No. 814,411. PATENTED MAR. 6, 1906.

J. TROWBRIDGE.

TELEPHONIC RELAY.

APPLICATION FILED JULY 14, 1905.

5 SHEETS—SHEET 1.

Fig. 1.

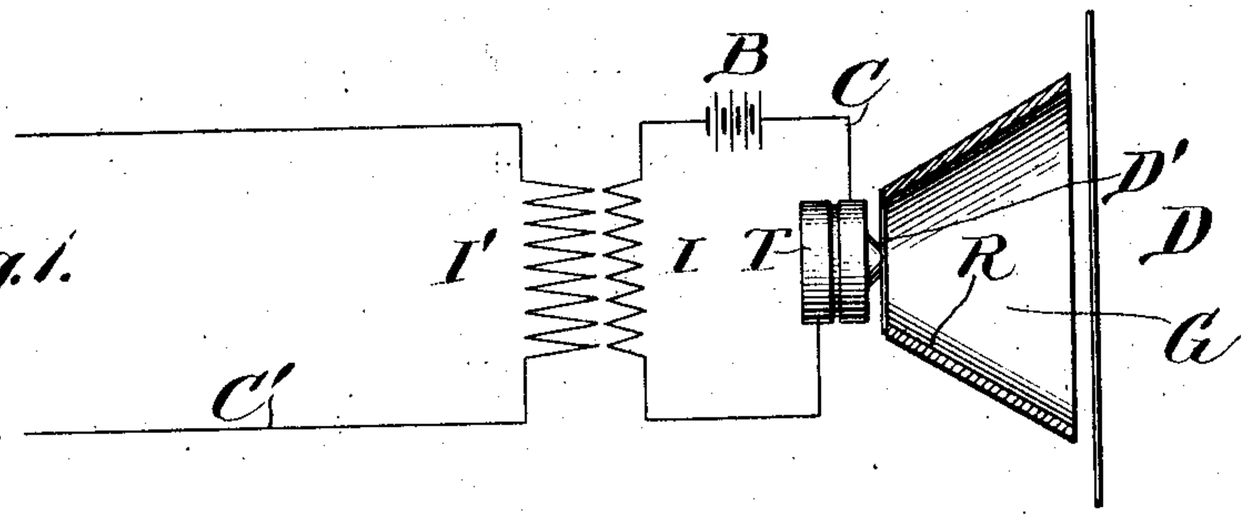


Fig. 2.

