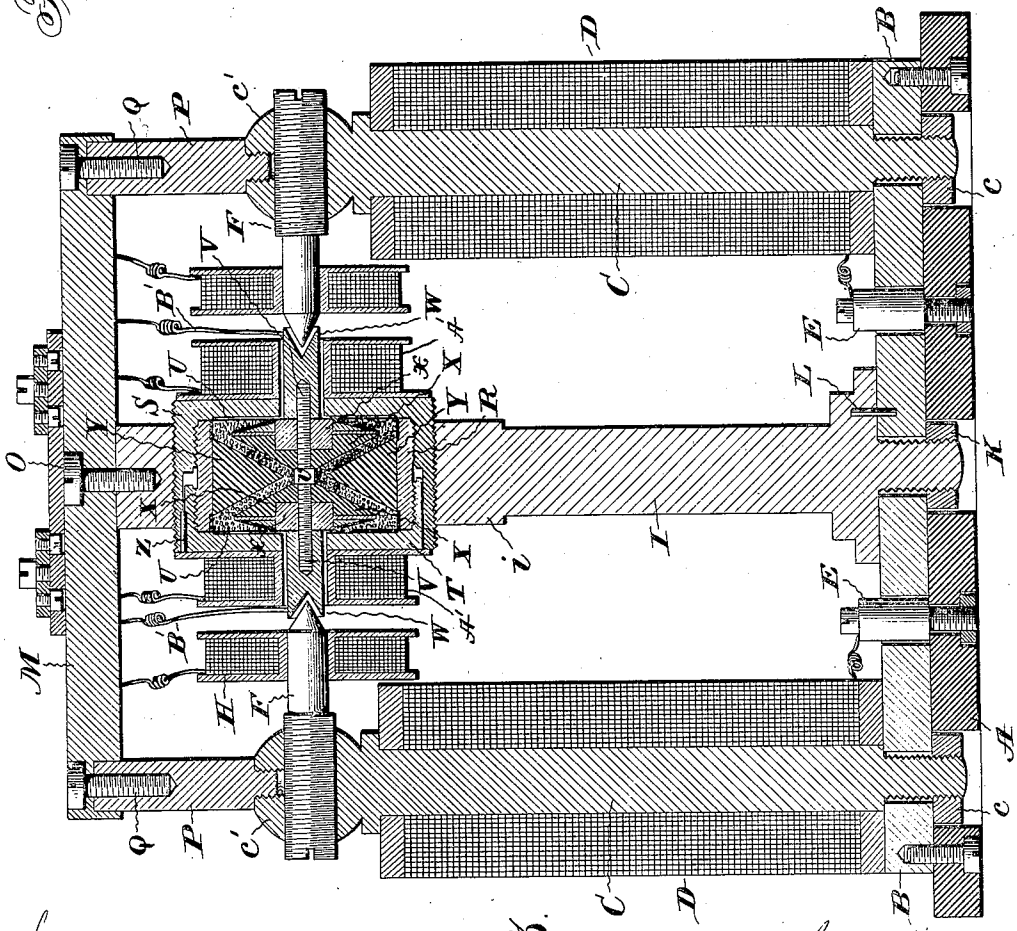

Fig. 3.

Witnesses:
Jas. E. Hutchinson
Henry C. Hazard

Inventor.
Elwood Grissinger,
by Edwin J. Prindle,
his Attorney.

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3 SHEETS—SHEET 3.

Fig. 5.

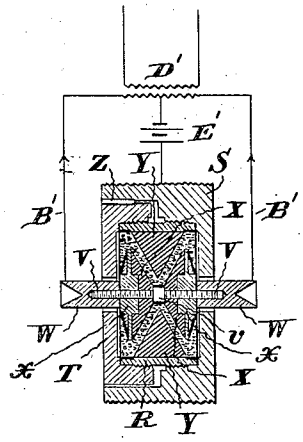


Fig. 8.

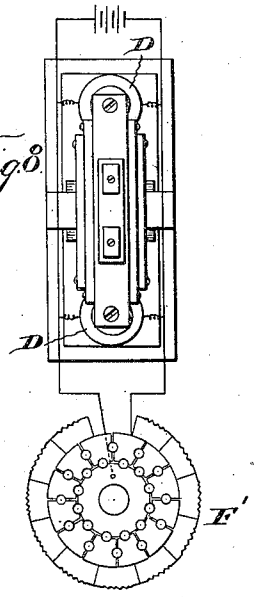


Fig. 9.

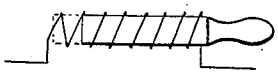


Fig. 6.

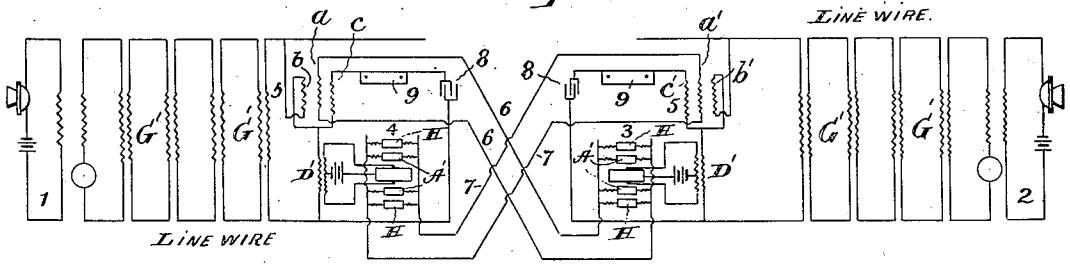
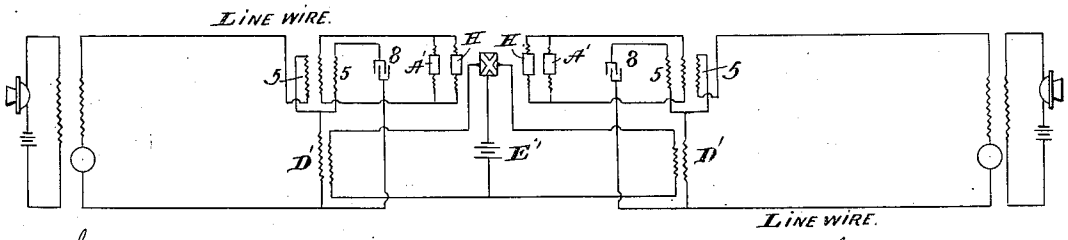


Fig. 7.



Witnesses:
Jas. E. Hutchinson
Henry C. Hazard

Inventor.
Elwood Grissinger,
by Edwin J. Prindle,
his Attorney.

UNITED STATES PATENT OFFICE.

