

E. GRISSINGER.

TELEPHONE RELAY OR REPEATER.

APPLICATION FILED MAY 19, 1911. RENEWED SEPT. 18, 1916.

1,203,326.

Patented Oct. 31, 1916.

7 SHEETS—SHEET 1.



Fig. 10.

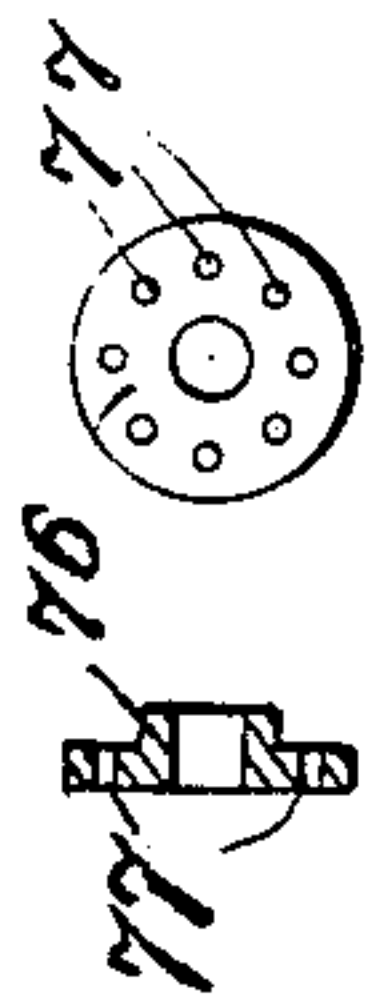


Fig. 9.

Fig. 1

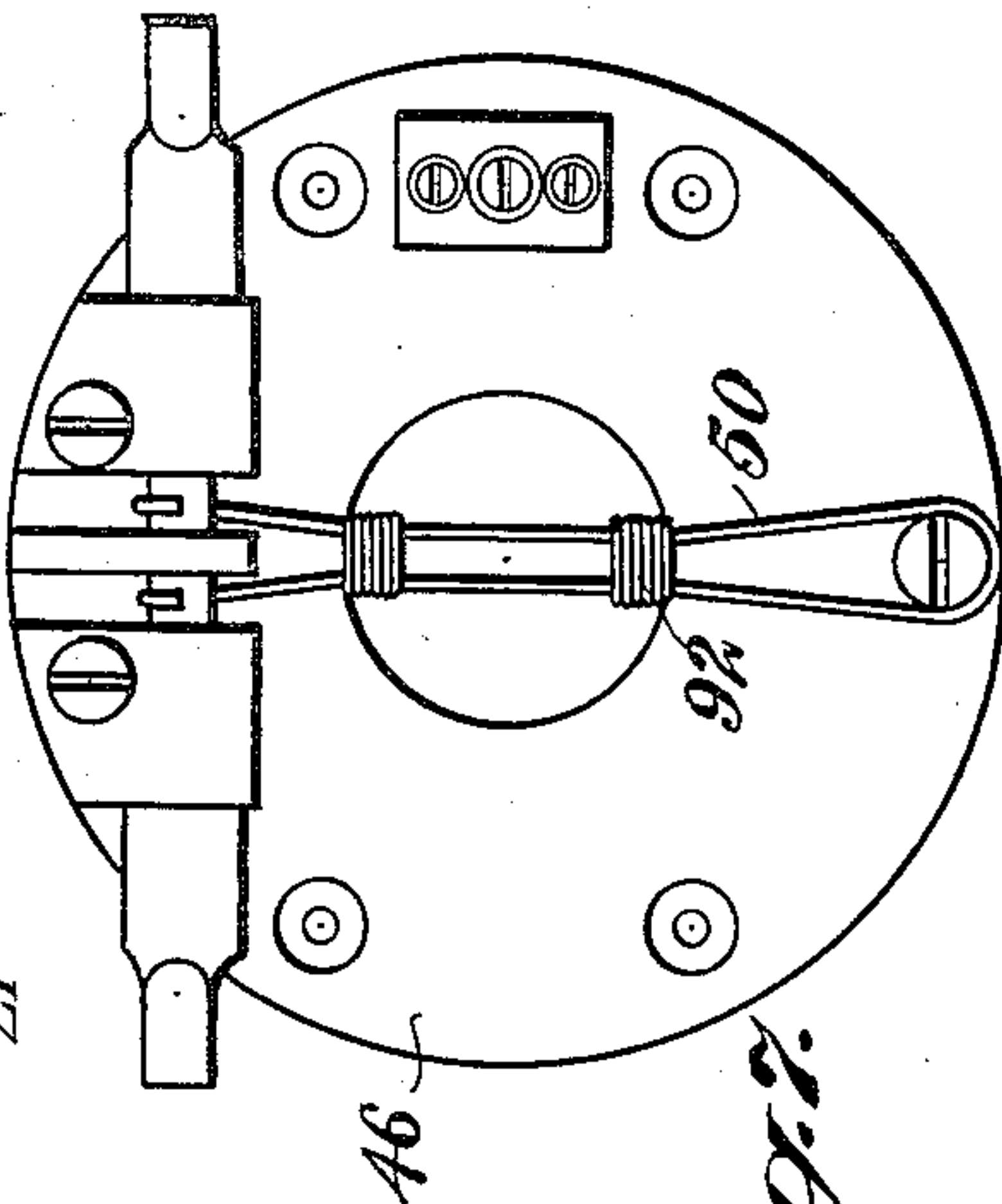
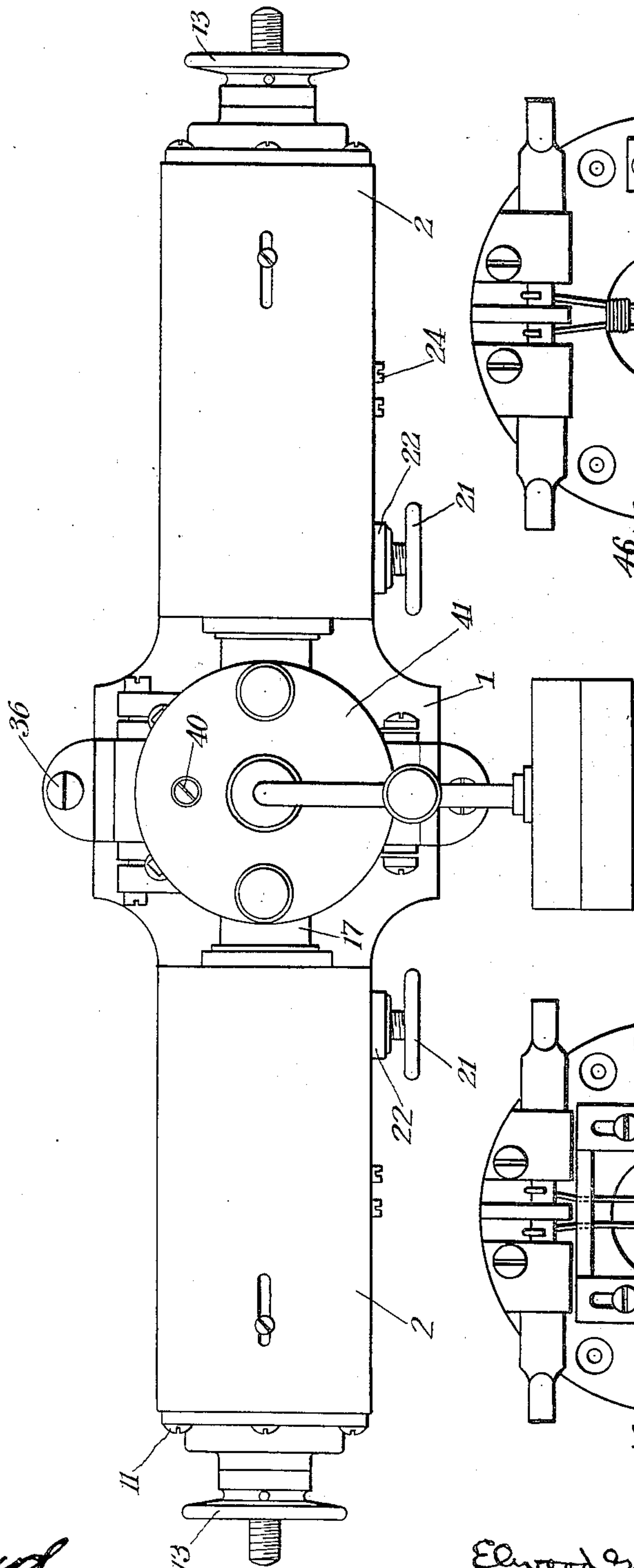


Fig. 2.