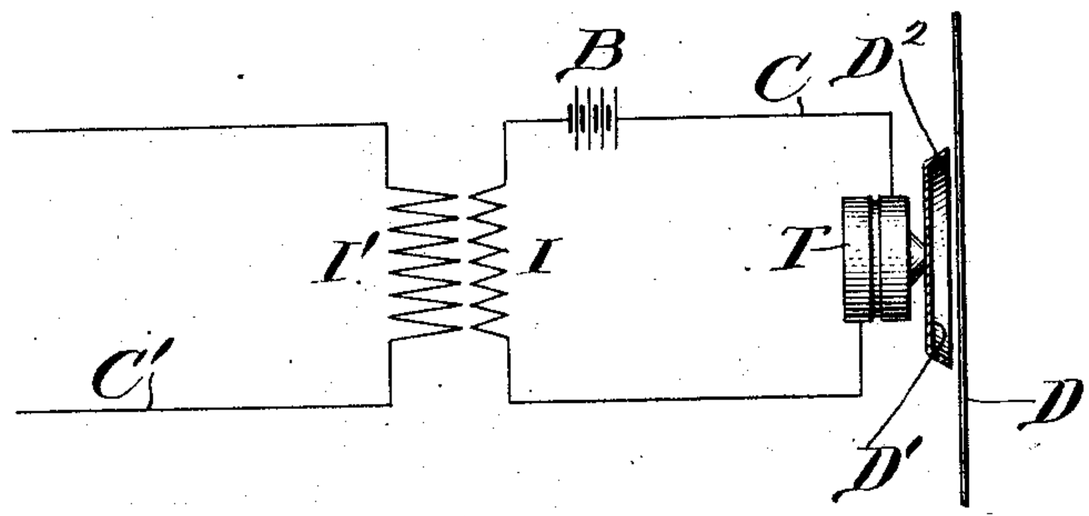
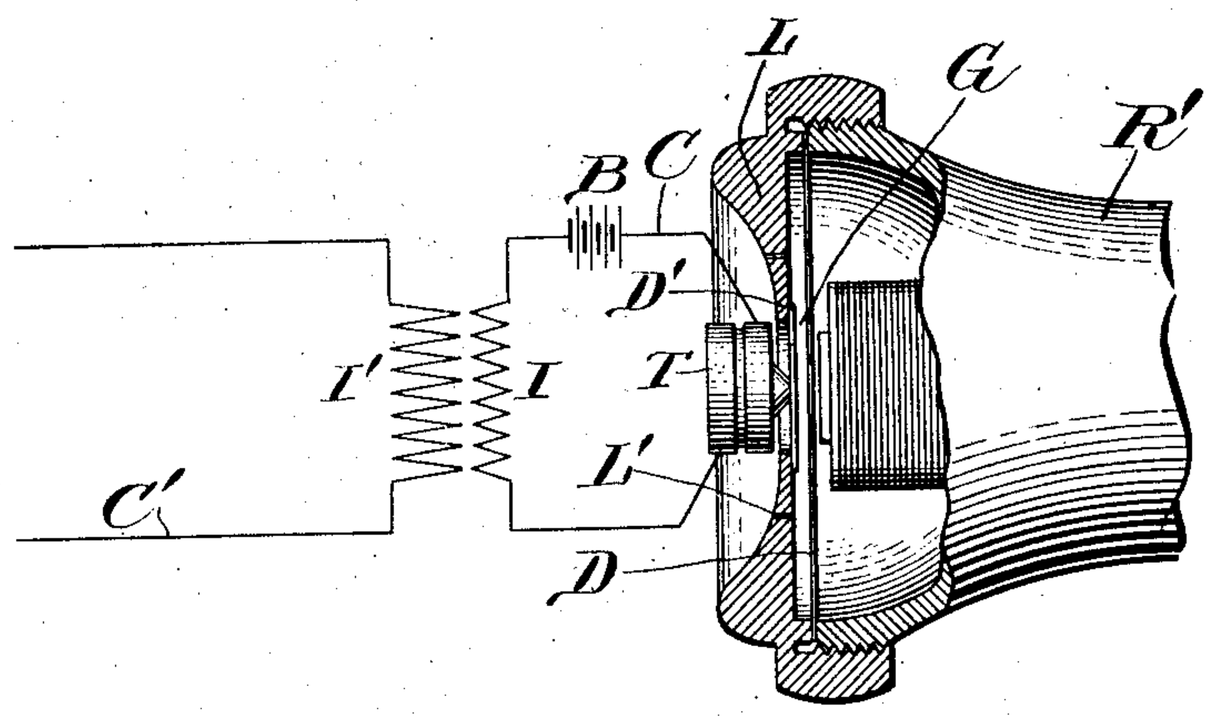


Fig. 3.



Witnesses:
Joseph T. Brennan.
Charles J. Wadsworth

Inventor:
John Trowbridge
by Roberts & Mitchell
Attorneys.

No. 814,411. PATENTED MAR. 6, 1906.

J. TROWBRIDGE.

TELEPHONIC RELAY.

APPLICATION FILED JULY 14, 1905.

