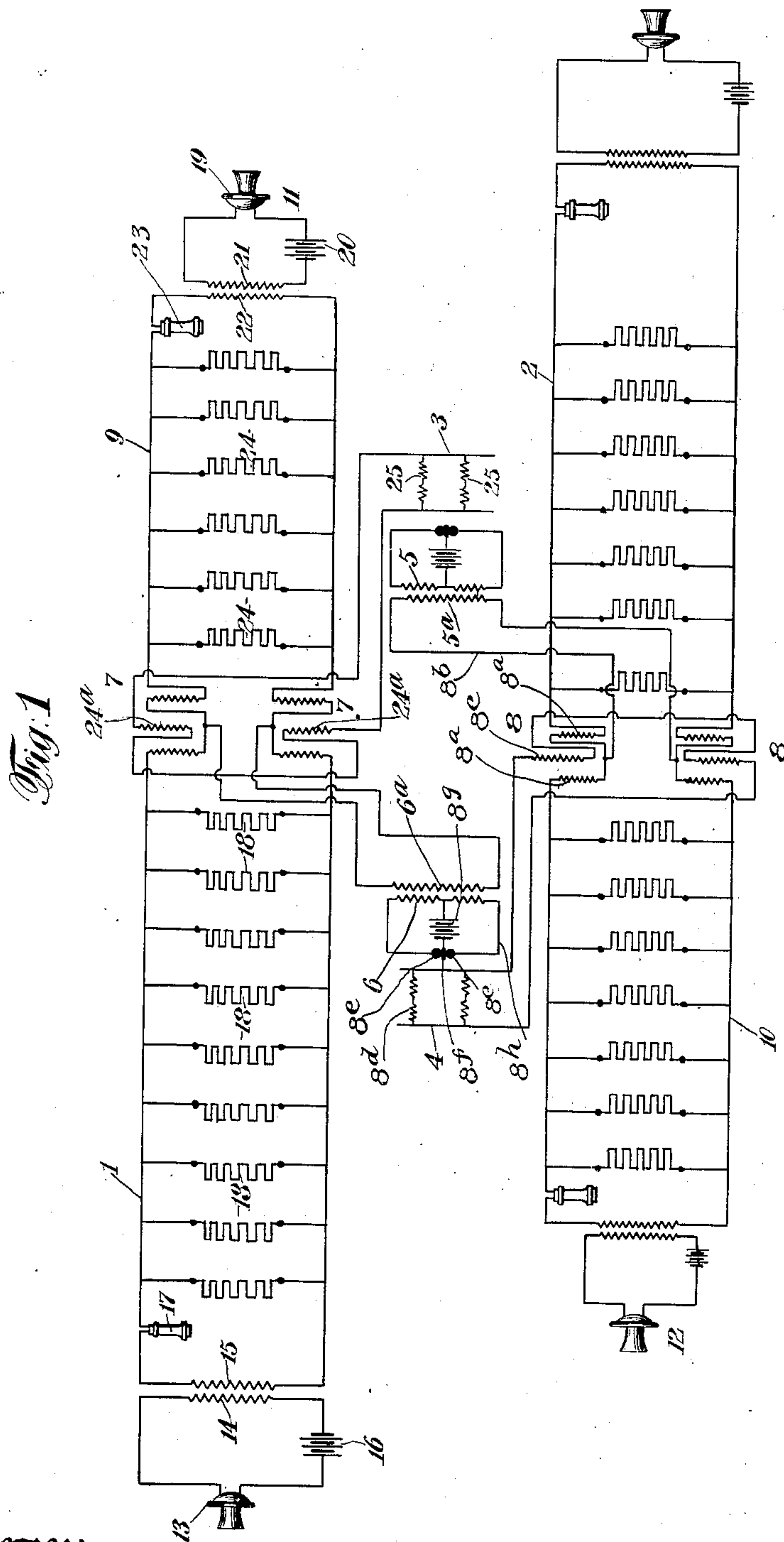


E. GRISSINGER.
TELEPHONE SYSTEM.
APPLICATION FILED NOV. 18, 1911.

1,198,214.

Patented Sept. 12, 1916.

3 SHEETS—SHEET 1.



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3 SHEETS—SHEET 2.