ELWOOD GRISSINGER, OF BUFFALO, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

TELEPHONE-REPEATER.

1,198,212. Specification of Letters Patent. **Patented Sept. 12, 1916.**

Application filed February 24, 1902. Serial No. 95,380.

To all whom it may concern:

Be it known that I, ELWOOD GRISSINGER, of Buffalo, in the county of Erie, and in the State of New York, have invented certain new and useful Improvements in Telephone-Repeaters, and do hereby declare that the following is a full, clear, and exact description thereof, reference being had to the accompanying drawings, in which—

Figure 1 is a top plan view of a repeater embodying my invention; Fig. 2 a side elevation thereof; Fig. 3 a vertical, longitudinal section; Fig. 4 a vertical, cross section; Fig. 5 a detail view, in section, of the variable resistance medium chamber, showing diagrammatically the circuit arrangement; Fig. 6 is a diagram of a telephone line equipped with two repeaters, so arranged as to enable the line to be operative in either direction; Fig. 7 a diagram of a telephone line, showing the manner in which a single repeater may be used for operation in either direction, and Fig. 8 is a diagrammatic view showing the repeater magnet circuit, including a shunt resistance, and Fig. 9 is a diagrammatic view illustrating an inductive resistance that may be used.

Letters of like name and kind refer to like parts in each of the figures.

The object of my invention is to provide a repeater for telephones that will be very sensitive, capable of faithfully retransmitting the waves it receives, of efficiently operating in either direction, without waste of electrical energy, or other objectionable features, and to insure the delivery to the repeater of waves in their original form as nearly as possible, and to this end, said invention consists in the repeater and in the construction of the circuits therefor, substantially as hereinafter specified.

In constructing my improved repeater, I employ a base A of hard rubber, or equivalent material. Secured to said base is a plate or piece B of magnetic material, steel, for example, which may be of rectangular form, at each end of which and perpendicular thereto is a rod or bar C, of soft steel or iron, and constituting the magnetic core of coils D wound around the same, and connected with a source of current through binding posts E and E attached to the base A, and passing through, but not touching the plate B. The core C may conveniently be fastened at one end to the plate B by a nut *c* on a threaded extension of the core that is passed through a hole in the plate. At its other end the core has, preferably, the form of a ball *c'*, and passing through the latter at right angles to the core, is a pole piece F, threaded to engage thread in the core-opening through which it passes. The thread is very fine to enable close adjustment of the pole piece, and to securely hold the latter in its adjusted position a lock screw G is provided. Upon the pole piece is a coil H, whose terminals are connected in the telephone circuit, as hereinafter described. Said pole piece is preferably of soft iron.

Secured to the plate B, midway between the magnets formed by the cores C and C and the coils D and D is a standard I, its connection with the plate being by a threaded extension and a nut K thereon, as in the case of the cores C. A dowel pin L engaging the standard and the plate B holds the standard from displacement by turning. Having an axis coinciding with the axis of the pole pieces F and F is a ring-form enlargement *i* of the standard, within the opening of which is placed the variable resistance medium chamber, hereinafter described. To hold the standard and the magnet cores rigid and relatively immovable, a plate M of brass is attached to all three, a screw O being used to connect the standard and the plate, while to connect the plate and each core a post P is screwed at one end to the ball *c'* and at its other end is connected to the plate by a screw Q.

In the construction of the variable resistance medium, I employ a cylindrical shell R, upon the exterior of which, at one end, is screwed a cap S, and upon which at the other end is screwed a cap T. At each end of the shell is a diaphragm U of mica, that is clamped between the shell end and the cap S or T thereat. Passing centrally through the shell R and through the diaphragm U is a soft steel or brass rod V, which is threaded throughout its entire length, except at its center, where it has an enlargement or collar *v*. On the portion of the rod outside of each diaphragm is screwed an armature W of soft iron that is in alinement axially with, and is contiguous to a pole piece F, the ends of the caps S and T being centrally perforated for the accommodation of the respective armature. The size of the holes through which the armature pass is

such as to bring the caps very close to, but not touching, the armatures. On the threaded portions of the rod on the inside of the diaphragms are two carbon electrodes X and X which at their inner ends abut against the rod collar *v*. Forming a back for each electrode on the side next the diaphragm is a brass plate *x* having a portion which projects into a cavity in the electrode and soldered to the electrode. Said plate is threaded to engage the thread of the rod and is screwed with the electrode along the rod until the electrode abuts against the rod collar *v*.

Attached to the shell R and projecting therefrom into the space between the two electrodes X is an electrode Y in the form of an annulus or ring. Each face of the ring has a conical cavity or depression, and the opposing face of each electrode X has a conical form. The electrodes are of very hard carbon and their faces are most highly polished. In the space between the electrodes, and almost filling the same, is finely comminuted or granulated carbon of great hardness, that is placed therein before the mica diaphragms are fixed in position. The armatures W are most conveniently applied to the rod V after the caps S and T are screwed on the shell R to clamp the diaphragms. An insulating medium covers the edges of the backing plates *x*, the inner surfaces of the shell R adjacent the electrode Y, and the rod collar *v* to prevent passage of current except through the electrodes. The cap S is threaded exteriorly, and it is thereby screwed into the ring-form enlargement of the standard I. The cap T is of less diameter than the cap S and enters a cavity in the latter which it fits as closely as possible, and to hold the two in fixed relation a soft iron pin Z is driven into an opening formed partially in each cap.

Fastened to the side of each cap so as to encircle the armature W projecting therethrough, is a telephone coil A′ having the same electrical dimension as the coils H on the pole pieces F. Said coils, as well as those on the pole pieces, are wound on non-magnetic bobbins, and they come very close to, but do not touch, the armatures.

Soldered to the armatures W are leads B′ that, respectively, are connected to terminal boards C′ attached to the plate M, insulation C^2 being interposed between said boards and plate and from each other, and to each terminal board C′ is attached one end of the primary of a local induction coil D′. From the middle of said coil a wire is run to one pole of the battery E′, and the other battery pole is connected with the standard I. By the arrangement described, the current from the battery passes to the electrode Y and through the granulated carbon, dividing and thence passing to the electrodes X and thence out through the armatures W and through half of the primary of the induction coil, back to the battery. This circuit is best shown in Fig. 5.

The telephone coils H and A′ are connected preferably in multiple to terminal boards F′ and F″ fastened to and insulated from the plate M, the ingoing leads of the coils being connected to one board and the outgoing leads to the other board.