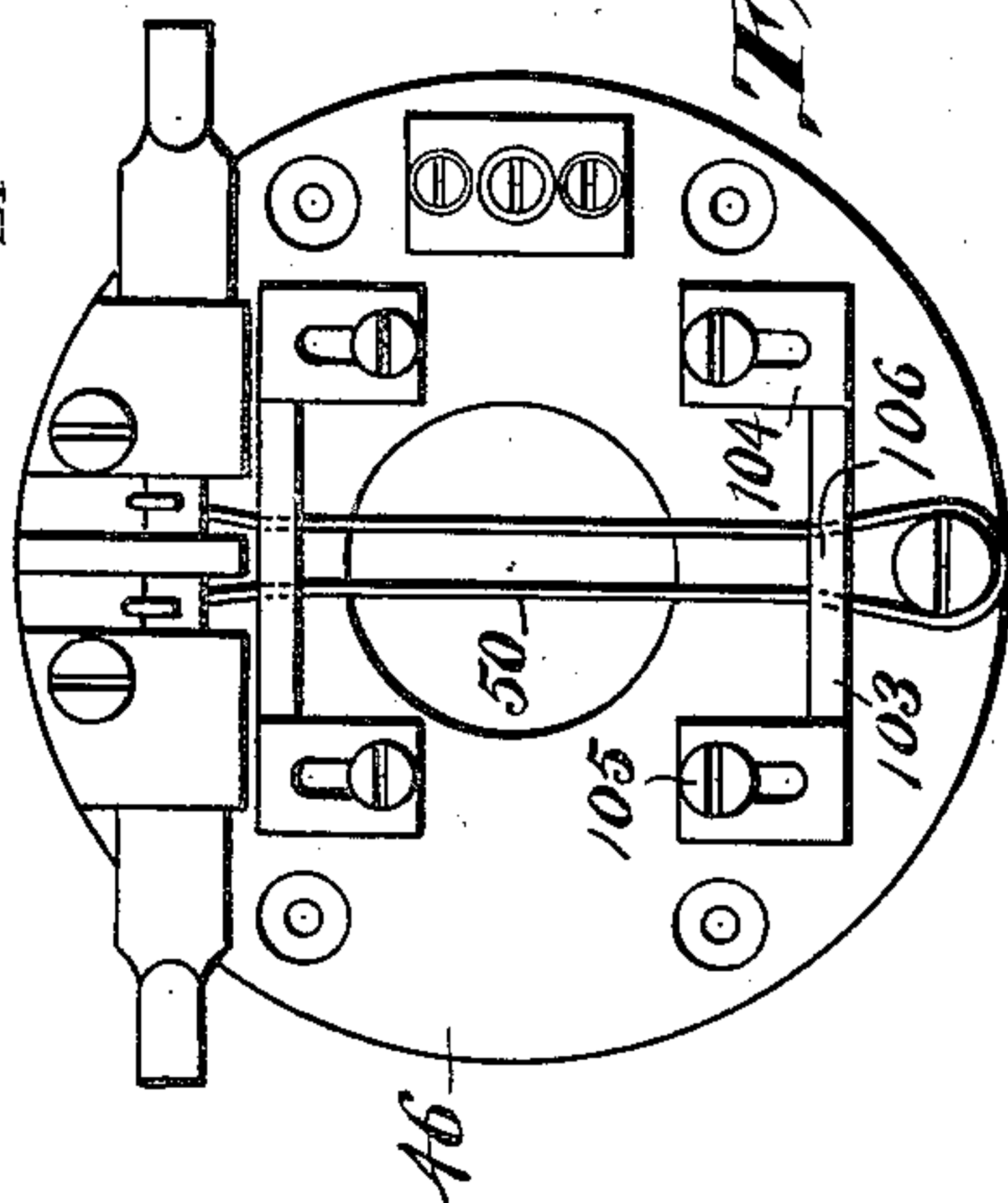


Fig. 6.

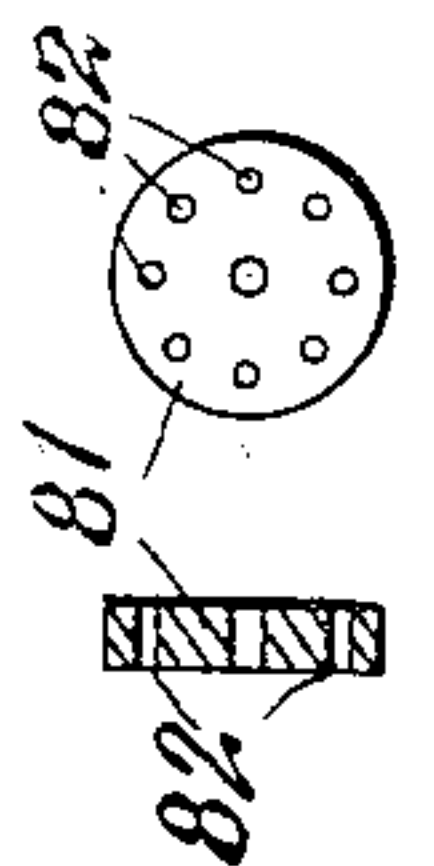


Fig. 8.

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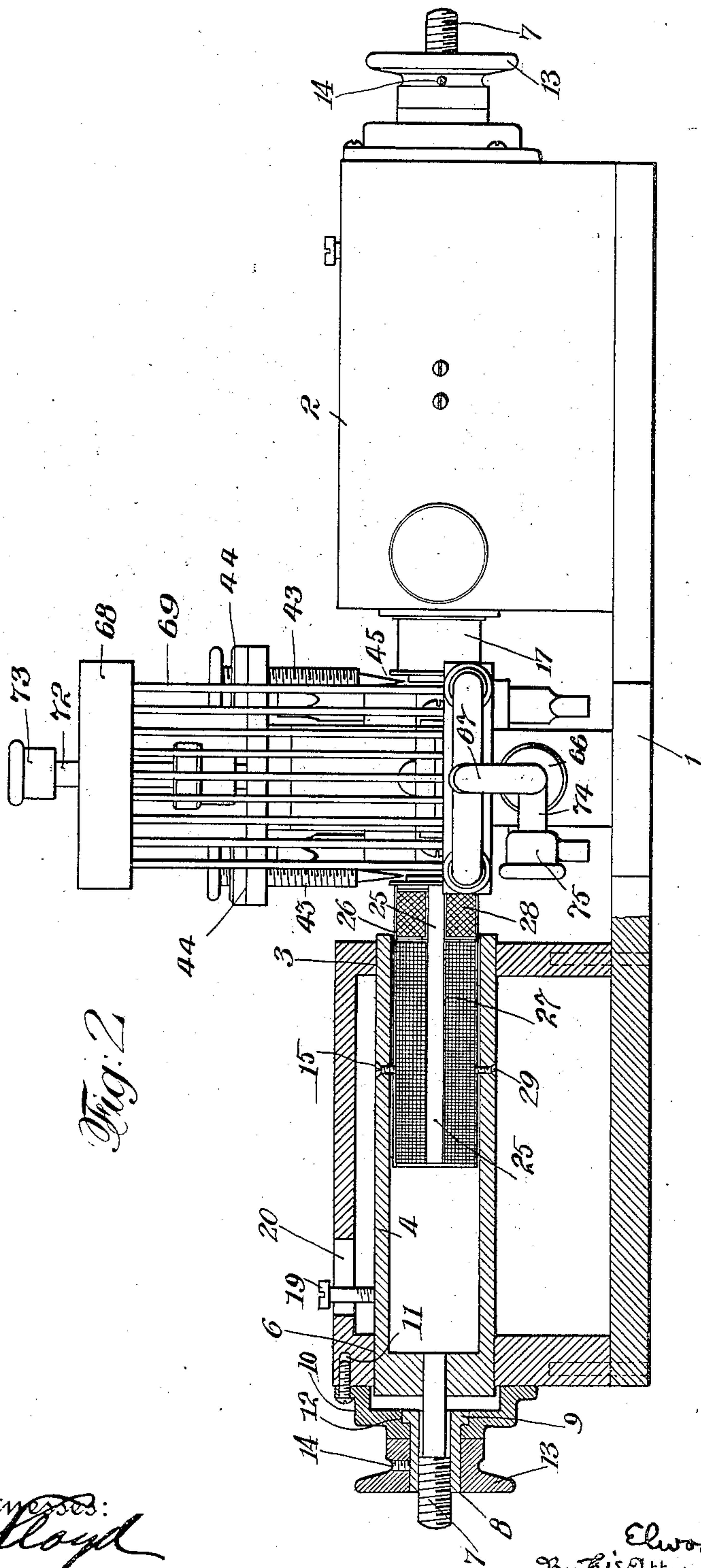


Fig. 2

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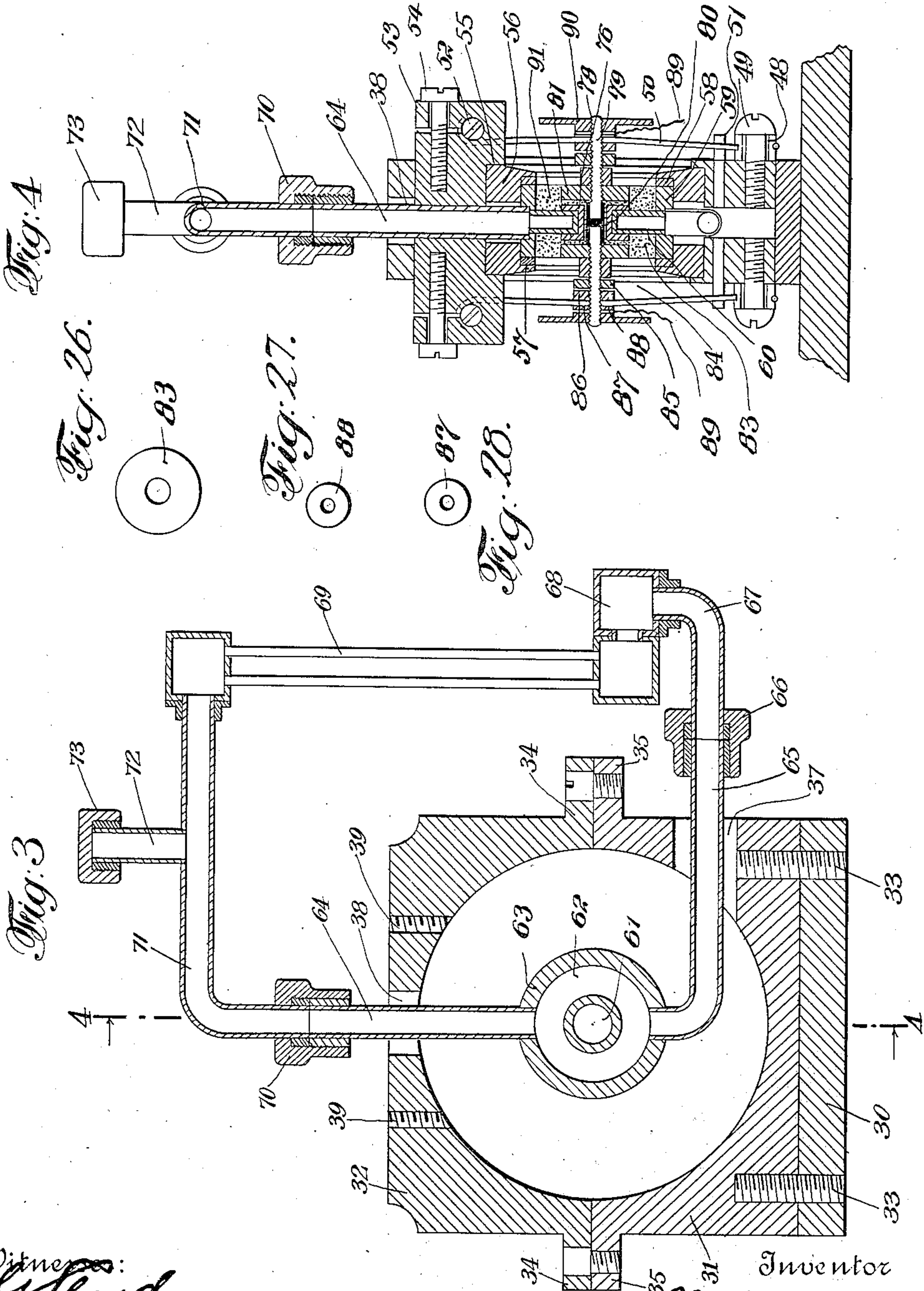
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7 SHEETS—SHEET 3.