Fig. 4

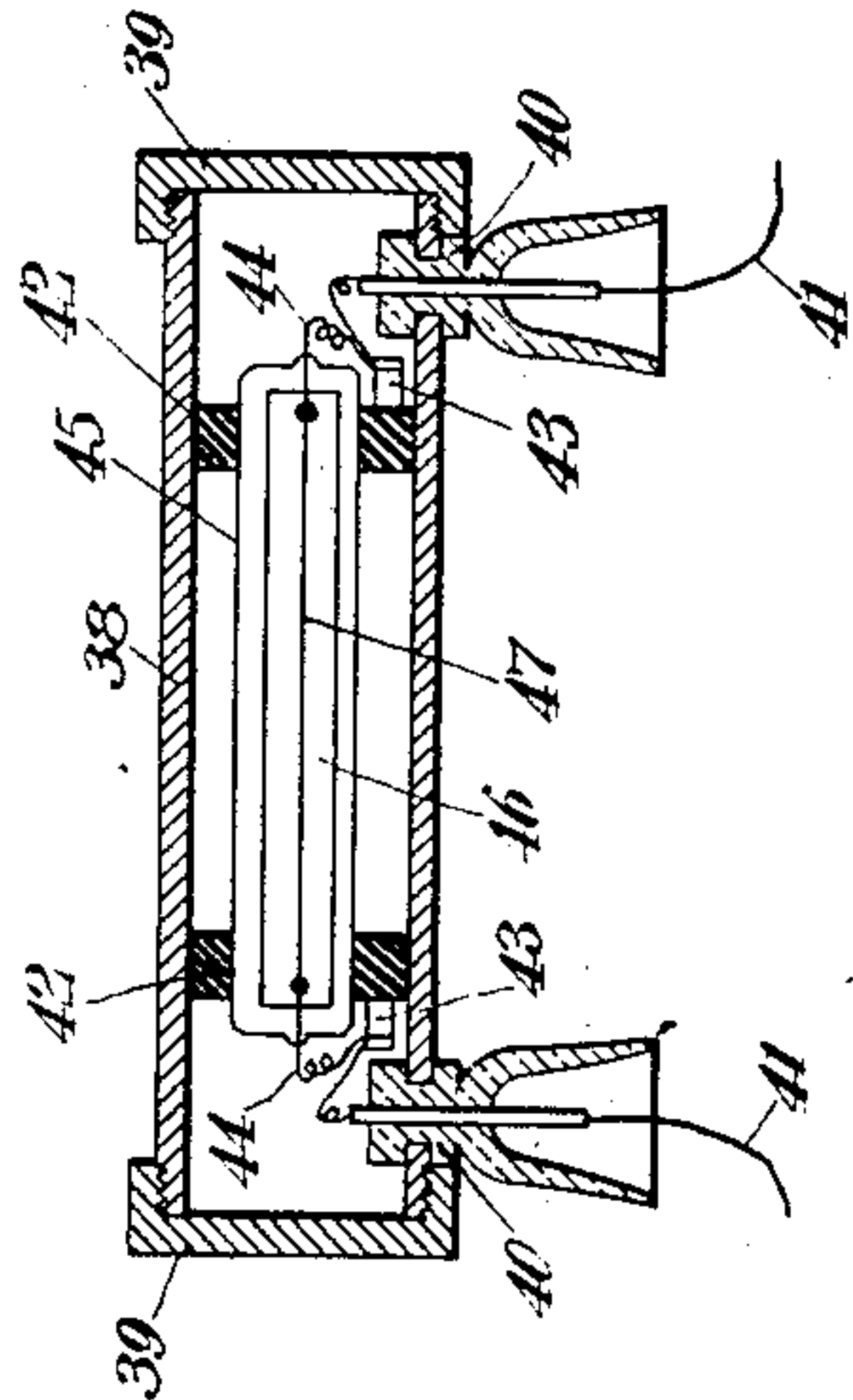


Fig. 5

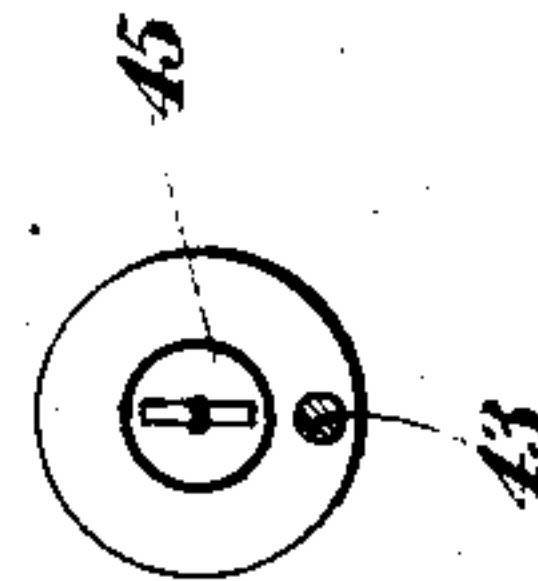