5 SHEETS—SHEET 2.

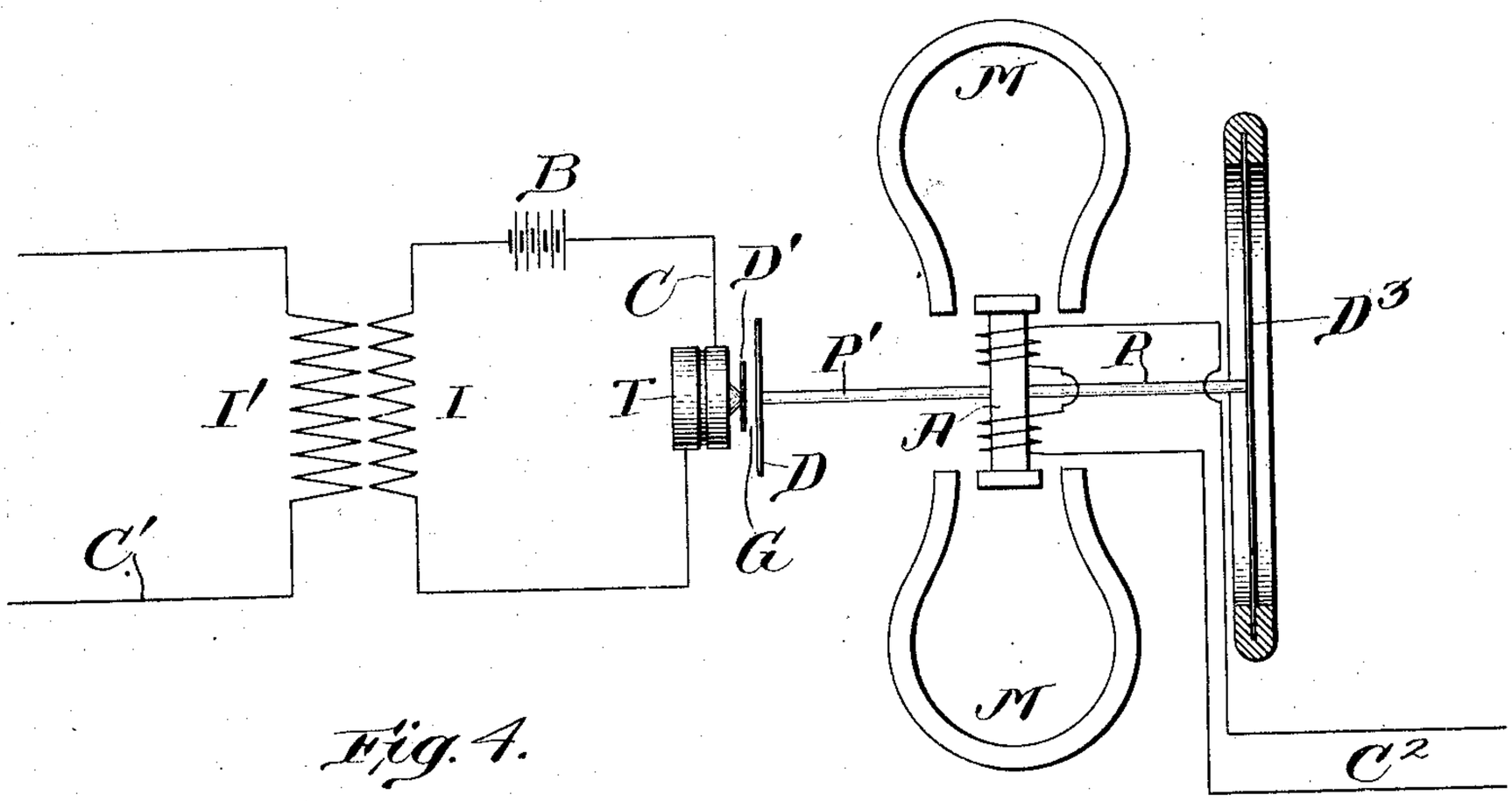


Fig. 4.

Witnesses:
Joseph T. Brennan
Charles S. Wadsworth

Inventor:
John Trowbridge.
by Roberts & Mitchell
Attorneys.

No. 814,411. PATENTED MAR. 6, 1906.

J. TROWBRIDGE.

TELEPHONIC RELAY.

APPLICATION FILED JULY 14, 1905.

5 SHEETS—SHEET 3.

Fig. 6.