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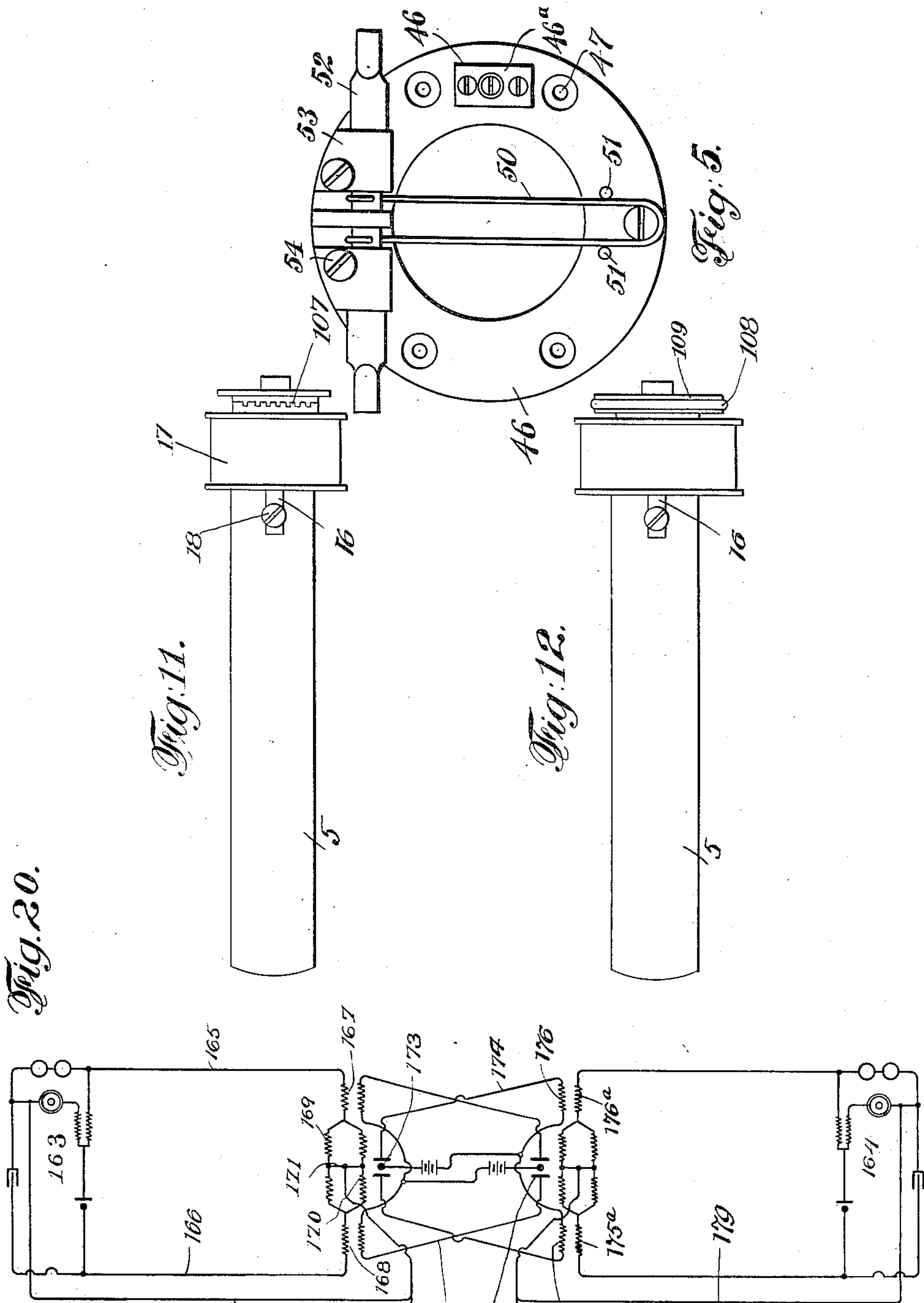
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7 SHEETS—SHEET 4.



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7 SHEETS—SHEET 5.

Fig. 13.

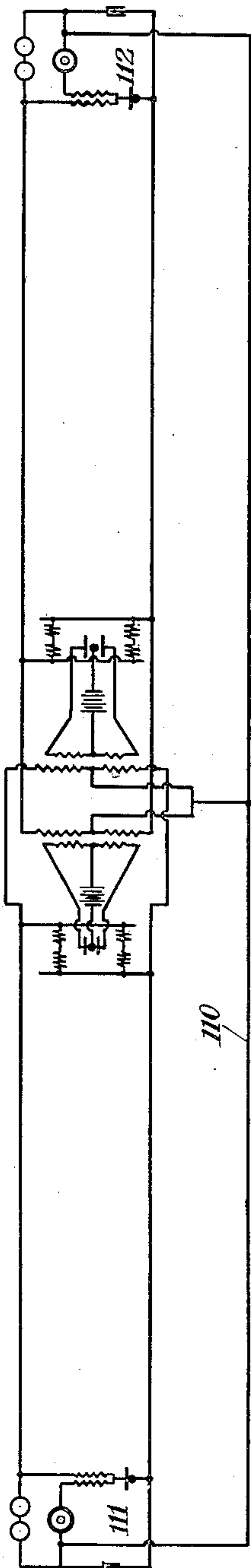
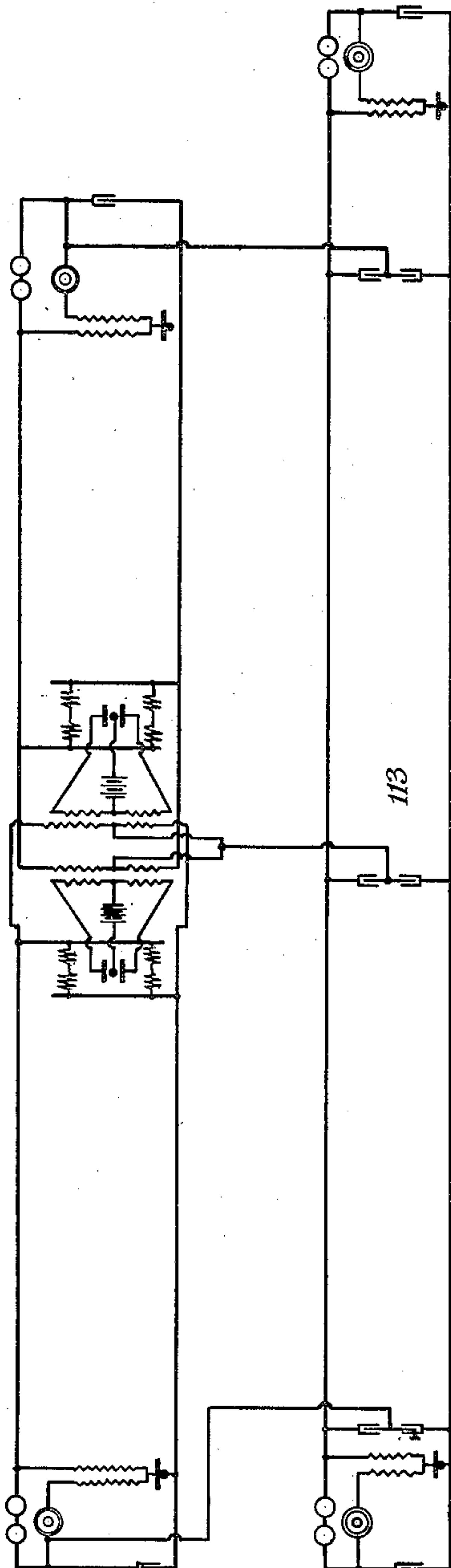


Fig. 14.



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7 SHEETS—SHEET 6.

Fig. 1 is a schematic diagram of a semiconductor device. The device is bounded by regions 130 and 131. A central region 124 contains a series of resistors 127 and 132, and a central component 126. This central region is flanked by regions 123 and 125. A terminal 128 is connected to region 125.

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7 SHEETS—SHEET 7.