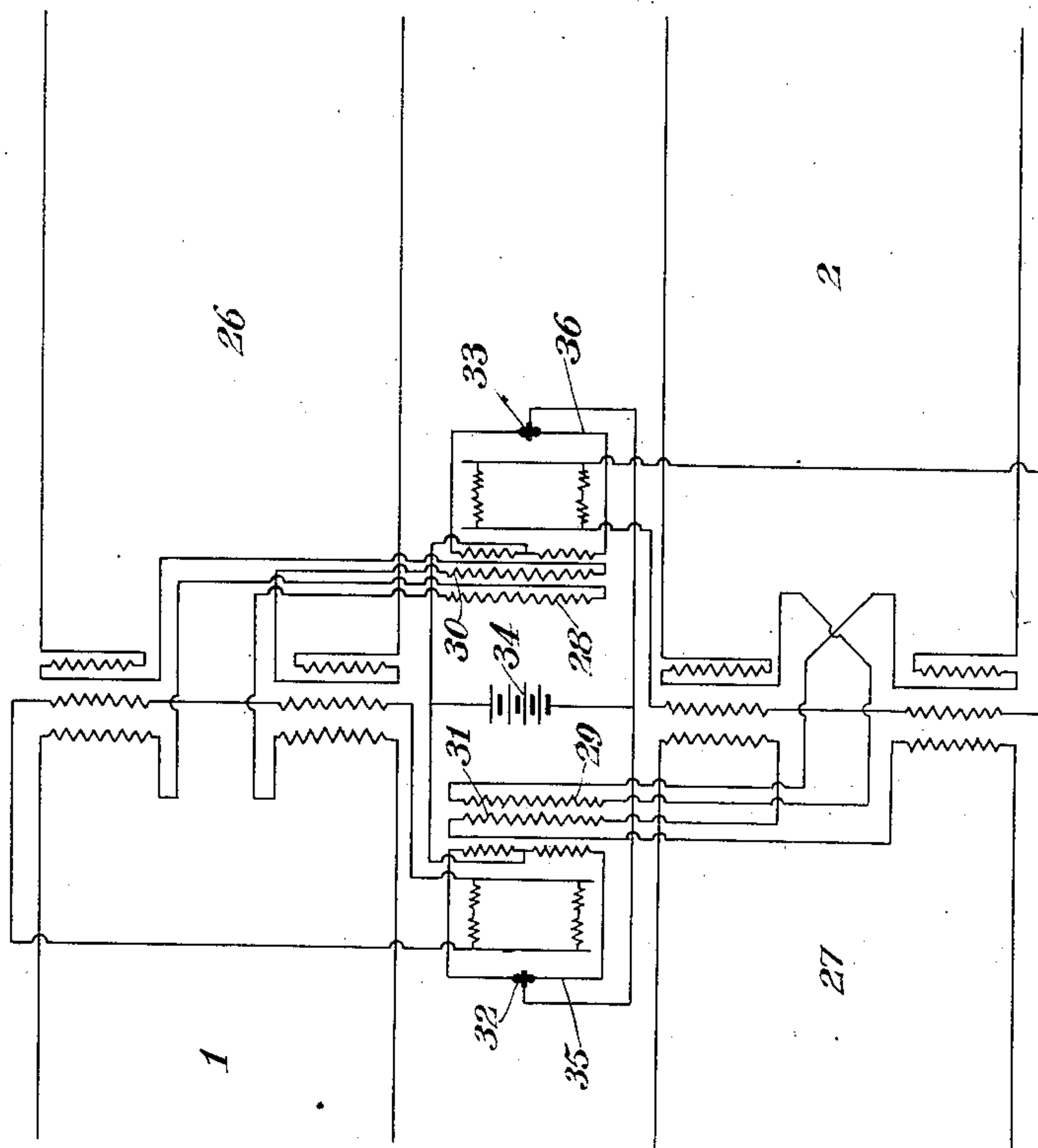


Fig. 2



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3 SHEETS—SHEET 3.