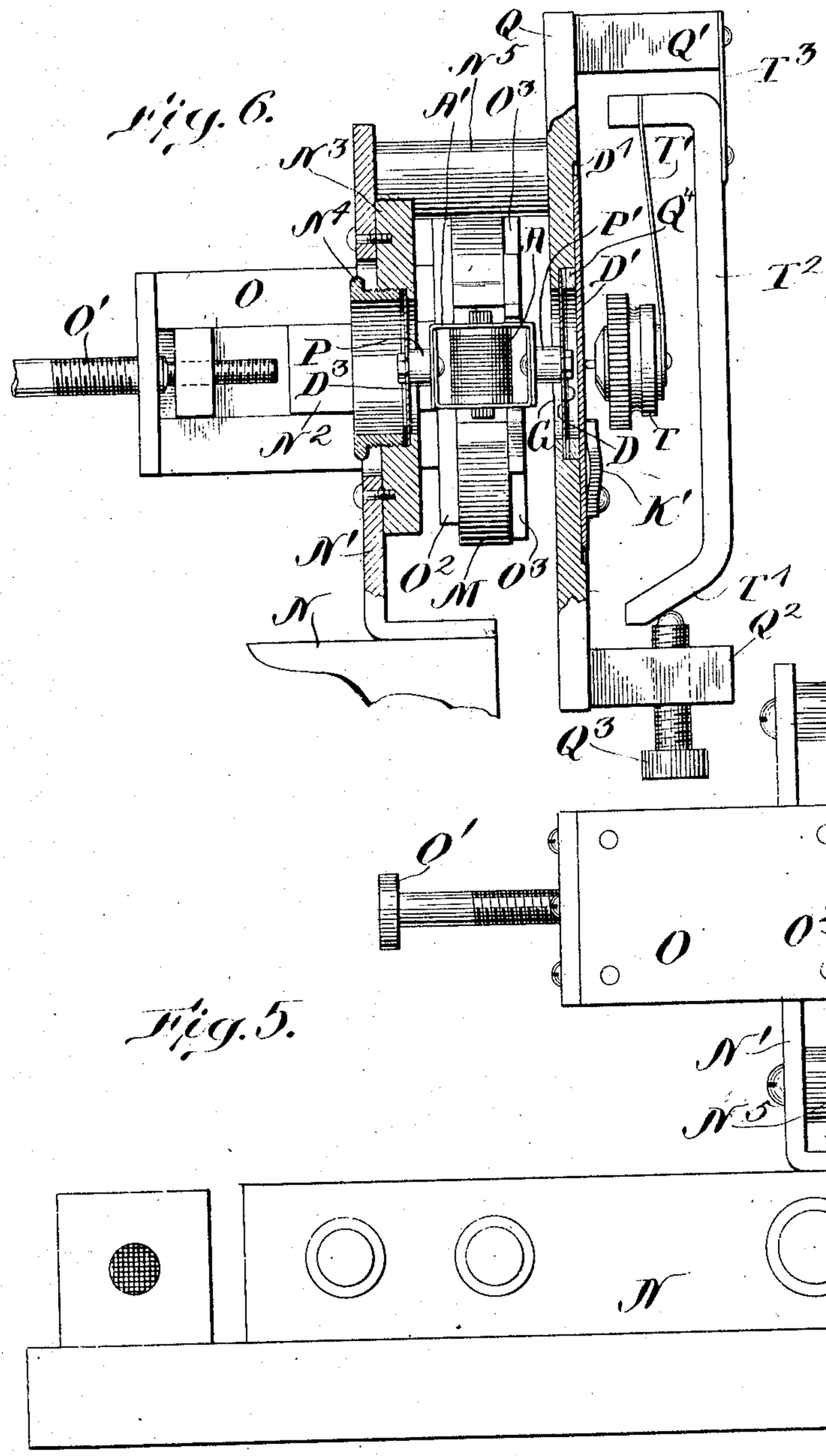


Fig. 5.

Witnesses:
Joseph T. Brennan
Charles J. Wadkins

Inventor:
John Trowbridge
by Roberts & Mitchell
Attorneys.

No. 814,411. PATENTED MAR. 6, 1906.

J. TROWBRIDGE.

TELEPHONIC RELAY.

APPLICATION FILED JULY 14, 1905.

5 SHEETS—SHEET 4.

Fig. 7.