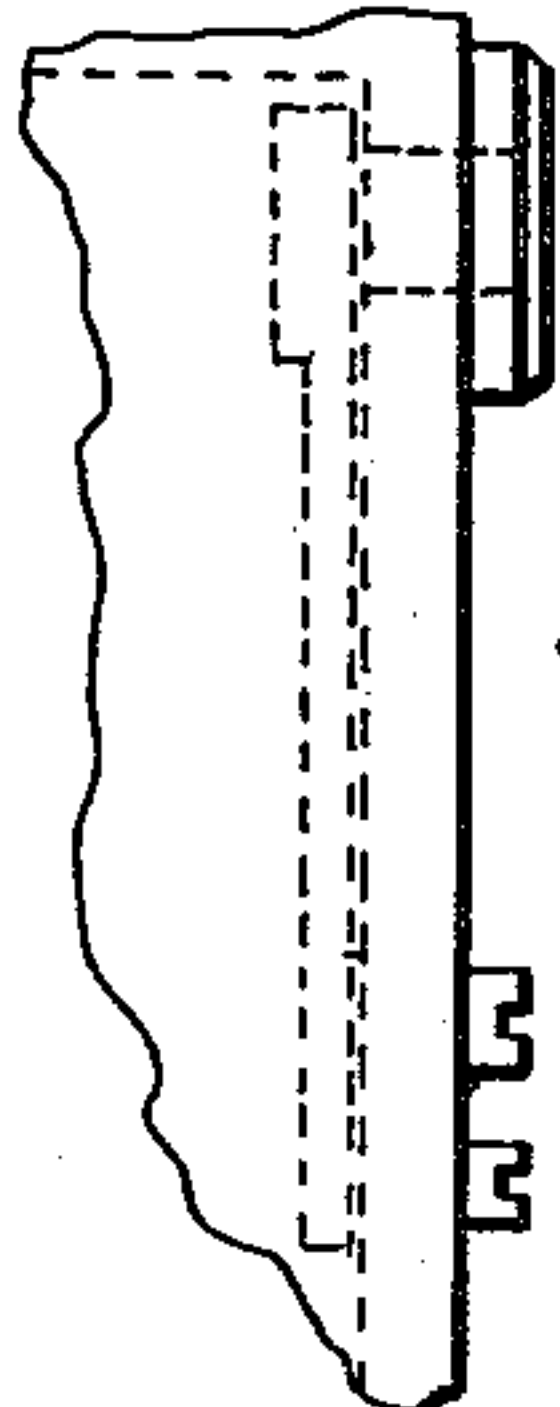
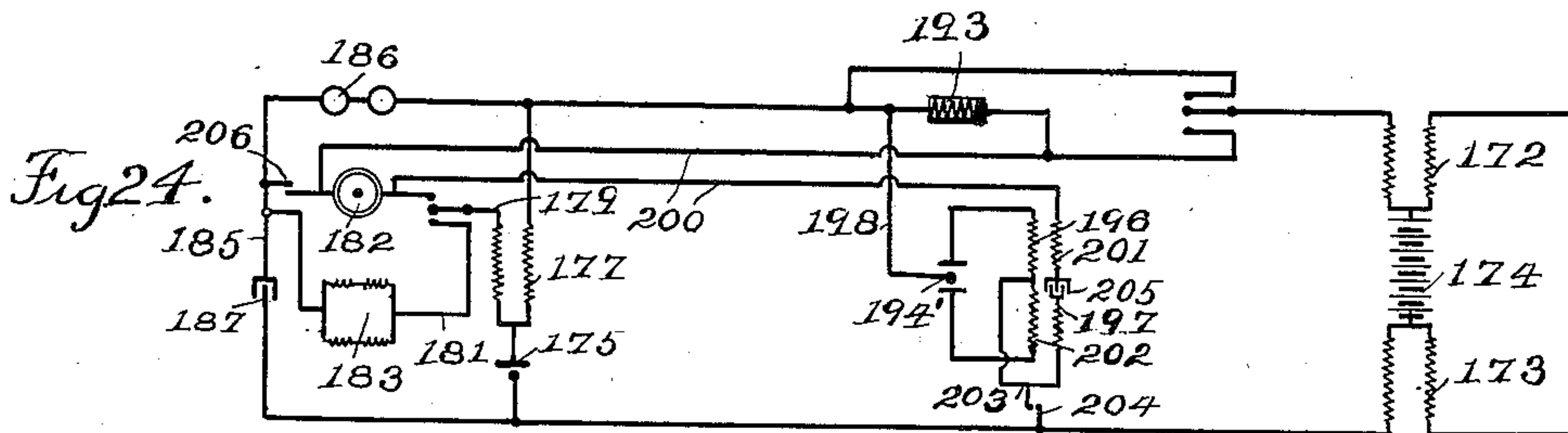
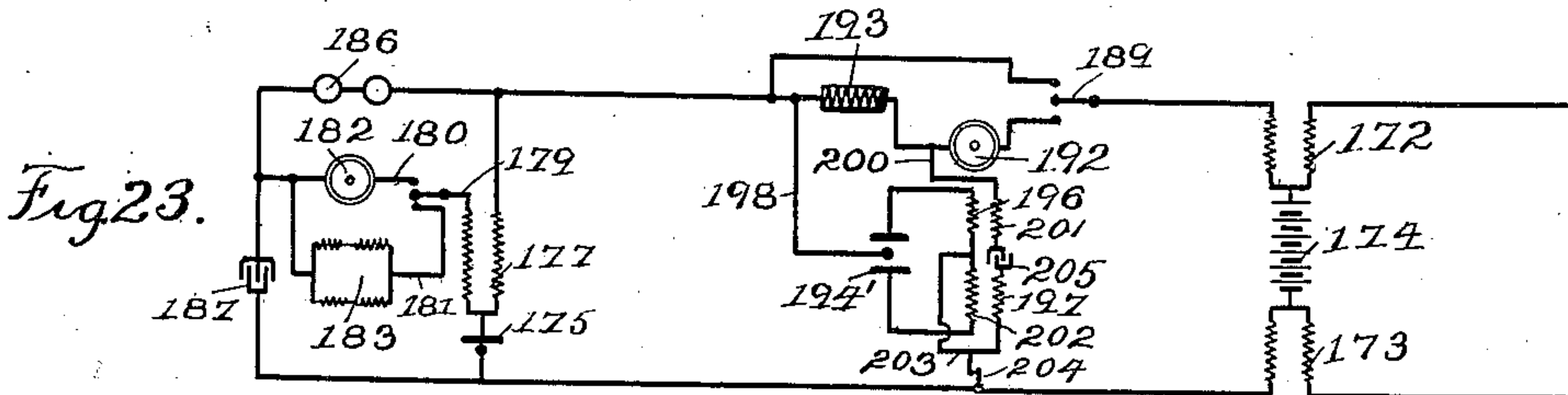
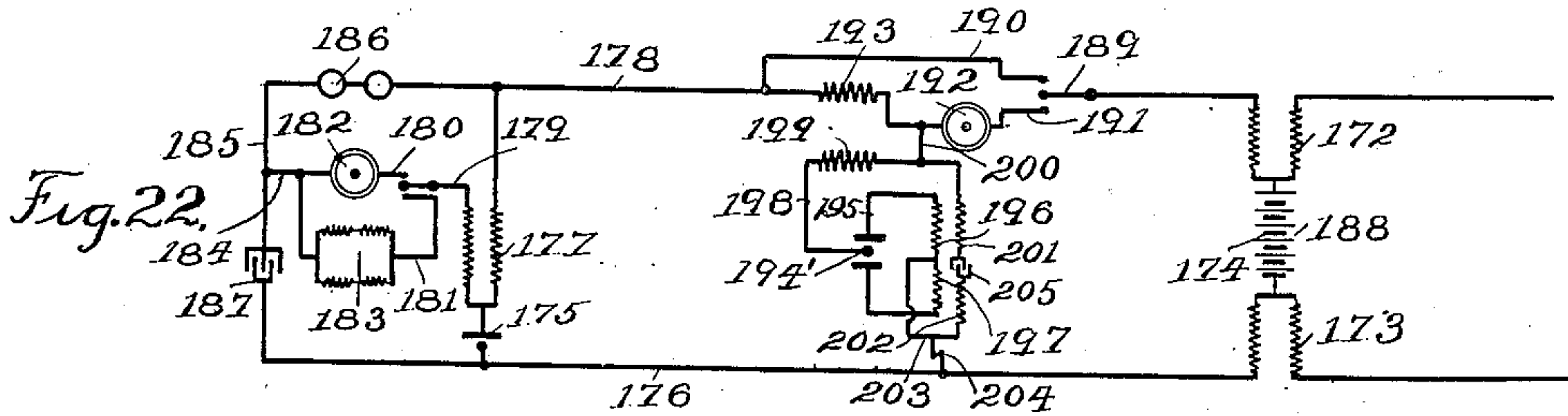
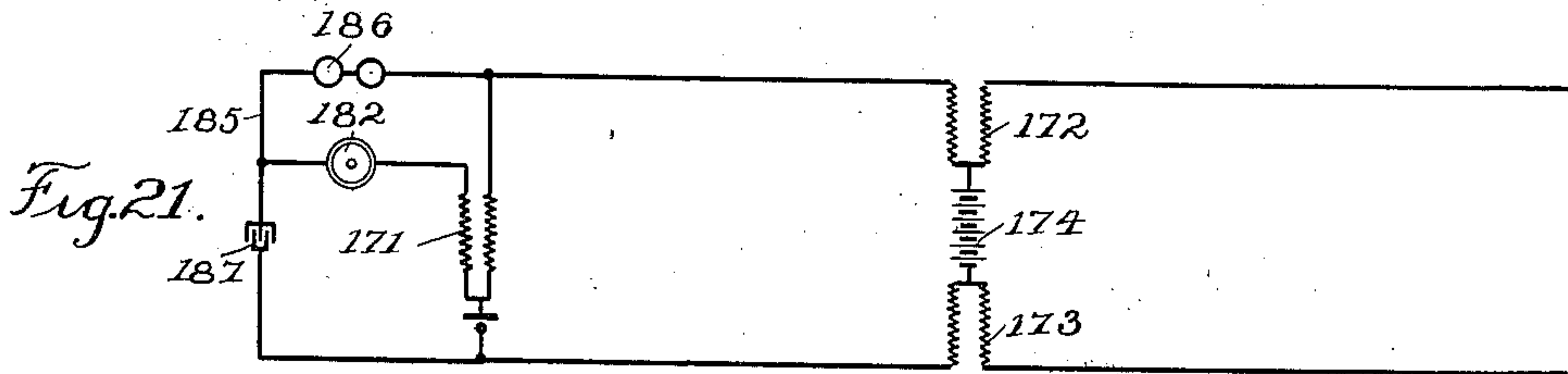


Fig. 25.

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UNITED STATES PATENT OFFICE.

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

TELEPHONE RELAY OR REPEATER.

1,203,326.

Specification of Letters Patent.

Patented Oct. 31, 1916.

Application filed May 19, 1911, Serial No. 628,148. Renewed September 18, 1916. Serial No. 120,890.

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 Relays or Repeaters, and do hereby declare that the following is a full, clear, and exact description thereof.

The object of my invention is to provide a telephone relay, which is so arranged as to avoid the effects of resonance, which has an improved means of adjustment whereby a permanent adjustment may be made; which is very strong in construction; which is provided with means for reducing the temperature of the variable resistance medium in the variable resistance chamber during the operation of the relay; which contains a new type of armature suspension adapted to generate electrical waves substantially without distortion or mutilation; which is provided with means for preventing interference with the electrical waves generated in the instrument due to the presence of metallic or other particles lodged between the poles of the electro-magnets and the armatures of the relay; which contains means for balancing the double-acting variable resistance medium in such a manner that in the condition of rest the same current strength is present in the circuit passing through both halves of the variable resistance medium; which is so constructed that the packing of the variable resistance medium is avoided; which is provided with means within the control of the telephone operator for changing the power of the relay at will; which is so constructed that it is capable of reciprocal working, both in balanced and unbalanced circuits; and which has certain other advantages which will be observed from the detailed description of my apparatus appearing hereinafter.