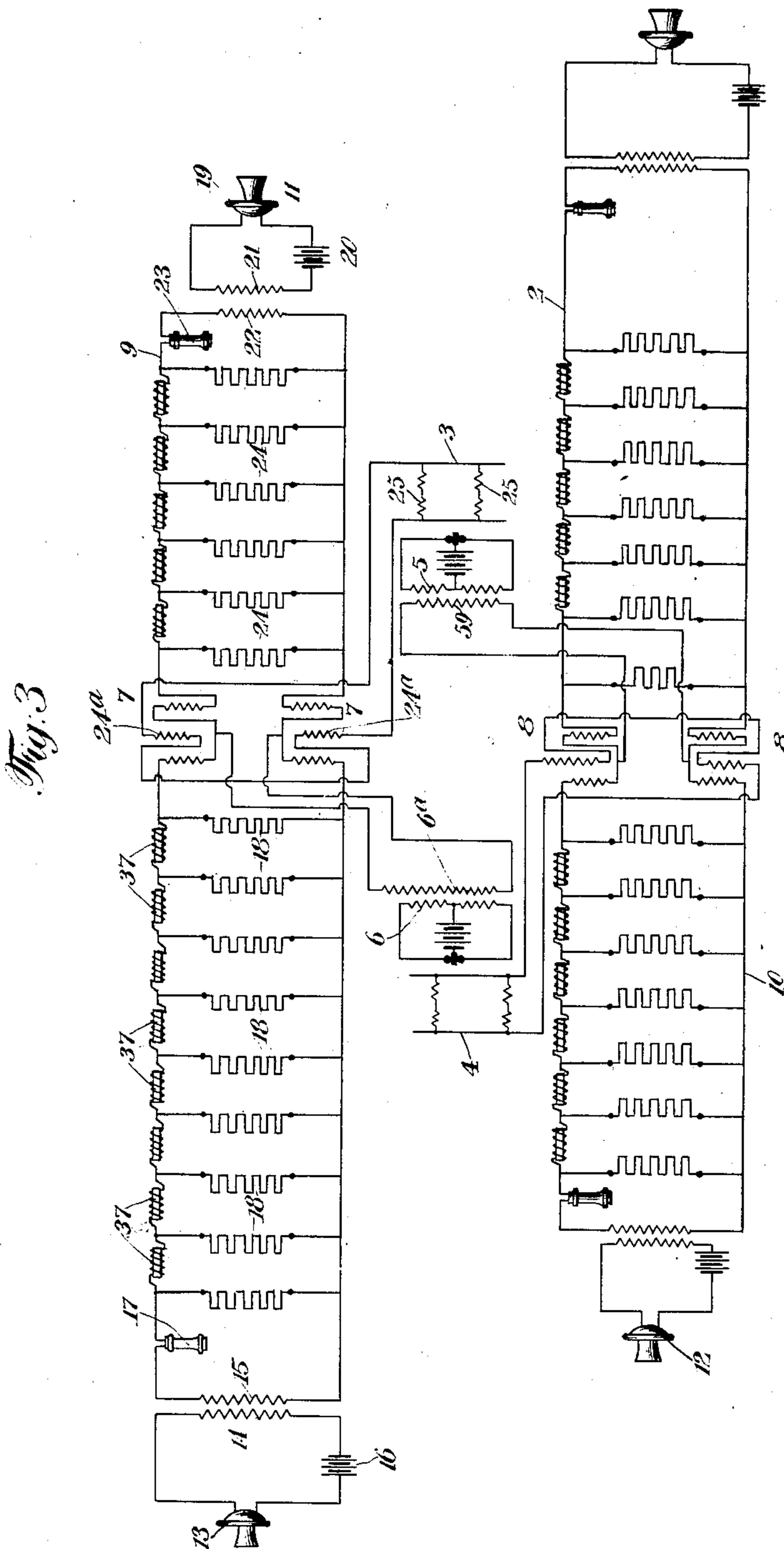


Fig. 3

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UNITED STATES PATENT OFFICE.

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TELEPHONE SYSTEM.

1,198,214.

Specification of Letters Patent. Patented Sept. 12, 1916.

Application filed November 18, 1911. Serial No. 660,994.

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 a certain new and useful improvement in Telephone Systems, and do hereby declare that the following is a full, clear, and exact description thereof.