The magnet coils D, when energized, produce a magnetic field, the path of which is through the poles F and F of both magnets, across the air space between each pole and the adjacent armature, from the latter to the contiguous cap S or T through the air space between the armature and cap, and from the cap to the standard I. A short, closed magnetic circuit of great strength is thus produced for each armature W, within which the latter is suspended. The magnet coils are so connected that the poles F and F are like poles, either N or S, and the armatures W and W are, therefore, attracted in opposite directions and thus magnetically balanced. For such adjustment as may be necessary for accurate balancing, the pole pieces are threaded, as heretofore described, and to obtain increased accuracy of adjustment a shunt resistance may be used for either or both coils. Said resistance is high in comparison to the magnet coil and is arranged in steps to enable a very delicate balance to be obtained.

The telephone coils H and A′ are so connected that those on one side of the variable resistance medium chamber tend to increase the magnetism on that side, while those on the other side tend to produce the opposite effect, the result being that variations in the telephone currents circulating in the coils will disturb the magnetic balance, or equilibrium, and cause vibrations of the armatures and electrodes in unison, producing similar variations in the local circuit of which the variable resistance medium forms a part.

The construction of my variable resistance medium chamber is such, furthermore, that the effects due to heat expansion in the variable resistance medium are equalized so as to avoid any resulting displacement of the electrodes. When a current is passing through one side of the variable resistance chamber the current is also simultaneously passing through the other side thereof. The variable resistance medium is, therefore, equally heated throughout, and any expansion thereof, due to the increasing temperature at one side of the variable resistance chamber, is equalized by an expansion in the opposite direction at the other side of the variable resistance chamber. The electrodes X and Y are, therefore, arranged so that they constantly maintain their proper

positions, irrespective of any influence due to the expansion of the variable resistance medium under the influence of heat.

The armatures W are cylindrical in form, and though the outer ends thereof can be made flat or plane, I preferably provide in such end of each a conical cavity, or one with inclined sides, and correspondingly form the contiguous ends of the pole pieces. I have found that with the adjacent extremities of armature and pole piece thus formed, a considerably greater tractive force is developed than can be done with plane or flat faces. I am thus able to employ an armature of small diameter, but of ample power, and to reduce the weight thereof by the amount removed to make the recess, qualities of importance as affecting the sensitiveness of the action of the instrument. The armature coil A′, it is to be noted, is not attached to the armature, and, therefore, neither the weight thereof nor the resistance of the air which its large surface would cause, is an obstacle to the movement of the armature, which would be the case were the coil attached to the armature. It will, therefore, be seen that the reduction of size of the armature is of decided importance, since thereby both diminution of its weight and lessening of its air-engaged surface are secured. Though unattached to the armature, the coil produces the same effect thereon as if it were wound upon it. If desired, no coil at all around the armature need be used, and with no coil, the armature could be made smaller than with one.

Because the armatures and pole pieces are of substantially the same diameter or cross-section, strong tractive forces can be obtained without magnetically saturating the armatures or the pole pieces, and which will thus be free to respond to the slightest increase or decrease of current through its coil. When an armature smaller in available cross-section than the pole of the magnet is used, such armature becomes magnetically saturated and cannot fully respond to an increase or decrease in the force of the current. My armatures, however, being of substantially the same cross-sectional area as the pole pieces can fully respond to any change in the exciting current. A more efficient response also is obtained because the initial attraction between the magnet and armature is brought to a maximum by making the armature of sufficient cross-sectional area to receive all the lines of force generated by the magnet. No springs, weights, levers or devices for mechanically increasing the motion of the electrodes are used in my repeater, and loss of energy due to the use of such elements is therefore avoided. By the use of the current of the sending telephone in the bobbins of both armatures and in the bobbins of the opposite magnets, the greatest possible movement of the armatures through the energy of such current is secured. The location of the two armatures between the opposite magnets causes the armatures to be partly supported by the magnetism when the magnetic field is present. When an armature is provided with an exciting coil, it becomes *per se* a magnet and tends to pull or push the electrodes toward or from its magnet, and thus to increase the movement of the electrodes. I have found by actual experience that, contrary to my first impressions and expectations, the increased weight due to the making of the armatures of the same cross-sectional area as the pole pieces was completely overcome by the increased attractive force so that the net result was a most desirable increase in the sensitiveness of the instrument.

If desired, permanent magnets may be used in place of the magnets formed by the coils D and cores C, but the latter are preferable, as permanent magnets are not adjustable, and not so well fitted for the service required of them. Preferably, I inclose the repeater by a casing that will protect it from external magnetic, or other disturbing influences.

To enable the transmission of electrical waves in either direction, and automatically, I have devised a circuit which effectually prevents "whistling", does not impair the sensitiveness of the instrument, and involves no local circuit about the repeater with consequent expenditure of energy that should be used on the line, all of which disadvantages characterize the repeater systems with which I am familiar.

A circuit embodying my invention is illustrated in Fig. 6, in which two subscribers' stations marked 1 and 2 are shown, each having an ordinary equipment of apparatus, and for the repeating work of the station 1 a repeater 3 being provided, and for the repeating work of the station 2 a repeater 4 being provided, the two repeaters being of the construction hereinbefore described. For each repeater there is an induction or as I shall term it, repeater coil 5 having three windings or limbs wound on the same core, the limb *a* of one coil being connected by leads 6 with the telephone coils H and A′ of the repeater 3, and the similar limb *a′* of the other coil being connected by leads 7 with the telephone coils of the repeater 4. A second limb *b* of one coil 5 and *b′* of the other coil 5, is connected to one of the line wires and the second limb *b* is connected to the third limb *c*, while the second limb *b′* is connected to the third limb *c′*. Intermediate the limbs *b* and *c*, or *b′* and *c′*, as the case may be, a connection is made with the secondary of the repeater induction coil, D′ and from the latter to the other line wire, and from the third limb *c* or *c′*, as the case may be, a

connection is also made with the other line wire, said connection including a condenser 8 and, preferably, an inductive resistance 9. To illustrate the operation of this circuit, suppose the subscriber at station 1 is talking. All of the current from one line wire will pass through the limb b of the induction coil 5, and dividing, some will pass to the other wire through the secondary of the induction coil D′ of repeater 4, and some through the limb c and condenser 8. The current passing through the limbs b and c induces in the limb a a current of the same form, which passes to the telephone coils H and A′ of the repeater 3 by the leads 6, and actuates the repeater armatures, producing disturbance of the equilibrium of the variable resistance medium thereof, and consequent undulations in the primary of the induction coil of repeater 3. The current thereby induced in the secondary of the induction coil of repeater 3, passes to the two limbs b' and c' of the induction coil 5, the part going through the limb b' passing to the line and thence to the receiver of station 2, and the part going through the limb c' passing through the condenser connected therewith and thence to the line wire and back to the secondary of the induction coil of the repeater 3. The passage of currents through the limbs b' and c' induces currents in limb a', but they are in opposite directions and nullify each other, so that no current thus induced in the limb a' will pass to the other repeater 4. Besides inducing a current in the limb a', the current passing through the limb c' induces a corresponding current in the limb b'. Since at the same time the current from the secondary of the induction coil of the repeater 3 is passing through the limb b', a current is induced in the limb b' by the current passing through the limb c', the current induced in the limb b' differing in phase with the current from the secondary, would conflict with the latter current. This, however, is avoided by the condenser which gives just enough lead to the current in the limb c' to place the current induced by it in the limb b' in phase with the current from the secondary of the repeater 3. The neutralizing action on the limb a or a' of currents passing through the limbs b or b' and c or c' occurs only when the current passes from the secondary of the working repeater, and does not take place when the current is passing in the opposite direction from the line to said limbs.