A further object of my invention is to provide a subscriber's set with a telephone relay or repeater which is connected to the set in such a manner that when the subscriber wishes to talk over long distances, a switch can be thrown to include the relay or repeater in the circuit to increase the strength of the electrical waves of the circuit.

The most important object of my invention is to avoid the effects of resonance in

the relay and to transform, reproduce or reinforce telephone current waves so that all waves are transformed, reproduced or reinforced with the same relative degrees of loudness. When the relay is so constructed as to permit resonance effects, distortion invariably follows.

By distortion in the reproduction of sound waves is meant the reproduction of different pitched tones in different degrees of loudness assuming initial loudness of every tone to be the same. The fundamental condition for the reproduction of sound without distortion is that the mechanical system which is set in motion shall have a very high proper frequency, that is to say, its frequency of vibration when struck and allowed to vibrate freely by itself must be as high as possible consistently with such amplitude of mechanical movement as is necessary to produce the required efficiency of the microphone in performing its function and subject, of course, to the elastic limit of the material. To meet this condition, the mass or inertia of the moving element may be reduced or its elasticity (stiffness) increased, or both.

Sensitiveness, that is range of motion of the moving element for a given exciting force, is greater, the smaller the mass or inertia of a body and the less the stiffness of the support, and in consequence of the decrease of sensitiveness with increasing stiffness of support, it is very highly desirable to obtain the high proper frequency of the moving element which is required to eliminate distortion by reducing the mass rather than by increasing the elasticity (stiffness). When the reproducing element has no elasticity, then the sensitiveness is in exact inverse proportion to the mass of the moving element and in exact inverse proportion to the frequency of the sound to be reproduced. Therefore, a heavy moving element without stiffness has two distinct disadvantages, namely: (a) distortion, because of greater sensitiveness to low pitched sounds than to high pitched sounds, and (b) low degree of sensitiveness for all sounds as compared with the degree of sensitiveness which would be realized if the moving element were light. Sensitiveness depends also upon stiffness of the moving

element. The greater the stiffness, the less the sensitiveness. The distortion which is referred to in the above discussion may be thought of as of two kinds (for both of which my invention corrects), namely: (a) the distortion which is represented in the motion of a moving element which has no elasticity (stiffness); and, (b) the distortion which is represented in the motion of the moving element which has both mass and elasticity (stiffness).

The first kind of distortion reduces the loudness of high pitch sounds relative to low pitch sounds and the reduction is in proportion to the pitch. The second kind of distortion is the undue magnification of those sounds which are nearly in unison with the natural frequency of vibration of the moving element. This kind of distortion is produced by resonance. Damping tends to correct the second kind of distortion but does not tend to correct the first kind of distortion.

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

Figure 1 is a plan view of a relay or repeater constructed in accordance with my invention; Fig. 2 is a side elevation of the same, partly in section; Fig. 3 is a vertical cross-section of the same taken at the center of the apparatus to show the details of the radiator; Fig. 4 is an elevation of a ring attached to the side of the variable resistance medium chamber, containing one form of tension device; Fig. 5 is a similar view of said ring carrying another form of tension device; Fig. 6 is a view similar to that shown in Fig. 4, but showing the binding means employed; Fig. 7 is an elevation of one of the movable electrodes; Fig. 8 is an elevation of one of the stationary electrodes; Fig. 9 is a view similar to that shown in Fig. 7, but showing a different type of electrode; Fig. 10 is a cross-section of another type of electro-magnet used as the exciting means; Fig. 11 is an elevation of an electro-magnet and its corresponding pole provided with means for preventing the interference of particles of matter with the operation of the device; Fig. 12 is a similar view of another form of apparatus designed for the same purpose; Fig. 13 is a diagrammatic view of a reciprocal repeating circuit utilizing a common third wire return; Fig. 14 is a diagrammatic view of a similar circuit showing the substitution of another telephone circuit for the common return; Fig. 15 is a diagrammatic view of a repeating circuit adapted to be used in balanced telephone lines, the circuit containing but a single repeater; Fig. 16 is a diagrammatic view of a similar circuit with the repeating circuit at the repeating station associated inductively and in series with the telephone

lines; Fig. 17 is a diagrammatic view of a reciprocal repeating circuit applied to the standard form of telephone lines, showing a plurality of relays or repeaters; Fig. 18 is a diagrammatic view of a local relay circuit containing two repeaters and having controlling rheostats and impedances in the circuit; Fig. 19 is a diagrammatic view of a reciprocal circuit used for balanced lines; Fig. 20 is a diagrammatic view of still another form of reciprocal repeating circuit adapted to use a third wire return; Fig. 21 is a diagrammatic view of a simple circuit arrangement of a subscriber's set in combination with the repeating coil arrangement at the central exchange; Fig. 22 shows the same arrangement with the subscriber's set supplied with a relay to reinforce the current when the subscriber is talking at long distances; Fig. 23 is a diagrammatic view of a circuit arrangement such as that shown in Fig. 22 but connected in such a way as to use only one retarder, instead of two retarders as shown in said figures; Fig. 24 is a diagrammatic view of a circuit arrangement similar in many respects to the circuit arrangements shown in Figs. 22 and 23 but with the circuits arranged in such a manner that the entire subscriber's outfit is supplied with a single receiver instead of two receivers as shown in said figures; Fig. 25 is an elevation of a portion of the relay casing showing a spring clamp; and Figs. 26, 27 and 28 are elevations of details.

In the drawings 1 represents a base plate which is provided at either end with a metallic box 2 which is secured thereto by means of screws not shown. Each of the boxes 2 is provided at its inner end with an aperture 3 to receive one end of a non-magnetic cylinder 4 adapted to carry as shown in Figs 11 and 12, a permanent magnet 5. The other end of the cylinder 4 projects through a similar opening 6 at the upper end of the box 2, this end of the cylinder 4 having attached thereto a screw-threaded extension 7 which is adapted to receive an interiorly screw-threaded cylinder 8 having a flange 9 at its inner end. The cylinder 8 is pivotally supported in a housing 10 which is secured to the end of the box 2 by means of screws 11, the flange 9 being adapted to rest within a corresponding groove 12 located in the housing 10. Upon the outer end of the cylinder 8 there is secured a knurled thumb-screw 13, the thumb-screw being secured in position upon the cylinder 8 by means of a screw 14. The magnet 5 is held in its proper position in the cylinder 4 by means of a screw 15 passing through the cylinder 4. Said magnet has at its inner end a slot 16 to receive one pole of an electro-magnet 17 where it is secured in position by means of a screw 18. Attached to the top of the cylinder 4 there is

provided a screw 19 which is adapted to project through a slot 20 in the top of the box 2, to act as a guide. The cylinder 4 is held in position by means of a thumb-screw 21 passing through a threaded bushing 22 in the side of the box 2 and bearing upon a spring 23 secured to the inner face of the box 2 by means of screws 24, the spring 23 being adapted to be pressed against the cylinder 4 by the operation of the thumb-screw 21. As shown in Fig. 2, instead of using a permanent magnet 5, as described above, I may make use of an electro-magnet which is constructed with a hollow core 25 carried in the center of an iron cylinder 26, a plurality of coils 27 for energizing the magnet and coils 28 to take the place of the electro-magnet 17 connected in the main line, for producing the variations in the variable resistance medium. Screws 29 hold the cylinder 26 in position within the cylinder 4.

At the center of the base plate 1, I provide a central standard 30 which is divided into a lower portion 31 and an upper portion 32, the lower portion 31 being provided with screw-threaded holes 33 to receive screws, not shown, passing through the base plate 1, to hold the standard in position. The upper and lower halves of the standard 30 are provided with perforated shoulders 34 and 35 to receive screws 36 to hold the two halves together. The lower section 31 has a horizontal aperture 37 to permit the passage of one of the radiator pipes and the upper half 32 is provided at its top with a similar aperture 38 to permit the passage of another one of the radiator pipes. The upper half of 32 is also provided with diametrically opposite screw-threaded holes 39 to receive screws 40 designed for holding in position a plate 41. The plate 41 has a pair of apertures for the passage of adjustable screws 43 which are carried in said apertures by means of screw-threaded bushings 44. Each of the screws 43 has at its lower end a small pointed permanent magnet 45 which may be adjusted to and from the poles of the electro-magnet 17 to adjust the magnetic force of said magnets, upon the armatures of the relay.

Within the standard 30 there is supported a pair of oppositely facing rings 46, said rings being secured together by screws passing transversely through holes 47 in the same. Each of the rings 46 carries at one side, a binding post 46^a for attaching one of the terminals of the local relay circuit. Each of the rings 46 also carries at its lower end a steel sleeve 48 which is held upon the base of the ring 46 by means of a screw 49. A steel wire 50 passes around the sleeve 48, the two ends of the wire 50 being directed upwardly between a pair of guide-posts 51 and being secured to the center of a key 52 extending entirely

across the face of the ring 46 and carried by split shoulders 53. The key 52 is designed for the purpose of adjusting the tension of the wire 50 and when so adjusted the adjustments may be made permanent by the operation of screws 54 located at the split portions of the shoulders 53. The inner face of each of the rings 46 is constructed with a circular depression 55 to hold in position a ring 56 having a flange 57 on one face extending toward the opening in the ring. The flange 57 is designed for the purpose of holding in position a ring 58 which abuts against the outer face of an inner casing 59 of the variable resistance medium chamber. The casing 59 is cylindrical in shape having a centrally disposed wall 60 with an aperture 61 at the center of said wall. Within the body of the wall 60 there is located an annular chamber 62 which communicates at the upper and lower portions of the casing 59 with cylindrical openings 63. The cylindrical openings are designed to be connected with the pipes of the radiator, the upper opening 63 being connected to a pipe 64 passing out through the aperture 38 in the upper half 32 of the standard 30, and the lower opening 63 being connected to an angle tube 65 passing out through the aperture 37 in the lower half 31 of the standard 30. A packing joint 66 connects the tube 65 to the lower tube 67 of a radiator 68, the radiator being comprised of a plurality of vertical radiating tubes 69. The pipe 64 is attached by means of a packing joint 70 to the upper pipe 71 of the radiator 68, said pipe 71 having attached thereto a filling pipe 72 having a cover 73. Attached to the pipe 67 there is a cleaning or discharge pipe 74 having a cap 75. The radiator 68 is filled with any suitable liquid for absorbing and emitting heat, but preferably an oil of some character.