My invention relates to an improvement in telephonic transmission whereby advantage is taken of the method of inserting leakage resistances across the line so proportioned that the magnetic energy of an electromagnetic wave traversing the line may be kept in equality with the electric energy of the same wave; or expressed differently, the leakage resistances shall be so proportioned and inserted across the line, that the rate of decay of the magnetic field associated with a telephone wave traversing the line shall be approximately equal to the rate of decay of electric field associated with the same wave. It has been established that when this equality exists, a distortionless transmission exists and a wave of the same characteristics is delivered at the end of a line which was originally created.

It is understood that a pure electromagnetic wave on a telephone transmission line consists of electric and magnetic fields traveling together and mutually sustaining each other; that the immediate effect of wire resistance is to cause a progressive decay of the magnetic field associated with the wave and that the immediate effect of imperfect insulation between the transmission wires is to cause a progressive decay of the electric field associated with the wave. Generally the energy loss in a transmission line due to the wire resistance is termed the "wire loss", while the energy loss because of imperfect insulation between the transmission wires is called the "leakage loss."

It so happens that the wire loss of a line, under the normal conditions of a well insulated line, exceeds the leakage loss and therefore the rate of decay of the magnetic field is greater than the rate of decay of the electric field.

The method now in use of loading a telephone line with inductance coils has the effect of reducing the wire loss and of increasing the leakage loss. The leakage loss really remains unchanged for a given value of voltage, but, since the loading of the line

reduces the velocity of transmission, the leakage loss continues for a longer period of time.

It is practically impossible to so load a telephone line that distortionless transmission will result, or that the range of transmission over a given line can be largely increased. The best that can be done is to increase the efficiency of transmission to a certain extent and improve the quality. If, however, we combine a loaded line, which is also provided with the properly proportioned leakage resistances, as will be described in detail hereinafter, with a telephone repeater to compensate for leakage losses, we will then have a highly improved condition of transmission, which will greatly extend the range of transmission and which will also vastly improve the quality of transmission over existing lines.

The insertion of such leakage resistances materially reduces the volume of energy delivered and because of this I use in connection therewith a telephone repeater and particularly a special form of repeater, which I have perfected, to compensate for the loss of volume which the insertion of such leakage resistances creates.

The magnetic energy of a unit length of transmission line (including the two wires of a line, in and out) is expressed as $\frac{1}{2}LI^2$ and the electric energy of the same unit length of transmission line is expressed as $\frac{1}{2}CE^2$. Distortionless transmission of electric waves will be accomplished so long as $\frac{1}{2}LI^2 = \frac{1}{2}CE^2$. In these expressions, L is taken as the inductance per unit length of line, C as the capacity of the same, I the current in the line associated with the wave and E the voltage across the line due to the electric field in the wave. In these equations also, everything may be expressed in c. g. s. units, or L may be expressed in henrys per mile, C in farads per mile, I in amperes of current strength and E in volts. When these conditions are satisfied and, therefore, the potential energy of the electric field associated with a wave is maintained equal to the kinetic energy of the magnetic field associated with the same wave, then distortionless transmission results.

I have shown certain modifications of my invention in the accompanying drawings, in which—

Figure 1 represents a circuit arrangement

to which my invention is applied; Fig. 2 represents a slight modification of the arrangement shown in Fig. 1; Fig. 3 represents a circuit arrangement such as that shown in Fig. 1, but carrying loading coils; Fig. 4 shows a longitudinal cross-section of a form of leakage resistances which may be used; and Fig. 5 represents a transverse cross-section of the same.

My invention which has been outlined in general above is applicable to almost any type of telephone circuit, but I have, for the purposes of illustration and explanation, shown it as applied to only one type of circuit arrangement, as shown particularly in Fig. 1.

In Fig. 1 line 1 and line 2 represent virtually a telephone line divided into two parts at the central or some other intermediate point. Wherever such division in the line is made telephonic repeating instruments are installed, such instruments being represented here as relays 3 and 4, respectively. These instruments with their complement of induction coils 5, 5^a, 6 and 6^a, and repeating coils 7 and 8, together with artificial balancing lines 9 and 10 and operator's telephone sets 11 and 12 respectively, are all situated preferably at the same central or intermediate point where the main telephone line is separated and re-connected through the repeating apparatus, or where it is desired to repeat from one of two different telephone lines into the other and vice versa.