The inductive resistances 9 are provided, as there may be times when the condition of the telephone line will require their use, and if found necessary such resistances may be placed in the main circuit. In general, however, these resistances need not be employed, if the induction coils 5 and 5 are properly made and the condensers are of the right capacity.

In Fig. 7 I illustrate a circuit in which a single repeater is employed. As in the circuit illustrated in Fig. 6 there are two induction coils 5 and 5, each comprising three limbs, which are connected in the circuit the same as in the other case, excepting that the telephone coils H and A′ on one side of the repeater are connected with the limb a of one coil, and those on the other side of the repeater are connected with the limb a' of the other coil. The single repeater is in circuit with the primary of each induction coil D′. The only difference in the operation of the single and double repeater systems is that in the former, the current induced in the limb a or a', as the case may be, acts through but one set of telephone coils H and A′ thereby attracting or releasing the armature subject to said coils and changing the current flowing through the two primaries of the induction coils D′ and D′, which are in circuit with the repeater. Both primaries being in the same circuit, it follows that the current passing through the secondary from the talking station, will induce a current in the primary of such secondary that, passing around the local battery, will induce a current in the secondary of the other induction coil, which will be superimposed upon the current from the repeater and act as a booster. Of course, the two currents are in phase.

The function of a repeater is to faithfully reproduce the form of electrical waves it receives and to add to their strength, its office thus being to compensate for the loss of energy due to the ohmic resistance of the line. It cannot be made to remedy the conditions due to the capacity and inductance of the telephone circuit. These must be remedied otherwise, and being remedied, the repeater will reproduce the original form of the original waves, and reinforce them. The capacity of a circuit, though it does not cause a loss of energy, impairs the transmission of the waves because it acts as a condenser, and it alters the character of the undulations by absorbing the higher frequencies much more than the lower ones and changing the phase relations of the different frequencies and altering their form by causing the current to lead the E. M. F. The inductance of a telephone circuit causes the current to lag behind the E. M. F. in this respect producing the opposite effect of capacity, and it also affects the higher frequencies more than the lower ones, distorting the phase relations of the different frequencies. As inductance and capacity produce opposite effects, and as the capacity of a telephone circuit is large compared with its inductance, I distribute inductance along

the line to neutralize the effect of the capacity of the line. Distortion is thereby minimized and transmission improved, the result being the reception by the repeater of the wave in substantially its original form for repetition with added strength. As will be readily understood, inductance may be distributed in the line in various ways, and to illustrate one way in which to do it, I show induction coils or converters G' and G' placed at intervals in the line.

In the course of this specification I have indicated some changes in construction which may be resorted to without involving any departure from the scope of my invention. Besides those mentioned, others may be made which will involve no departure from the principle of my invention, and it is, therefore, to be understood that I consider the scope of my invention to comprehend constructions other than those set forth herein.

Having thus described my invention, what I claim is:—

1. In a telephone repeater, the combination of a telephone circuit, a magnet, an armature, a coil surrounding the same in inductive relation with said circuit, and electrodes, one of which is adapted to be moved by the armature.

2. In a telephone repeater, the combination of a telephone circuit, a magnet, an armature, a coil for the magnet and a coil surrounding the armature both coils being in inductive relation with the telephone circuit, and electrodes, one of which is adapted to be moved by the armature.

3. In a telephone repeater, the combination of a telephone circuit, magnets having their poles opposite each other, armatures for such magnets, said armatures being connected together, coils on the magnets and surrounding the armatures, said coils being in inductive relation with said circuit, the coils on one magnet and its armature being opposed to the magnetism therein, and the coils on the opposite magnet and its armature increasing the magnetism therein, a second telephone circuit, and electrodes by which said second circuit can be influenced, one of said electrodes being connected to the armatures.

4. In a telephone repeater, the combination of a telephone circuit, magnets having poles opposite each other, coils on said magnets in inductive relation with the telephone circuit, a casing between said poles, diaphragms extending across said casing opposite the poles, a rod extending through the diaphragms, armatures on the rod, electrodes, one of which is carried by said rod, a second telephone circuit, and means whereby such second circuit can be influenced by the electrodes.

5. In a telephone repeater, the combination of a telephone circuit, magnets having poles opposite each other, coils on the magnets in inductive relation with said circuit, a casing between the poles, diaphragms extending across said casing opposite the poles, a rod extending through said diaphragms, armatures on said rod, electrodes, one of which is secured to the rod, and the other having an aperture through which the rod freely passes, a second telephone circuit, and means by which said second circuit can be influenced by the said electrodes.

6. In a telephone repeater, the combination of a telephone circuit, magnets having poles opposite to each other, and having coils thereon in inductive relation with said circuit, a casing between the poles, diaphragms extending across the casing, a rod passing through the diaphragms, armatures on the rod having coils in inductive relation with the telephone circuit, electrodes, one of which is carried by the rod, a second telephone circuit, and means by which said second circuit can be influenced by said electrodes.

7. In a telephone repeater, the combination of a telephone circuit, magnets having poles opposite each other, coils on such magnets in inductive relation with such circuit, a casing between such poles, non-magnetic diaphragms extending across the casing opposite the poles, a rod extending through the diaphragms, armatures on said rod, electrodes, one of which is carried by said rod, a second telephone circuit, and means by which said second circuit can be influenced by said electrodes.

8. In a telephone repeater, an armature having a coil surrounding such armature and in inductive relation with the sending telephone circuit, in combination with a variable resistance medium that is operated by such armature.

9. In a telephone repeater, the combination of sending and receiving telephone circuits, a magnet, means for varying the strength of such magnet in proportion to that of the sending current, an armature for such magnet, a variable resistance medium and an induction coil in circuit with each other, said variable resistance medium being operated by said armature, and a coil in inductive relation to the receiving circuit and surrounding the armature but unattached thereto.