Within the opening 61, I secure a pair of oppositely disposed stationary electrodes 76, the electrodes 76 being provided with a plurality of holes 77. Through the opening 61 and without touching the stationary electrodes 77, I pass a composite rod 78 comprising two screw-threaded metal bars 79 attached to each other by means of an insulating sleeve 80. The insulating sleeve 80 falls within the center of the aperture 61. The insulating sleeve 80 is larger in diameter than the bars 79 and against each of the shoulders thus provided, I place a movable electrode 81 having a plurality of holes 82. Against the movable electrode 81, and upon the composite rod 78, I support a mica diaphragm 83, the periphery of which falls between one of the rings 58 and the outer face of the casing 59. A bushing 84 is next placed over the rod 78 adjacent to the mica diaphragm 83 and a lock nut 85 is then screwed upon the rod 78 to hold the bushing

84 and adjacent parts in position. An adjustable nut 86 is now screwed upon the rod 78 to act as a bearing for the wire 50, a mica washer 87 being interposed between the face of the nut 86 and the wire 50. A similar mica washer 88 is now placed over the rod 78 to bear upon the other side of the wire 50. These nuts, 86, on both ends of the electrode rod 78 are utilized to laterally displace the wires 50, as shown in the drawings, to thereby increase their tension beyond that which can be safely applied in the first instance by the key 53 without danger of rupture, all as described in detail in my previous application referred to herein. An electrical terminal 89 in the shape of a disk is then placed upon the rod 78 and finally the armature 90 is screwed upon the end of the rod 78. A body of material adapted to act as a variable resistance medium, preferably granulated carbon, 91 is placed in the chamber within the casing 59 as the parts are assembled. The outer peripheries of the electrodes 76 and 81 and the inner surface of the casing 59 are preferably covered with an insulated coating though this is not absolutely necessary.

Referring to Fig. 7, it will be seen that I preferably bind the two free ends of the wire 50 together instead of using the posts 51. The binding in this instance comprises a wire winding 92, located above and below the connection with the rod 78. This gives an additional amount of tension which cannot be obtained by an adjustment of the nut 86.

Referring to Fig. 6, I have shown a pair of vertically adjustable guide-plates 103 each of which has a slotted extension 104 upon each end cooperating with a screw 105 carried on the face of the ring 46. The wire 50 passes through a hole in the center of each of the guide-plates 103. By adjusting the distance separating the two guide-plates 103, the lengths of the free ends of the wire 50 supporting the movable armatures and attached parts may be adjusted. By this means the fundamental wave or frequency of vibrations of the system carrying the movable electrodes may be adjusted, so as to alter the pitch high enough to avoid substantial distortion or mutilation, even to a note if found necessary above the sense of audition, although of course within the elastic limit of the wire or to give different relays attached to the same line different fundamental waves so that any mutilations resulting by the use of the several instruments will not be cumulative. It is necessary for the core of the electro-magnet 17 to be located very close to the armature 90. This however, allowed particles of dust of various kinds to become lodged between these parts. Under the influence of the vibrations of the system including the movable

electrodes 81, I have found that such particles of dust produce a great amount of noise and interfere very markedly with the correct transmission or reproduction of the electrical waves. I have also discovered, however, that by placing a small amount of heavy oil such, for example, as lubricating oil between these parts, this disadvantageous effect of particles of dust can be entirely removed. I, therefore, preferably place between the poles of the electro-magnet 17 and the armatures 90, a quantity of oil for this purpose.

Referring to Fig. 11, I have shown a slightly modified form of apparatus in which I provide the pole of each of the electro-magnets 17 with a number of small slots 107 to more effectively retain the body of oil in position.

Referring to Fig. 12, I have shown another modified form of apparatus for accomplishing the same effect. This includes a disk 108 of the same size as the armature 90 and a band of some kind of fabric 109 surrounding the disk 108 and the armature 90. The band of fabric 109 prevents the access of foreign particles to the space between the poles of the magnets and the armatures.

The arrangement of the local repeating circuits in the various forms of circuits which I use in connection with my repeater and shown in Figs. 13, 14, 15, 16, 17, 19 and 20 is the same as the arrangement of the local repeating circuit in my co-pending application for relay or repeater, Serial No. 558,045, filed April 27, 1910, reference being had particularly to Fig. 11 in said application. The arrangement of the circuit shown in Fig. 13 is the same as that shown in the circuit appearing in Fig. 15 of my application above referred to except that in Fig. 13 I employ a common return wire 110 which leads from one of the subscriber stations 111 at one end of the line to the other subscriber station 112 at the other end of the line. The circuit arrangement shown in Fig. 14 is the same as that shown in Fig. 13, except that instead of using a common return 110, there is substituted a separate telephone circuit 113. In both of the modifications shown in Figs. 13 and 14, the relay system is capable of reciprocal working irrespective of the electrical characteristics of the telephone lines on the two sides of the repeating station.

In Fig. 15 I have shown another form of circuit which makes use of a single relay. In this circuit arrangement it is necessary for the electrical characteristics of the two circuits 114 and 115 on the opposite sides of the relay, to be the same. In this arrangement of the circuits, I provide an induction coil 116 having two primary windings 117 and 118, as in the arrangement of the other local repeating circuits, but I provide in ad-

dition thereto two secondary windings 119' and 120. The secondary windings 119' and 120 are connected respectively to repeating coils 121 and 122. It is necessary when
 5 using this construction that the electrical characteristics of the repeating coils 121 and 122 shall be the same.

In Fig. 16, I have shown another form of circuit arrangement in which I employ a
 10 single relay. In this instance, the electrical characteristics of the two circuits on opposite sides of the relay must be the same as has already been described in connection with Fig. 15. In this construction the re-
 15 lay and the induction coil are the same as those used in the circuit shown in Fig. 15, except that one of the secondaries 123 of the relay is connected in series with one winding 124 of a triple-wound repeating coil 125
 20 while the other secondary 126 is connected in series with a second winding 127 of said repeating coil 125, the two windings 124 and 127 of the repeating coil 125 being connected together at one end and being connected
 25 at the point of union to one terminal of a condenser 128, the other terminal of which leads directly to one side of the main telephone circuit 129, the other ends of these windings 124 and 127 having leads 130 and
 30 131 located in the main telephone circuit. The third winding 132 of the triple-wound repeating coil is connected to the terminals of the relay exciting coils 133. The three windings are situated upon the same core.
 35 The waves from the secondary coils of the relay have no effect upon the relay owing to their neutral action through the windings of the repeating coil 125.

The circuit arrangement shown in Fig.
 40 17 exemplifies the manner of arranging a standard form of telephone line with two or more repeating stations. In this circuit, repeating coils 134 and batteries 135 are located in the central exchanges operating the
 45 subscribers' sets 136 and 137, respectively. In this instance, the common return wire extends between the central exchange and the relaying stations and between the consecutive relaying stations instead of between
 50 a subscriber's station and a relaying station as in the circuit arrangement previously described. This circuit arrangement shows a telephone line containing four relays 138, 139, 140 and 141. The relays 138, 139, and
 55 141 are connected in the circuit in the same manner as the relays shown in Figs. 13 and 14 while the relay 140 is arranged differently and in such a manner that it is in series with the main line 142 and 143. A partial unbalancing of the main line may result owing to the changed connection of the repeating coils. This unbalancing is, how-
 60 ever, compensated by the resistance of the batteries 135 at the central stations.

65 Between the two central exchanges 135,

two other central stations are supposed to exist on the same line as extending between stations 136 and 137. In each of the intermediate central stations a set of two repeaters are installed and connected to the main
 70 telephone line. One of these exchanges contains repeaters 140 and 141 and the other contains repeaters 138 and 139. Between the exchange serving station 136 and that serving station 137, the telephone circuit
 75 comprises three wires.

It will be assumed that subscriber 136 is conversing with subscriber 137, and that the momentary direction of a current wave is as shown by the arrows, then the initial
 80 wave from the subscriber 136 is represented in direction by the arrows "a." This wave passes through the windings of the repeating coil of the first exchange as shown and a new wave is induced in the other wind-
 85 ings of the repeating coil as "b." A part of this induced current is short-circuited on itself through one-half the repeating coil and the battery 135. That portion of the energy induced by the other half of the
 90 same repeating coil passes through the battery and along the main transmission line as shown by the arrows "b" to the first main line station where the first pair of repeaters 140 and 141 are installed. Each of these
 95 repeaters has the usual exciting coils 230 and an induction coil 231. In the case of repeater 141, the secondary windings of its induction coil are bridged across the line and have a high impedance factor, therefore
 100 the current wave "b" does not pass there-through, but finds a path through the exciting coils 230 of the repeater 140. The wave "b" actuates repeater 140 and this instrument generates a new wave through its in-
 105 duction coil 231 as "C," which new wave traverses the main line as shown to the second intermediate exchange, passing through the exciting coils 230 of repeater 138. The wave "C" is kept out of the secondary wind-
 110 ing of the induction 231 of repeater 139 because of the high impedance factor of such coil, and the last feature also reacts to prevent the wave "C" from passing through the exciting coils 230 of the repeater 141. The
 115 wave actuates the repeater 138 which with its induction coil 231 generates a new wave "d." The duplex secondary windings of the induction coil associated with repeater 138 is so connected that the new wave "d" 120
 passes in the direction shown by the arrows, i. e., in opposite directions from the neutral point. This results in no difference of phase or potential across the terminals of the ex-
 125 citing coils 230 of the repeater 139, which repeater therefore remains inert. The new wave "d" passes along the main telephone line as shown by the arrows, using the third wire as a return. Part of the new wave
 130 passes through the battery only on return

and part through both windings of the repeating coil of the exchange associated with the subscriber 137. An induced wave "e" results in the other windings of the repeating coil which wave "e" actuates the receiver of the station 137 in the usual manner. The secondary windings of all induction coils are duplex. Those associated with repeaters 141, 139 and 138 have a high impedance factor to prevent the passage of telephone current waves therethrough other than those which are generated by the particular repeater immediately associated with it. The secondary windings of the induction coils related to repeaters 138, 139 and 141 are so connected that they induce currents in the same way and direction as shown for repeater 138 of the above description. The secondary winding of induction coil 231 associated with repeater 140 is so connected that its duplex winding is in series relation as distinguished from the induction coils associated with the other repeaters. The same winding also has a low impedance factor for the reason that the waves from repeater 139 must pass therethrough to actuate the repeater 141 when talking in the opposite direction to that used as an illustration for the description herein offered. Conversation in the opposite direction to that herein described is effected in the same way except in so far as relates to the change of connections between the secondary winding of the induction coil 140 and the exciting coils 230 of repeater 141. The circuit is reciprocal in its action without regard to the lengths of lines between the different stations, and without the use of artificial means of balance, assuming, of course, that the main line telephone wires between adjacent stations have approximately the same electrical characteristics.