The relays are constructed and are associated with the repeating coils in the following manner: Between the main circuit 2 and the corresponding balancing circuit 10, there are located two separate repeating coils 8. Each of these repeating coils 8 comprises a pair of primary windings 8^a which are wound in opposite directions, and a wire 8^b is bridged across the main circuit 2 at points located between the primary coils 8^a of both of the repeating coils 8. This wire 8^b contains the secondary 5^a of the induction coil contained in the relay 3. Inductively associated with each pair of coils 8^a is a secondary 8^c, the two secondaries 8^c being located in the same circuit with a set of exciting coils 8^d which are provided in the relay 4. The exciting coils 8^d are located adjacent to and are adapted to produce movements of a pair of armatures 8^e, which are connected to movable electrodes and which cooperate with a stationary electrode 8^f, these electrodes being adapted to actuate a double variable resistance medium in such a manner that when the resistance between the stationary electrode 8^f and the movable electrode 8^e on one side thereof is increased, the resistance between the stationary electrode and the other movable electrode on the other side thereof is decreased. These electrodes and variable resistance mediums are connected in a special double local

circuit, comprising a battery 8^g, one terminal of which is connected to the stationary electrode and the other terminal of which is branched and is connected to two separate primary coils 6, each of which coils is connected by means of a wire 8^h to one of the movable electrodes 8^e. The other relay 3 and its associated exciting coils and corresponding induction coils in the main circuit 1 are connected in a similar manner. The purpose of arranging the repeating coils in this manner is to enable a message being sent from the main line 2, for example, to be transferred to the corresponding relay 4 and finally to the main circuit 1 without reacting upon the other relay 3 and sending a corresponding message back into the main circuit 2. In sending a message in this manner, the electric waves passing through all the primaries 8^a pass through said primaries in the same direction and have the same effect in inducing a current in the secondary 8^c, which current is conducted through the exciting coils 8^d, thereby moving the movable electrodes 8^e and setting up waves in the wires 8^h in the local circuit of the relay 4. Owing to the fact that when the resistance is increased in the variable resistance medium in one side of the local relay circuit, and at the same time decreased in the other side thereof, corresponding waves will be induced upon the secondary 6^a by the primaries 6 in the two sides of the local relay circuit. A current of great strength will thus be induced in the secondary 6^a which is conducted through the primaries of the repeated coils 7, which primaries correspond in value to the primaries 8^a already described as being in the repeating coil 8. It will be noted, however, that this current is caused to pass through the two primaries of the same repeating coil 7 in different directions. As a consequence, the effects of these two primaries upon the secondary 24^a will be neutralized and no current will therefore be induced in the secondaries 24^a. It will therefore be seen that the sending of electrical waves from the relay 4 into the main circuit 1 can be accomplished without in any way influencing the other relay 4, and without influencing the condition of the current in the main circuit 2 from which the message has been sent.

In Fig. 1 13 indicates a transmitter located at the end of line 1 in one of the subscriber's sets, 14 and 15 indicate, respectively, the primary and secondary coils of the induction coil associated therewith, 16 represents the battery of the subscriber's set and 17 indicates the receiver contained in the subscriber's set. As shown in this figure, I locate at regular intervals along the line 1, one or more leakage resistances 18 which are bridged across the line.

The artificial line 9 is made to balance

the real line 1 by making its electrical characteristics approximately the same as those of said real line, preferably by duplicating as nearly as may be the different parts and instruments thereof, and arranging them in inverse order or symmetrically with respect to the point of junction of the real and artificial lines. In Fig. 1 the artificial line 9 is diagrammatically indicated as comprising a plurality of artificial units corresponding to the real line. The subscriber's instruments in the real line, are symmetrically duplicated at the remote end of the artificial line by the relay operator's instruments, which include a transmitter, 19, a battery, 20, an induction coil having primary and secondary windings, 21 and 22, and a receiver, 23. The six leakage resistances, 24, shown as distributed in the artificial line, are equal in the aggregate and correspond in distribution to the nine leakage resistances, 18, shown in the real line, 1. The smaller number of these resistances in the artificial line and the shorter length of the latter indicates that the distribution in the artificial line will usually be in fewer units or elements than in the real line.