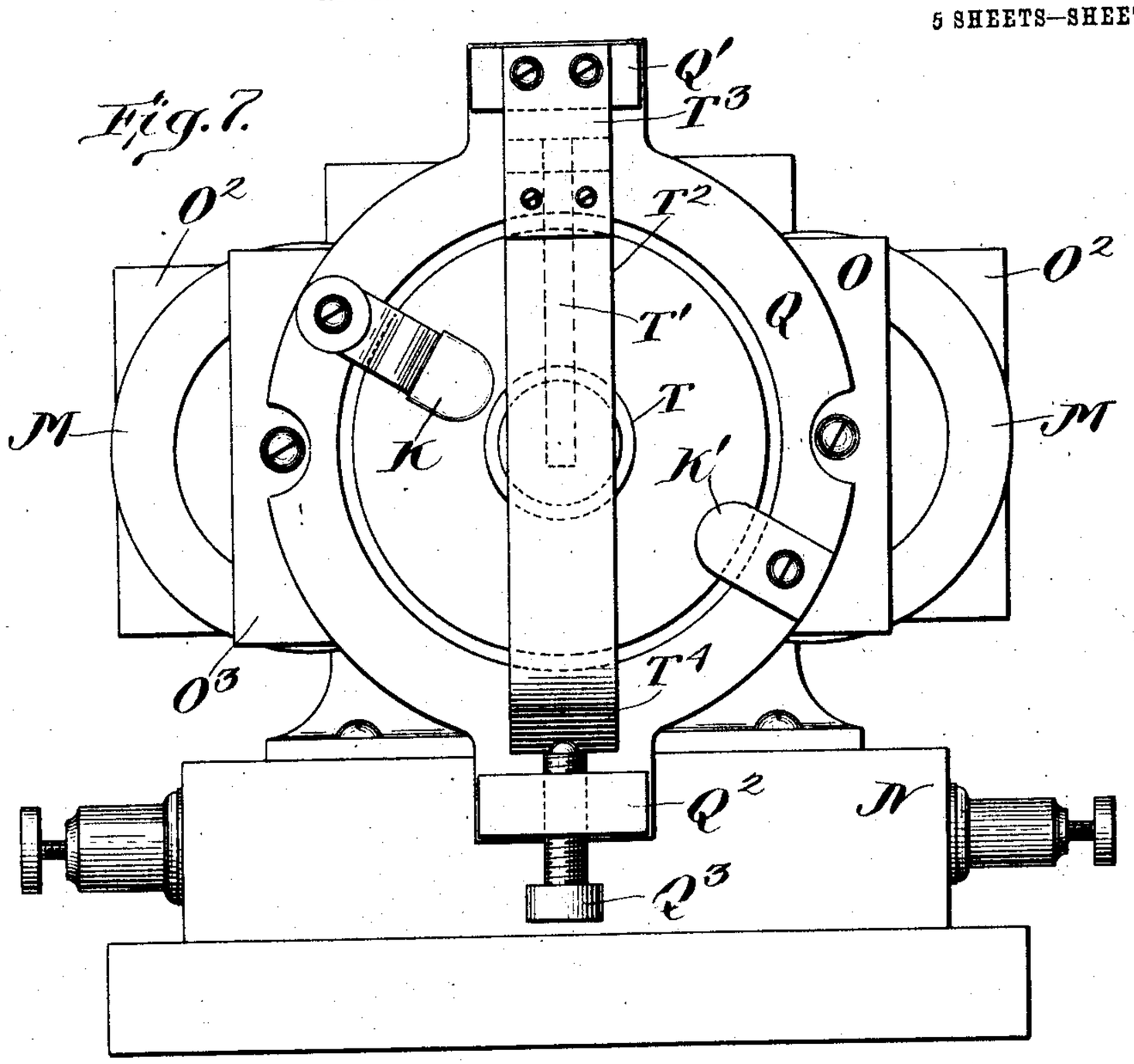