In Fig. 18 I have shown a special arrangement of local primary repeating circuits in which two or more such circuits are energized from the same source. In this arrangement of circuits I provide a source of electricity such as a battery 144 one pole of which is connected by means of wires 145 and 146 to the primaries 147 and 148 of the induction coils of the local relay circuits. These wires 145 and 146 are provided with rheostats 149 and 150 to vary the strength of the current as desired. The other ends of the local relay circuits are connected by means of wires 151 and 152 to the other pole of the battery 144 and impedance coils 153 and 154 are located in the wires 151 and 152 to neutralize the effect of the primary variations of one relay upon another.

In Fig. 19 I have shown another form of circuit which may be used where the lines on the opposite sides of the relay are balanced as to their electrical characteristics. Secondaries 155 and 156 are connected in this circuit

across the main line 157 and 158, and 159 and 160 of the two sending and receiving circuits. One pair of the opposite sides of these circuits 157 and 160 are directly connected by a wire 161 while the other pair of opposite sides of said lines 158 and 159 are connected together through relay exciting coils 162.

Fig. 20 shows still another form of circuit adapted to use a third wire return. The special feature of this circuit arrangement is that the exciting coils of the relay are connected in series with the secondaries of the induction coils. In this figure 163 and 164 represent the two subscribers' sets, the two outside leads 165 and 166 of the former leading to secondaries 167 and 168 of two induction coils. Between the secondaries 167 and 168 are located the two pairs of exciting coils 169 and 170 of the relay. The two pairs of exciting coils are connected together at their central points by means of a wire 171 and from this wire 171 leads the third wire 172 of the systems. A variable resistance medium 173 associated with the exciting coils 169 and 170 is connected in a local relay circuit 174 of the type used in the other modifications previously described. This circuit includes primaries 175 and 176 of the induction coils associated with the other subscriber's set, having the secondaries 175^a and 176^a. The other subscriber's set 164 is connected in a similar manner to similar exciting coils which influence the other local relay circuit 177 containing a variable resistance medium 178, the subscriber's set 164 being provided with a third wire or return 179. As shown in Fig. 20 the third wires 172 and 179 are connected, thereby forming a common return for the entire system. The operation of this form of circuit is such that the regenerated or relayed telephone waves divide at and pass through the several windings of the exciting coils such as the exciting coils 169 and 170, in opposite directions, thereby producing no change in the magnetic field of which the exciting coils form a part.

Subscribers' sets as they are now constructed are built merely for the purpose of operating with sufficient power for local calls owing to the fact that if the instruments were built with the power to convey electrical waves with proper strength to long distances, the strength would be too great for convenient use in making local calls. Such being the case I have devised a means whereby a subscriber's set may be provided with a telephone relay or repeater in such a way that the particular subscriber can connect a relay or repeater in the circuit when he desires to talk over long distances, thereby making use of the power required for this purpose.

In Figs. 21, 22, 23 and 24 I have shown

circuit arrangements designed to explain how I accomplished this end. In Fig. 21 I have shown a circuit arrangement which includes a subscriber's set 171 connected to the central exchange by means of repeating coils 172 and 173, between which a battery 174 is bridged in the usual manner. The circuit arrangement of the subscriber's set as shown in this figure is of the usual form in general use and for this reason does not require detailed explanation.

In Fig. 22 I have shown one way in which a telephone relay or repeater may be connected to a subscriber's set having the circuit arrangements, such as those shown in Fig. 21. In this figure the subscriber's set as shown, comprises a transmitter 175 which is connected at one side to one wire 176 of the main line and at the other side to one limb of an induction coil 177, which leads to the other wire 178 of the main line. The other limb of the induction coil 177 leads to a switch 179 having two branches 180 and 181, the former of which is connected to a receiver 182 of the subscriber's set, and the latter of which is connected in shunt of the receiver 182 with a set of exciting coils 183 carried by the telephone relay or repeater of the subscriber's set. The other side of the receiver, 182, is connected by means of a wire 184 to a wire 185 which shunts one limb of the induction coil 177 and carries a bell 186 and a condenser 187. In the wire 178 between the subscriber's station and the central exchange 188 is located a switch 189, one position of which is designed to complete the main circuit excluding the relay through a wire 190 and the other position of which is designed to exclude the wire 190 and to include a wire 191 which contains a receiver 192, and a retardation coil 193. The receiver 192 is designed to be used when the telephone relay or repeater is thrown into the circuit when the subscriber is talking over long distances and the purpose of the retardation coil 193 is to prevent regenerated telephone waves from influencing the exciting coils 183 of the relay or repeater. The telephone relay or repeater has a variable resistance medium or device 194 of the type already described above in this application. The two outside electrodes of this variable resistance device are contained in a local circuit 195 containing two primary windings 196 and 197 of the repeater induction coil. The central electrode of the variable resistance device is connected by a wire 198 through a retardation coil 199 to a wire 200 leading to the wire 191 and to the secondaries 201 and 202 of the repeater induction coil and thence to a wire 203 which leads to the point of union of the two primaries 196 and 197. A switch 204 is provided to make connection between the wire 203 and the wire 176. The retardation coil

199 prevents regenerative telephone waves from influencing the variable resistance device 194. If desired all of the switches 179, 189 and 204 can be mounted in such a manner as to be operated by single lever. When the switches are thrown in such a manner as to exclude the various connections of the telephone relay or repeater, the subscriber's set operates in the usual manner, as in the case of the circuit arrangement shown in Fig. 21. When, however, it is desired to talk over a long distance the switches are thrown so as to connect the several portions of the relay or repeater with the main line thereby excluding the receiver 182 and including the receiver 192. When the connections have been made in this manner the use of the transmitter 175 operates the exciting coils 183 and through the agency of the variable resistance device 194 a current is induced in the secondaries 201 and 202 of the repeater induction coil, which current is added to the current of the main line thereby strengthening it. The retardation coils 193 and 199 prevent regenerated telephone waves from affecting the exciting coils 183 and the variable resistance device 194 and the presence of a condenser 205 prevents the passage of a current from the main line through the secondaries 201 and 202.

In Fig. 23 I have shown the same circuit arrangement as that appearing in Fig. 22 except that the wire 198 is connected direct to the side of the retardation coil 193 which is nearest to the subscribers' instruments thereby avoiding the necessity of using the second retardation coil 199.

In Fig. 24 I have shown a modified form of circuit arrangement in which only one receiver 182 is used and in which only one retardation coil 193 is necessary. The circuit arrangement in this figure is the same as the circuit arrangement shown in Fig. 23, except that the receiver 182 is omitted from the wire 181 while the wire 200 is extended so as to include the receiver 182 and except that a switch 206 is provided between the receiver 182 and the wire 185 while the exciting coils 187 are connected direct to said wire 185. The operation of this form of my invention is the same as that shown in Fig. 23, except that the same receiver 182 is used for local calls and for talking at long distances, and except that the switch 206 must complete the connection between said receiver and the wire 185 when local calls are being made. These circuit arrangements shown in Figs. 21, 22, 23 and 24 merely exemplify different ways in which a telephone relay or repeater can be associated with a subscriber's set of the usual type but a telephone relay or repeater can be associated with a subscriber's set of any other type such, for example, as a set operated by local battery.

In the case of all the circuits shown in Figs. 13 and 14, and in some instances in the modification shown in Fig. 17, the secondary windings of the induction coils have a high impedance factor so as not to be influenced by telephone waves while the secondary windings of the induction coils of the relays used in the circuits shown in Figs. 15, 16, 19 and 20, have a low impedance factor for the reason that the telephone currents utilized for actuating the relay must circulate through said windings.

The provision of the wires 92 is one of the most important features of my invention. The object of these windings is two-fold. First, their effect is to raise the fundamental frequency of a vibratory system of appreciable mass (inertia). The presence of such wires tends to dampen and thereby lower the frequency, but the added tension imposed by the wires 92 on the wires 50 compensates for the former.

The other object is to increase the tension of each of the wires 50 to such an extent that the frequency of the fundamental wave of vibration of the wires 50, and hence of the system as a whole has been substantially increased above that attained by tension applied by the key 53 and subsequent bowing by the nuts 86. As a consequence any sympathetic of resonant vibrations set up in the wires 50 or any of the sections thereof will not materially affect the waves reproduced by the instrument.

Another important feature of my invention is to construct the variable resistance chamber in such a way that the body of granular carbon between the electrodes is exceedingly small, to correspond to the extraordinary minuteness of electrode movement incident upon the high elastic tension or stiffness which is necessary to raise the fundamental frequency of the vibratory system of the relay to the point that prevents distortion. I have found that the distance separating the stationary and movable electrodes should be approximately one-thirty-second of an inch ($1/32''$).

Still another feature of my invention of great importance is the arrangement whereby I connect a telephone relay or repeater directly in a subscriber's set in such a manner that when the particular subscriber wishes to talk over a long distance the relay or repeater can be utilized to augment the strength of the telephone waves at that point.