The more perfectly the artificial elements are made to simulate the real line, the more perfect will be the phase balance. How perfect the phase balance should be will depend on other conditions but in general it may be said that the more perfect this is the wider latitude there will be for permissible variations in other parts of the repeater system. The more repeaters there are on the line, the nearer the repeater stations are together, and the greater the amplifying power of the repeaters, the more perfectly should the artificial line simulate the real line. There are two of the repeating coils 7, one being located at each side of the main line. These coils are arranged so that their secondaries 24^a are located in the same circuit with a series of exciting coils 25 contained in the relay 3. Lines 2 and 10 are constructed in exactly the same manner as lines 1 and 9, the details of which have already been described. The arrangement of both lines is symmetrical. Relay 3, for instance, receives its exciting current by induction from the main line 1 through the repeating coil 7. Relay 3, therefore, creates a new wave which is transmitted to the middle points of the windings comprising the coil 8 situated in lines 2 and 10. The new wave from relay 3, therefore, divides between line 2 and its artificial balancing line 10. It is to be noted, however, that the wave created by relay 3 and impressed upon line 2 is the only wave which is impressed upon line 2 and its artificial balancing line 10, and that therefore there are no other waves in interference with or tending by induction, or otherwise, to throw the

lines out of phase. As a matter of fact, the phase relations between lines 1 and 2 will vary from one another, but as these lines are entirely independent, this will make no difference. Similarly, relay 4 derives its exciting current by induction from line 2 through the repeating coil 8. The new wave created by relay 4 is therefore impressed upon line 1 and its artificial balancing line 9 at the middle point of the windings comprising the repeating coil 7.

Thus the system comprises a real line cut up into a plurality of real line sections, each provided with a symmetrically constructed phase balancing artificial line extension, with a two-way talking, two-repeater local circuit interconnecting the sections at the balancing points, in such manner as not to disturb the balance of either of them. Fig. 1 is a modification of Fig. 6 in my present application for United States patent, Serial No. 95,380, differing from the said figure in that windings of the repeating coil are inserted in each side of said line for the express purpose of making a more complete balance in the characteristics of the main and artificial lines. Another difference to be noted is that instead of simple inductance inserted in the artificial line, there is in the present figure an operator's set included, which is intended to have an inductance value in the transmitter set approximately equal to that of the subscriber's telephone set. The simple inductance would very well serve the purpose of balancing the subscriber's set at the other end of the real line, but the use of an operator's set at this point is of very great value. The relayed voice currents applied at the balancing point or junction of the real and artificial line sections divide equally and traverse electrically similar and equal conductors. Hence they are of precisely the same quantity and quality in the operator's receiver, 21, at the end of the artificial line, as they are in the subscriber's instrument, 17, at the end of the real line. The relay operator hears exactly the same volume and quality of sound that the subscriber hears, and by listening in at the ends of the two artificial lines he may supervise without producing the slightest effect on the volume of current delivered or the sound produced at the subscribers' stations. The next and most pronounced difference between my present invention and that of my said prior application, is the insertion of leakage resistances across the main and balancing lines.

The manner in which the size of the leakage resistances 18 may be calculated is as follows: The rate at which energy is lost in a unit length of telephone line by wire resistance is represented by $2R_w I^2$ where R_w equals wire resistance and I equals current.

The loss in same unit length of line by leakage is represented by $\frac{E^2}{R_1}$ where E equals electro-motive force and R_1 equals resistance to leakage. Distortionless transmission is accomplished when

$$2R_w I^2 = \frac{E^2}{R_1}$$

The ratio $\frac{E^2}{I^2}$ is, however equal to $\frac{L}{C}$ so that the above equation would become

$$R_w = \frac{L}{2C} \cdot \frac{1}{R_1}$$

or by transposing

$$R_1 = \frac{L}{2C} \cdot \frac{1}{R_w}$$

from which the value of R_1 can be determined, the other quantities being known. The value of R_1 being known, the dimensions of the leakage resistances for distortionless transmission can be determined.

The construction shown in Fig. 2 is substantially the same as that shown in Fig. 1 except that the main lines 1 and 2 are not connected directly in circuit with their corresponding balancing lines 26 and 27, but are inductively associated therewith. In this modification, furthermore, the main lines 1 and 2 and the balancing lines 26 and 27 each have independent secondary coils 28, 29, 30 and 31, in the induction coils associated with the relays 32 and 33. Furthermore, in this construction the local circuits of the relays 32 and 33 are arranged with a main source of energy shown as a battery 34, from which branch circuits lead to the two local circuits 35 and 36 of the relays 32 and 33.