10. In a telephone repeater, the combination of a magnet, a bar-form armature, an electrode attached to the armature, a chamber inclosing the electrode through an opening in which the armature projects, a diaphragm secured to and closing said chamber and receiving and supporting said armature, and a telephone coil surrounding but un-

attached to the armature, said coil being in inductive relation with the sending telephone circuit.

11. In a telephone repeater, the combination of a magnet, an armature, a diaphragm actuated by the armature, a support of magnetic material for but out of contact with the armature, and a connection of magnetic material between said magnet and the armature support.

12. In a telephone repeater, the combination of a magnet, an armature, a support of magnetic material for the armature that does not have contact therewith, and a connection of magnetic material between said magnet and the armature support.

13. In a telephone repeater, the combination of a magnet, an armature, a support of magnetic material for but out of contact with the armature, the latter being in a magnetic field between the magnet and said support, and a connection of magnetic material between said magnet and the armature support.

14. In a telephone repeater, the combination of a magnet, an armature, an electrode movable thereby, a support of magnetic material for the armature in a magnetic field between the magnet and said support, a connection of magnetic material between the magnet and the armature support, and a telephone coil.

15. In a telephone repeater, the combination of a magnet, an armature, a support of magnetic material for but out of contact with the armature, a yielding nonmagnetic connection between the armature and its support, and a connection of magnetic material between said magnet and the armature support.

16. In a telephone repeater, the combination of a magnet, an armature, a support of magnetic material for but out of contact with the armature, the armature being in a magnetic field between the magnet and said support, a yielding connection of nonmagnetic material between the armature and its support, and a connection of magnetic material between said magnet and the armature support.

17. In a telephone repeater, the combination of a magnet, an armature, an electrode movable thereby, a telephone coil applied to the pole piece of the magnet, a support of magnetic material for but out of contact with the armature, the armature being in a magnetic field between the magnets and said support, and a connection of magnetic material between the magnet and the armature support.

18. In a telephone repeater, the combination of two magnets, an armature for each magnet, an electrode movable by each armature, a support of magnetic material for but out of contact with the armatures, the armatures being in a magnetic field between the magnets and said support, and a connection of a telephone circuit, magnets havport and the magnets.

19. In a telephone repeater, the combination of two magnets, an armature for each magnet, an electrode movable by each armature, a support of magnetic material for the armatures, the armatures being in a magnetic field between the magnets and said support, a connection of magnetic material between said support and the magnets, and telephone coils on the pole pieces of the magnets.

20. In a telephone repeater, the combination of two magnets, an armature for each magnet, an electrode movable by each armature, a support of magnetic material for the armature, the armature being in a magnetic field between the magnets and said support, a connection of magnetic material between said support and the magnets, and telephone coils for the pole pieces of the magnets and for the armatures.

21. In a telephone repeater, the combination of opposing magnets, armatures for and between said magnets, an electrode movable by each armature, a magnetic casing containing said electrodes, nonmagnetic diaphragms in said casing, said diaphragms supporting the armatures and electrodes, and a magnetic standard upon which said casing is supported, said standard being in magnetic connection with said magnets.

22. In a telephone repeater, the combination of two electro-magnets, an armature for each, a substantially unyielding mechanical connection between the armatures, and electrical means for balancing the action of the magnets upon the armatures.

23. In a telephone repeater, the combination of electromagnets having opposing poles, armatures situated between such poles, electrodes operated by such armatures, and a means for keeping such armatures between but not touching said poles, said means consisting of a shunt resistance in circuit with one of such magnets.

24. In a telephone repeater, the combination of two telephone circuits, a repeater, an induction coil in each circuit in reciprocal relation, means for operating the repeater by a current induced by one of said coils, and means for transmitting a current by the operation of the repeater, through the second induction coil to one of the telephone circuits only.

25. In a telephone repeater, the combination of two telephone circuits, an instrument adapted with increased force to transmit electrical waves from either one of said circuits to the other, a repeating coil in each circuit in electrical connection therewith, means for operating said instrument by a current induced by one of said coils, and

means for transmitting a current, by the operation of said instrument, through the second repeating coil to one of the telephone circuits only.

26. In a telephone repeater, the combination of two telephone circuits, an instrument adapted with increased force to transmit electrical waves from one circuit to the other, a repeating induction coil in each circuit in electrical connection therewith, and means for causing a current passing through such induction coil in one direction to induce a current in one telephone circuit, and for preventing a current passing through such induction coil in the opposite direction from inducing a current in the other telephone circuit.

27. In a telephone repeater, the combination of two telephone circuits, a variable resistance instrument and an induction coil, a three-wind repeating coil in electrical connection with each circuit, two of the windings of each of said three-wind repeating coils being in series in one line wire of its own circuit, there being a connection between the opposite line wire and the union between said two windings, the third winding thereof being in circuit with said variable resistance instrument, the induction coil whereof being interposed in said connection, and the said line wires being connected to a condenser.

28. In a telephone repeater, the combination of a telephone circuit, a repeater, and a three-limb induction coil, one limb of which is in circuit with the repeater and the other two limbs are in the telephone circuit.

29. In a telephone repeater, the combination of a telephone circuit, a repeater, a three-limb induction coil, one limb of which is in circuit with the repeater, and the other two limbs are in the telephone circuit, and a condenser in circuit with one of said other limbs.

30. In a telephone repeater, the combination of a telephone circuit having a three-limb induction coil, a repeater circuit including the primary of an induction coil, a second repeater circuit including one of the limbs of the three-limb induction coil, and connections between the other two limbs and the telephone circuit, one of which includes the secondary of the induction coil of the first mentioned repeater circuit, and the other a condenser.

31. In a telephone repeater, the combination of a telephone circuit, a repeater having a local circuit including the primary of an induction coil, a three-limb induction coil, and telephone coils on the repeater in circuit with one of said limbs, the other two limbs being in the telephone circuit, and the secondary of the primary of the local repeater circuit being connected with one line of the telephone circuit, and between said other two limbs.

32. In a repeater, the combination of two magnets having immovable cores, pole pieces threaded in openings in said cores, said pole pieces being directed toward each other, and a variable resistance medium having an armature interposed between said pole pieces.

33. In a repeater, the combination of two magnets having immovable cores, pole pieces threaded in openings in said cores, said pole pieces being directed toward each other, and a variable resistance medium having an armature interposed between said pole pieces, said pole pieces being conical, and said armature having corresponding conical recesses for the reception of said pole pieces.

34. In a telephone repeater, the combination of a carbon electrode, a backing therefor having a threaded hole, an armature, and a threaded rod passing through the electrode and its backing, to which the armature is attached by being screwed thereon.