While I have described certain modifications of my invention above in detail, I wish it to be understood that many changes may be made therein without departing from the spirit of my invention. It is also to be understood that wherever I have used the term "relay" said term is understood to

apply either to a device which regenerates telephone waves, or to a device which merely reinforces such waves.

I claim:

1. A telephone relay comprising a magnetic field controlled by the current to be relayed, a vibratory structure actuated thereby including an armature and a microphone electrode, a wire controlling the vibration of such structure connected thereto, and means for positively imparting a high and permanent tension to such wire, the organization of the said parts and the degree of tension of the wire being such as to raise the natural frequency of the said vibratory parts above that point where sympathetic vibration thereof effects distortion of the transmitted speech.

2. A telephone relay comprising a magnetic field controlled by the voice current to be relayed, a vibratory structure actuated thereby and including an armature, a double-acting microphone and a rod connecting said armature to the movable electrode of the microphone, a wire connected to such vibratory structure to control the vibration thereof by its resistance to lateral displacement, and means for imparting a permanent and very high degree of tension to such wire, the length of the same and the organization of said structure being such that the tension of the wire raises the frequency of the parts above the point where sympathetic vibration thereof effects distortion of the transmitted speech.

3. A telephone relay comprising opposite magnetic fields having oppositely-acting exciting-coils adapted for connection in the receiving line, a double-acting microphone between such fields, and a vibratory armature structure for such fields including the movable part of said microphone, a wire controlling the rate and velocity of vibration of such structure, and means for imparting a permanent and high degree of tension to such wire, the length thereof and the degree of its tension being coordinated to raise the fundamental frequency of the vibratory structure above the point where sympathetic vibration thereof produces distortion of the transmitted speech.

4. A telephone relay comprising opposite magnetic fields having exciting coils adapted for connection in the receiving line, a double-acting microphone between such fields comprising a central stationary part and two opposite movable parts, a vibratory structure between such fields comprising the said two movable microphone parts, the armatures of the said fields, and a connecting rod, in combination with two suspension means secured to the rod at separated points thereon and comprised of wires each subjected to a high degree of tension and hav-

ing their said tensions equalized by their said connection with the rod, the length of said wires and the equalized tension thereof producing a high fundamental frequency of

5 said structure which is above the region where sympathetic vibration thereof effects distortion of the transmitted speech.

5. A telephone relay comprising oppositely-acting magnetic fields having exciting-coils adapted for connection in the receiving line, a double-acting microphone between such fields, a vibratory armature structure for such fields including the movable part of the said microphone, a wire connected to said structure and subjected to a high degree of initial tension, and means for positively and permanently deflecting such wire transversely to the vibratory movement of the structure to increase the tension thereof.

6. A telephone relay comprising a magnetic field having exciting-coils subject to the voice current to be relayed, a vibratory armature structure in such field including the moving part of a microphone, a pair of adjacent wires controlling the vibration of such structure and connected thereto, said wires being subjected to a high degree of initial tension, and means for transverse-deflecting both such wires in a direction transverse to the movement of vibration of the armature structure to increase the tension thereof.

7. In a device responsive to speech vibrations, a member adapted to vibrate in accordance with such vibrations and suspension means for controlling and regulating the extent and velocity of such movement comprising a wire, means for placing the same under high initial tension and means for permanently and positively deflecting a portion of the length of said wire from a straight line to thereby further increase such tension.

8. In a device responsive to speech vibrations, a member adapted to vibrate in accordance with such vibrations and suspension means for controlling the extent and velocity of such vibration comprising a wire, means at the ends thereof for placing the same under high initial tension, and means intermediate of such ends for permanently and positively deflecting such wire in a direction transverse to the movement of vibration of said member, thereby increasing such tension.

9. A telephone relay comprising two opposing magnets having coils for connection in the receiving line, an annular microphone support between the magnets, a microphone inclosed in said support and having a rod or stem bearing armatures for the magnets, means controlling the vibration of said rod and armatures comprising a wire stretched

across the support and connected with the rod, and means on the said support for placing the wire under a high degree of initial tension.

10. In a telephone relay, the combination with the exciting electro-magnet having a coil adapted to be connected in the line, an armature and a microphone electrode actuated by the armature, a wire suspension for the armature, means for permanently and positively fixing the same in a state of tension, and means for permanently and positively deflecting said wire from a straight line, thereby increasing the tension.

11. A telephone relay circuit comprising in combination with the two line sections, a relay, a three-limb induction coil, one limb of which is in one line section, another in the other, and the third in circuit with the receiving coils of the relay, and a secondary coil for each line section in inductive relation to the primary of the relay.

12. A telephone relay circuit comprising in combination with the two line-sections, a relay, a three-limb induction coil, one limb of which is in one line section, and another limb of which is in the other line section, and the remaining limb of which is in circuit with the relay, a condenser for each line circuit in series relation with the induction coil limb therein, and a secondary coil for each line section in inductive relation to the primary of the relay.

13. In a telephone relay, means for producing a magnetic field, an armature actuated thereby, a variable resistance medium controlled by said armature, an electrode cooperating therewith, a tension device for supporting the same and means bowing said tension device in more than one direction.

14. In a device of the character described, a telephone relay comprising a magnet, an armature cooperating therewith, a variable resistance medium actuated by said armature and a film of liquid between said armature and magnet.

15. In a device of the character described, a telephone relay comprising a magnet, an armature cooperating therewith, a variable resistance medium actuated by said armature and a film of liquid between said armature and magnet, one of the film holding surfaces having depressions to retain the liquid in position.

16. In a device of the character described, a sending circuit, a receiving circuit, a relay for each of said circuits, each circuit having a low inductance winding for its own relay and a connection with the opposite relay, and a high inductance winding in said connection, and a return circuit connected to the middle of each of said high inductance resistances.

17. In a device of the character described, a sending circuit and a receiving circuit, each of said circuits having a coil connected between its two wires and each of said circuits having a relay with a double coil adapted to co-act with each of said first mentioned coils whereby equal and opposite currents are generated in said first mentioned coils and sent along said wires in the same direction.

18. In a device of the character described, a sending circuit and a receiving circuit, each of said circuits having a coil connected between its two wires and each of said circuits having a relay with a double coil adapted to co-act with each of said first mentioned coils whereby equal and opposite currents are generated in said first mentioned coils and sent along said wires in the same direction, and a return connected between said first mentioned coils.

19. A telephone relay comprising adjacent magnetic poles, a vibratory structure including microphone and armature elements, the latter closely confronting said poles, and variable current windings, designed, arranged and connected to vary oppositely the effect of said poles upon said vibratory structure, in combination with a plurality of highly resilient vibratory members having their respective vibratory portions arranged to act in the line of movement of said vibratory structure and fixed to the latter at points spaced apart along said line, their initial, effective resiliences being approximately equalized by interdependent deflecting of their vibratory portions, by means of the vibratory structure acting as a mechanical stress transmitting linkage between them.

20. A telephone relay comprising adjacent magnetic poles, a vibratory structure, including microphone and armature elements, the latter closely confronting said poles, and variable current windings, designed, arranged and connected to vary oppositely the effect of said poles upon said vibratory structure, in combination with a plurality of short high tension wires extending transversely to and spaced apart along the lines of vibration of said vibratory structure, and having their respective vibratory portions fixed to said vibratory structure at substantial equal vibration points thereof, their initial, effective tensions being increased and approximately equalized by interdependently deflecting their free or vibratory portions by means of the vibratory structure acting as a mechanical stress transmitting linkage between them.

21. A telephone relay comprising adjacent magnetic poles, a vibratory structure including microphone and armature elements, the latter closely confronting said

poles, and variable current windings, designed, arranged and connected to vary oppositely the effect of said poles upon said vibratory structure, in combination with a plurality of short high tension wires extending transversely to and spaced apart along the line of vibration of said vibratory structure, and having their respective vibratory portions fixed to said vibratory structure at central or substantial equal vibration points thereof, said wires being longitudinally stretched nearly to their elastic limit and further tensioned by laterally deflecting the stretched portions thereof.

22. In a device responsive to speech vibrations a member adapted to be vibrated physically by and in accordance with the speech vibrations, in combination with a plurality of highly resilient vibratory members having their respective vibratory portions arranged to act in the line of movement of said member and fixed to the latter, their initial, effective resiliences being approximately equalized by initial, opposite, interdependent deflection of their free or vibratory portions through said member acting as a mechanical stress transmitting linkage between them.

23. In a device responsive to speech vibrations, a member adapted to be vibrated physically by and in accordance with speech vibrations, in combination with a plurality of short high tension wires extending transversely to the direction of vibration of said member and having their respective vibratory portions fixed to said member at substantial equal vibration points thereof, said wires being longitudinally stretched nearly to their elastic limits and further tensioned by laterally deflecting the stretched portions thereof.

24. In a telephone apparatus, the combination of a variable resistance medium comprising a central electrode, movable electrodes upon opposite sides thereof, vibratory members connected to said movable electrodes and tending to act in opposite directions, armatures connected to said movable electrodes and oppositely acting magnets acting upon said armatures.

25. In a telephone apparatus, the combination of a variable resistance medium comprising a central electrode, movable electrodes upon opposite sides thereof, vibratory members connected to said movable electrodes and tending to act in opposite directions, armatures connected to said movable electrodes and oppositely acting magnets acting upon said armatures, the inertia of the movable parts being small, relative to the resilience of said vibratory parts.

26. In a telephone apparatus, the combination of a variable resistance medium comprising a central electrode, movable elec-

trodes upon opposite sides thereof, vibratory members connected to said movable electrodes and tending to act in opposite directions, armatures connected to said movable electrodes and oppositely acting magnets acting upon said armatures, said vibratory parts comprising wire under strain.

27. In a telephone apparatus, the combination of a variable resistance medium comprising a central electrode, movable electrodes upon opposite sides thereof, vibratory members connected to said movable electrodes and tending to act in opposite di-

rections, armatures connected to said movable electrodes and oppositely acting magnets acting upon said armatures, the inertia of the movable parts being small, relative to the resilience of said vibratory parts, said vibratory parts comprising wire under strain.

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

ELWOOD GRISSINGER.

Witnesses:

DAN'L W. EMERLING,
FLORENCE TRAUTMAN.