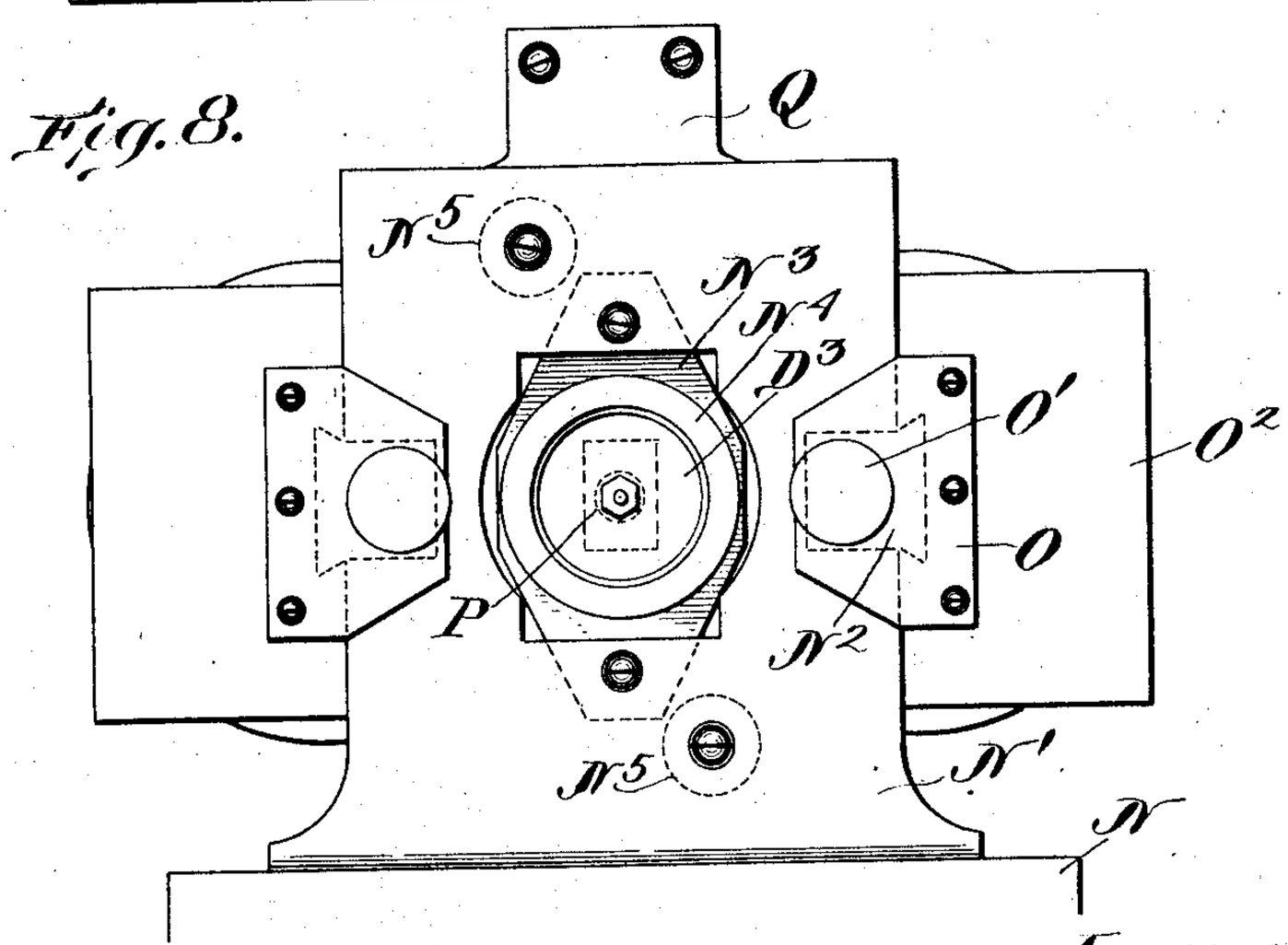