35. In a telephone repeater, the combination of a pair of electrodes of carbon, a backing for each electrode, an armature for each electrode, and a threaded rod passing through the carbons and backings, and into the armatures.

36. In a telephone repeater, the combination of two telephone circuits, an instrument adapted to transmit electrical waves from each circuit to the other, a coil in each circuit in electrical connection therewith, means for operating said instrument by a current induced by one of said coils, and means for transmitting a current by the operation of said instrument through the second coil to one of the telephone circuits only.

37. In a reciprocal telephonic repeating system, the combination with telephone-line sections, of repeating-relays, each inductively responsive to currents originated in its respective line-section and unresponsive to currents produced by it in the other line-section, as set forth.

38. In a telephone repeater, the combination of a variable resistance medium having armatures on opposite sides thereof, and a coil surrounding but not touching each of said armatures.

39. In a telephone repeater, the combination of a variable resistance medium having relatively movable electrodes, one of said electrodes having an armature on each side thereof, and an exciting coil surrounding but not touching each of said armatures.

40. In a telephone repeater or relay, the combination of a stationary electrode, a movable electrode having armatures on opposite sides thereof, and an exciting coil

surrounding but not touching each of said armatures.

41. In a telephone repeater or relay, the combination of pole pieces directed toward each other, a variable resistance medium between said pole pieces and composing a stationary electrode and a movable electrode, said movable electrode having oppositely opposed armatures facing said pole pieces, and an exciting coil surrounding but not touching each of said armatures.

42. In a telephone repeater or relay, the combination of pole pieces directed toward each other, a variable resistance medium between said pole pieces and composing a stationary electrode and a movable electrode, said movable electrode having oppositely opposed armatures facing said pole pieces, and an exciting coil surrounding but not touching each of said armatures, each of said pole pieces having an exciting coil surrounding the same.

43. In a relay for telephone lines; two induction-coils; two transmitting devices; magnetically-controlled means operatively connected therewith; and two independent electro-magnetic means included in closed circuits with the secondaries of said induction-coils.

44. In a relay for telephone lines, two induction coils, two transmitting devices, magnetically-controlled means operatively connected therewith, and two independent electro-magnetic means included in closed local circuits solely with the secondaries of said induction coils.

45. The method of transmitting messages which consists in transforming electrical undulations into qualitatively corresponding magnetic undulations within a supplemental magnetic field, producing thereby qualitatively corresponding resultant magnetic product undulations, equilibrating the torsional effects of the resultant magnetic product undulations and causing thereby qualitatively corresponding mechanical vibrations quantitatively proportionate to the resultant magnetic product undulations, thereby quantitatively enhancing the mechanical result while preserving therein the characteristic quality of the original electrical undulations.

46. In a telephone repeater system, a telephone line divided into two sections; a telephone relay, an induction coil having one winding in one of said line sections and its other winding in a local circuit including the receiving magnet of said relay, whereby said relay may receive energy from said section of the line; an artificial line associated with the other section of said line, and means for passing the relayed currents from said relay into said other section and said artificial line in multiple.

47. In a telephone repeater system, two sections of a telephone line extending from a relay station; a telephone relay; an induction coil having one winding connected to the receiving magnet of said relay and its other winding in one of said line sections; an artificial line associated with the other section of said line and having similar electrical characteristics; and means for passing the relayed currents from said relay into said other section and said artificial line in multiple.

48. In a telephone repeater system, two sections of a telephone line joined at a relay station; a telephone relay; an induction coil associating said relay with one of said line sections; an artificial line associated with the other section of said line; means for passing the relayed currents from said relay into said other section and said artificial line in multiple; and a second relay having its receiving coil associated with said other line section and said artificial line, whereby relayed currents from said first relay do not affect the receiving element of said second relay.

49. In a telephone repeater system, a telephone line divided into two sections; a telephone relay; an induction coil having one of its windings connected in the circuit of one of said line sections and its other winding connected with the receiving magnet of said relay; an artificial line associated with the other section of said line; a local circuit for the transmitting element of said relay; a source of current in said local circuit, and an induction coil having its primary in said local circuit and its secondary in a common path in said artificial line and said other section of said telephone line.

50. In a telephone repeater system, a telephone line divided into two sections; a telephone relay, an induction coil connected to inductively transmit energy from one of said line sections to the receiving magnet of said relay; an artificial line associated with the other section of said line; a local circuit for the transmitting element of said relay; a source of current in said local circuit; an induction coil having its primary in said local circuit and its secondary in a common path in said artificial line and said other section of said telephone line; and a second relay having its receiving coil differentially associated with said other line section and said artificial line, whereby relayed currents from said first relay do not affect the receiving element of said second relay.

51. In a telephone repeater system, a pair of line sections joined at a repeater station; a pair of telephone relays, each capable of receiving feeble currents from one line section and impressing augmented currents on the other line section; a pair of artificial lines, one for each line section; an induction coil for each line section, each having its

primary in the local circuit of the relay corresponding to the other section and its secondary in a common path of its own line and the corresponding artificial line; and a second induction coil for each line section having one-half its primary in its line section and one-half in the corresponding artificial line, and its secondary connected with the relay magnet of that line section.

52. In a telephone repeater, the combination of a telephone circuit, a repeater, a three-limb induction coil, one limb of which is in circuit with the repeater and the other two limbs are in the telephone circuit, and means for controlling the angular phase displacement in the circuit including one of said other limbs.

53. In a telephone repeater, the combination of a telephone circuit, a balancing circuit, a repeater, a three-limb induction coil, one limb of which is in circuit with the repeater, one limb of which is in the balancing circuit, and the other limb of which is in the telephone circuit, and means for controlling the angular phase displacement in the balancing circuit.

54. In a telephone repeater, the combination of a telephone circuit, a balancing circuit, a repeater, a three-limb induction coil, one limb of which is in circuit with the repeater, one limb of which is in the balancing circuit, and the other limb of which is in the telephone circuit, and means for controlling the current values in the balancing circuit.

55. In a telephone repeater, the combination of a telephone circuit, a repeater, a three-limb induction coil, one limb of which is in circuit with the repeater and the other two limbs are in the telephone circuit, and means inserting inductance and capacity in circuit with one of said other limbs.

56. A current reinforcing and retransmitting apparatus, consisting of main line helical means; a magnet having a pole-piece extending into one end of said means; a microphone or variable resistance transmitting medium mounted adjacent to the other end of said means; and an iron core constituting a complementary and movable or vibratory pole-piece of said magnet, secured to one of the contact-electrodes of said transmitting medium and extending therefrom into said means, and into close proximity to said first-mentioned pole-piece.