The modification shown in Fig. 3 is the same as that shown in Fig. 1, except that at regular intervals along the main lines and artificial balancing lines are introduced between the leakage resistances 18, a series of loading coils 37.

It is to be understood that when leakage resistances are inserted into telephone lines already equipped with loading coils, that such leakage resistances when compared with similar equipment of lines that are not loaded, shall have a higher ohmic resistance. The reason for this is that the use of loading coils, as already pointed out, increases the leakage loss in such a telephone line while decreasing the wire loss. To express it in another way, lines possessing loading coils shall have a smaller number of artificial leakage resistances inserted than an unloaded line, but with the same number of such resistances the respective ohmic resistance values of each shall be different.

In Figs. 4 and 5 I have shown one form

of leakage resistance that may be advantageously used. As shown in these figures, 38 represents a non-inductive metallic tube having its ends closed by means of screw-threaded caps 39. At one side of the tube 38 openings are made to receive insulating bushings 40, said bushings being cemented in place in the openings. It will be noted by an inspection of Fig. 4 that the outer portions of the insulating bushings 40 are bell-shaped so as to form effective insulators for leading in wires 41 which are molded in the central portions of the bushings 40 and extend into the interior of the tube 38. Within the tube 38 there is located a pair of annular insulators 42, each of which is provided with a terminal block 43 to which the ends of the wires 41 are attached. From the terminal blocks 43 wires 44 lead into two ends of a vacuum tube 45, on the interior of which is a glass plate 46 having arranged longitudinally thereon upon the face of the glass a line of graphite, or a pencil mark 47 to which the ends of the wires 44 are connected. The resistance provided by the passage of the current through the lines of graphite 47 is the resistance referred to above as being bridged across the main lines and balancing lines above referred to. The artificial leakage resistance is shown as supported within a vacuum tube. The object of this arrangement is to provide a leakage resistance which shall have an approximately constant value irrespective of atmospheric or other conditions. These leakage resistances may assume a variety of forms depending upon the megohm resistance which they shall possess and, therefore, their number upon a given line. It is preferable that whatever form they assume they shall be straight ohmic resistances and therefore non-inductive.

While I have described certain modifications of my invention above, it is to be understood that many changes may be made in the subject matter without departing from the spirit of my invention.

I claim:

1. 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, another limb in a telephone circuit and means for controlling the angular phase displacement in said circuit comprising a line in circuit with the third limb of the induction coil and associated with the first mentioned line only inductively.

2. 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, another limb in a telephone circuit, and means for controlling the current values in said circuit

comprising a line in circuit with the third limb of the induction coil, and associated with the first mentioned line only inductively.

5 3. 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, another limb in a telephone circuit, and means for balancing the telephone circuit comprising another
10 circuit including the third limb of the induction coil and an operator's telephone set located at the remote end of said balancing circuit and symmetrically with respect to the
15 telephone set at the remote end of said telephone circuit.

4. In a telephone repeater, the combination of a telephone circuit, a repeater, a three-limb induction coil, one limb of which
20 is in circuit with the repeater, another limb in a telephone circuit, and means for controlling the angular phase displacement in said circuit comprising another circuit including the third limb of the induction coil, the leak-
25 age loss and wire loss being balanced in both said circuits.

5. In a two-way talking telephone repeater system, a telephone line, a repeater circuit and means for neutralizing on the
30 energy receiving side of the repeater, the outgoing amplified energy, said means including an artificial balancing circuit having its electrical parts or elements disposed

symmetrically, in combination with an operator's telephone set at the remote end of
35 said artificial circuit, for the purposes described.

6. In a device of the character described, the combination of a telephone system having a relay, and two separate three-limb
40 induction coils, each of said coils comprising two primary windings and a single secondary winding, the two primaries of one of said coils being in one side of the main line
45 of the telephone system, the two primaries of the other coil being in the other side of said line, and the secondaries of said coils being in circuit with the relay.

7. In a device of the character described, the combination of a telephone system having
50 a relay, and two separate three-limb induction coils, each of said coils comprising two primary windings and a single secondary winding, the two primaries of one of said coils being in one side of the main line
55 of the telephone system, the two primaries of the other coil being in the other side of said line, and the secondaries of said coils being in circuit with the energy receiving
60 side of the relay.

In testimony that I claim the foregoing I have hereunto set my hand.

ELWOOD GRISSINGER.

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