57. In a telephone-current retransmitting and reinforcing apparatus, the combination of the fixed magnet-pole and varying helical means of a receiving medium, the said pole extending into said means; and the contact members or electrodes of a variable-resistance transmitting medium mounted to closely confront said means, one of said electrodes being vibratory; of a light vibratory core serving as a complementary pole for said receiving medium extending into close proximity to said fixed pole; the said vibratory electrode and vibratory pole being directly, and without the intervention of a diaphragm, attached to each other to jointly constitute a magnetic mechanical connection between the receiving and transmitting media of low inertia, high relative mobility, and high sensitiveness to the variations of the receiving medium, adapted to be actuated by such magnetic variations and to produce corresponding resistance-variations in the said transmitting medium; whereby voice-currents traversing the circuit of said receiving medium may be retransmitted unimpaired in form and with increased effect in the circuit connected with said transmitting medium.

58. A repeating or reinforcing apparatus for telephone-lines, consisting of a receiving magnet and helical means; an intimately associated variable-resistance transmitting medium comprising a rigid fixed electrode, a movable or vibratory electrode, and granular carbon inclosed between said electrodes; and two iron cores attached to said magnet and vibratory electrode, and projecting oppositely into said helical means so that their free ends confront each other with a short separating space, in the interior thereof.

59. In a telephone apparatus for retransmitting telephone currents with renewed vigor between two main circuits or sections of circuits, the combination with a receiving-electro-magnet having independent magnetizing and magnetization-varying helical means, adapted for connection in local and main circuits respectively; and a fixed central iron core projecting into the latter of said means; of a variable-resistance transmitting device, comprising contact-electrodes, one of which is vibratory or movable; and a complementary iron core or rod attached at one end to said movable electrode, extending at the other end into the magnetic field of said latter means to nearly reach said fixed core, and constituting a connection of low inertia and high sensitiveness between the varying field of said receiving-magnet and the transmitting device.

60. The combination in a telephone retransmitting and reinforcing system, of an electro-magnetic receiving device comprising a magnetizing helical means establishing an initial magnetic field, a main-circuit magnetization-varying helical means adapted by the passage of voice-currents therein to vary said initial field accordingly, and fixed and movable magnetic cores in operative relation to said helical means and to one another, and responsive to said variations; and a variable-resistance transmitting medium having a movable electrode attached to said movable core to be actuated thereby; with a local circuit containing the

magnetizing helical means of said receiving device; and an adjustable resistance therein, for the regulation of said initial field.

61. A telephone-current reinforcing system and apparatus, consisting of a main circuit; a bridge between the conductors thereof; a local circuit; a magnetizing helical means in said local circuit; a magnetization-varying helical means associated with said main circuit and connected in the bridge thereof; a fixed iron pole-piece or core excited by said magnetizing helical means and extending into the said varying helical means, to establish an initial magnetic field variable by the action thereof; a transmitting medium comprising vibratory or movable and fixed electrodes; electrical connections between said transmitting medium and a second main circuit or main circuit-section; and a complementary and movable iron core or pole-piece, mounted loosely within said bridged varying helical means, with one end adjacent to the end of said fixed core in the said variable magnetic field, and having its other end attached to the movable electrode of said transmitting medium, and adapted thereby to actuate the same in conformity with the variations of said magnetic field, and to cause the same to establish reinforced currents corresponding to such variations in said main circuit.

62. In a repeater, the combination of two magnets the cores of which form two magnetic circuits, one branch of which is on each magnet, pole pieces threaded in the openings of the cores farthest removed from each other, said pole pieces being directed toward each other, a variable resistance medium supported upon the middle branch of the core and having an armature interposed between said pole pieces.

63. In a repeater, the combination of two magnets, the cores of which form two magnetic circuits, one branch of which is on each magnet, poles pieces threaded in the openings of the cores farthest removed from each other, said pole pieces being directed toward each other, a variable resistance medium supported upon the middle branch of the core and having oppositely directed armatures supported between said pole pieces, said armatures being attached to a movable electrode.

64. In a repeater, the combination of two magnets, the cores of which form two magnetic circuits, one branch of which is on each magnet, pole pieces threaded in the openings of the cores farthest removed from each other, said pole pieces being directed toward each other, a variable resistance medium supported upon the middle branch of the core and having an armature, said variable resistance medium comprising a central electrode and two connected electrodes on opposite sides of said central electrode, said latter electrodes each carrying an armature directed toward and between said pole pieces.

65. In a telephone repeater system, the combination with a main line circuit, of two sets of receiver transmitter-repeaters in local circuits associated with said main line inductively, and means for balancing said receivers in the local circuits against local self-action and reproduced line currents.

66. In a telephone repeater apparatus, local circuits, two repeaters in inductive local relation to a line, local balances for the repeaters producing a differential flow of local currents for controlling the repeaters to render them inoperative or inert to said locally produced currents.

67. In an automatic reciprocal telephone repeating system, the combination of a main telephone circuit divided into independent sections, two repeaters, differential windings in balanced relation to the reproduced or locally set up currents, circuit means for rendering the repeaters responsive to the originating line currents, local circuits for the repeaters inductively associated with the main circuit, current supply for the repeaters for renewing the originating line currents with increased power, each repeater transmitter operating to induce its reproduced current in one line section.

68. In a double or twin telephone repeater apparatus, twin local circuits each embracing a current supply and a receiver and transmitter associated in repeater relation to each other, means for associating both receivers and both transmitters with a line inductively, electrical balances in the twin local circuits for each repeater for preventing local self-action therein, the said inductive associating means rendering the said balances self-dependent and constant.

69. In a reciprocal telephone repeater system, a repeating apparatus at an intermediate station on a line circuit connected through said repeating apparatus for repeater service, said apparatus embracing two independent units, each unit comprising a receiver and a transmitter associated in repeater relation, the units being electrically associated in repeater relation and being in inductive relation to the line circuit, and associated local circuit means whereby the repeaters are constantly maintained unresponsive to their reproduced and locally set-up currents but are responsive to the initial line currents.

70. In a telephone repeater apparatus, the combination of two repeaters each comprising a receiver and transmitter associated in repeater relation, local circuits for the repeaters, each receiver being connected up in one of said local circuits and having a balance, said balance including differential windings for preventing interfering opera-

tion by its locally set up or reproduced currents.

71. In a telephone repeater system, the combination of a main circuit formed of two circuits or two circuit sections associated for repeater service, two repeaters, each comprising receiving and transmitting mediums, induction coil windings operatively associating all said repeater mediums inductively with said main circuit, each receiver actuating its repeater transmitter and each transmitter repeating into a different circuit section, each receiver being rendered inert by differential windings to the local or reproduced currents flowing in the differential windings but sensitive to the initial inward currents flowing through said windings non-differentially.

72. In a telephone repeater apparatus, the combination of two repeaters, local circuits therefor, said local circuits being divided and containing induction coil windings in inductive relation to a line circuit, and connected up or arranged to cause locally produced currents in the repeater apparatus to flow differentially with relation to the receivers to provide a neutral state for each and to avoid reaction.

73. In a telephone repeater, two repeaters, two divided local circuits by which the repeaters are controlled, each repeater having a local differential current balance to prevent interfering reaction.

74. In a telephone repeater apparatus, two repeaters reciprocally coöperative, two divided local circuits, one for each repeater, in which the repeaters are controlled by means of differential local current balances to prevent interfering reaction.

75. A telephonic voice-current repeating instrument, comprising an initially magnetized receiving magnet and its circuit connections; a transmitting microphone and its circuit connections, embodying a stationary rear electrode, an opposed electrode in the form of a single, peripherally-clamped, non-magnetic, diaphragmatic, composite electrode-diaphragm structure, electrically related to said stationary rear electrode, with the central axis of vibratory movement of said diaphragm-electrode structure substantially coincident with the central line of pull of said magnet; and a rigid block armature in the field of said magnet, rigidly and centrally attached to said diaphragm structure, the magnet iron and armature forming a substantially continuous ferric magnetic circuit, broken only by the air gap to permit armature movement; whereby said magnet acts magnetically on said microphone only through said block armature and whereby the magnetically caused armature vibration is communicated directly and rigidly to said diaphragm structure and the vibratory movement of the latter is free from the damping effect of any other clamped diaphragm.

76. A telephonic voice-current repeating instrument, comprising an initially magnetized receiving magnet and its circuit connections; a transmitting microphone and its circuit connections, embodying a stationary rear electrode, an opposed electrode in the form of a single, peripherally-clamped, non-magnetic, diaphragmatic, composite electrode-diaphragm structure, electrically related to said stationary rear electrode, with the central axis of vibratory movement of said diaphragm-electrode structure substantially coincident with the central line of pull of said magnet, together with a loose mass of carbon granules interposed between said electrodes; and a rigid block armature in the field of said magnet, rigidly and centrally attached to said diaphragm structure, the magnet iron and armature forming a substantially continuous ferric magnetic circuit, broken only by the air gap to permit armature movement; whereby said magnet acts magnetically on said microphone only through said block armature and whereby the magnetically caused armature vibration is communicated directly and rigidly to said diaphragm structure and the vibratory movement of the latter is free from the damping effect of any other clamped diaphragm.

77. A telephonic voice-current repeating instrument, comprising an initially magnetized receiving magnet and its circuit connections; a transmitting microphone and its circuit connections, embodying coöperating electrodes comprising a rear stationary electrode and one in the form of a single peripherally-clamped, non-magnetic, diaphragmatic composite electrode-diaphragm structure, electrically related to said stationary rear electrode with the central axis of vibratory movement of said diaphragm-electrode structure substantially coincident with the central line of pull of said magnet; and a rigid block armature in the field of said magnet, rigidly and centrally attached to said diaphragm structure, the magnet iron and armature forming a substantially continuous ferric magnetic circuit, broken only by the air gap to permit armature movement; whereby said magnet acts magnetically on said microphone only through said block armature and whereby the magnetically-caused armature vibration is communicated directly and rigidly to said diaphragm structure and the vibratory movement of the latter is free from the damping effect of any other clamped diaphragm.

78. In an automatic reciprocal telephone repeating system, the combination of a main telephone circuit divided into two sections, two repeaters, windings in differential relation to the reproduced or locally set up

currents, means including inductance for balancing the reproduced currents in said windings, circuit means for rendering the repeaters resposive to the originating line currents, local circuits for the repeaters inductively associated with the main circuit, and current supply for the repeaters for renewing the originating line currents with increased power, each repeater transmitter operating to induce its reproduced current in one line section.

79. In a telephone repeater or relay, the combination with a telephone circuit, of magnets having their poles opposite each other, coils on such magnets connected to said circuit, a casing between such poles, diaphragms extended across said casing opposite such poles, a rod extended through said diaphragms, armatures on such rod, electrodes, one of which is carried by said rod, a second telephone circuit, and means by which such second circuit can be influenced by the said electrodes, substantially as and for the purpose described.

80. In a telephone repeater or relay, the combination with a telephone circuit, of magnets having their poles opposite each other, coils on such magnets connected to said circuit, a casing between such poles, diaphragms extended across said casing opposite such poles, a rod extending through said diaphragms, armatures on such rod, electrodes that are substantially concentric with such rod, one of such electrodes being secured to said rod and another of such electrodes having a central aperture through which such rod freely passes, a second telephone circuit, and means by which such second circuit can be influenced by the said electrodes, substantially as and for the purpose described.

81. In a telephone repeater or relay, the combination with a telephone circuit, of magnets having their poles opposed to each other and having coils thereon which are connected to said circuit, a casing between such poles, diaphragms extended across said casing, a rod passing through such diaphragms, armatures on said rod having coils which are connected to such circuit, electrodes, one of which is carried by said rod, a second telephone circuit, and means by which said second circuit can be influenced by said electrodes, substantially as and for the purpose described.

82. In a telephone repeater or relay, the combination with a telephone circuit, of magnets having their poles opposite each other, coils on such magnets connected to said circuit, a casing between such poles, non-magnetic diaphragms extended across said casing opposite such poles, a rod extending through said diaphragms, armatures on such rod, electrodes, one of which is carried by said rod, a second telephone circuit, and means by which said second circuit can be influenced by the said electrodes, substantially as and for the purpose described.

83. In a telephone repeater or relay, the combination with two mechanically connected electrodes, of an electrode located between the first-mentioned electrodes, an induction coil having two primary circuits connected so as to conduct currents in opposite directions therein, the like ends of such circuits being connected to the said first-mentioned electrodes, the remaining ends of such circuits being connected to said last-mentioned electrode, means for moving such first-mentioned electrodes relative to said last-mentioned electrode, and a telephone circuit connected to the secondary circuit of such induction coil, substantially as and for the purpose described.

84. In a telephone repeater, the combination of opposing magnets, armatures for and between said magnets, an electrode movable by each armature, said armatures being connected together, a casing containing said electrode, diaphragms in said casing, said diaphragms supporting the armatures and electrode, and a standard upon which said casing is supported.

In testimony that I claim the foregoing I have hereunto set my hand this 19th day of February 1902.

ELWOOD GRISSINGER.

Witnesses:
M. F. DIRNBERGER, Jr.,
A. G. STRIKER.