Fig. 8.



Witnesses:

Joseph T. Brennan.
Charles J. Woodbury

Inventor

John Trowbridge

by Roberts & Mitchell

Attorneys.

No. 814,411 PATENTED MAR. 6, 1906.

J. TROWBRIDGE.

TELEPHONIC RELAY.

APPLICATION FILED JULY 14, 1905.

5 SHEETS—SHEET 5.

Fig. 9.

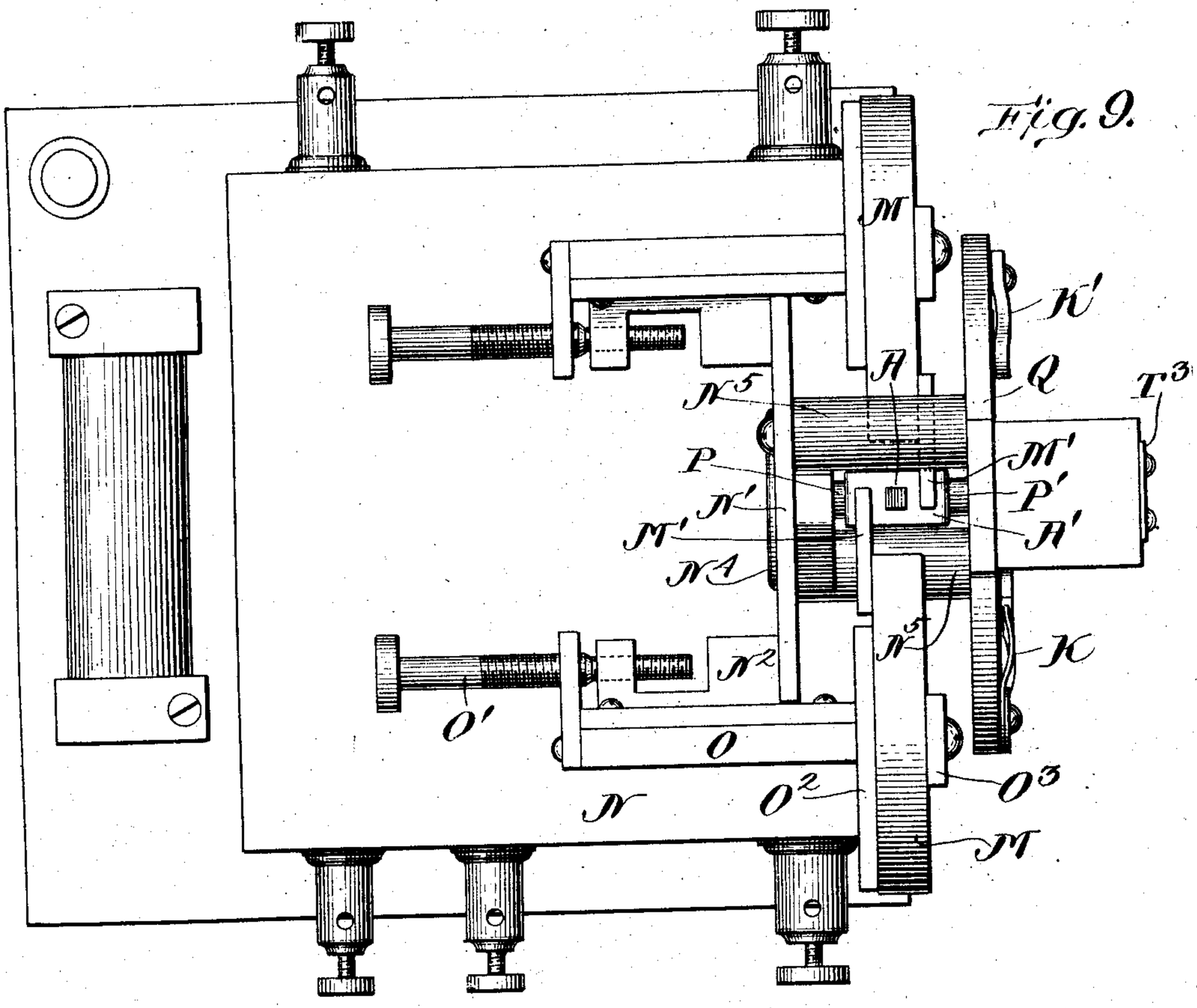
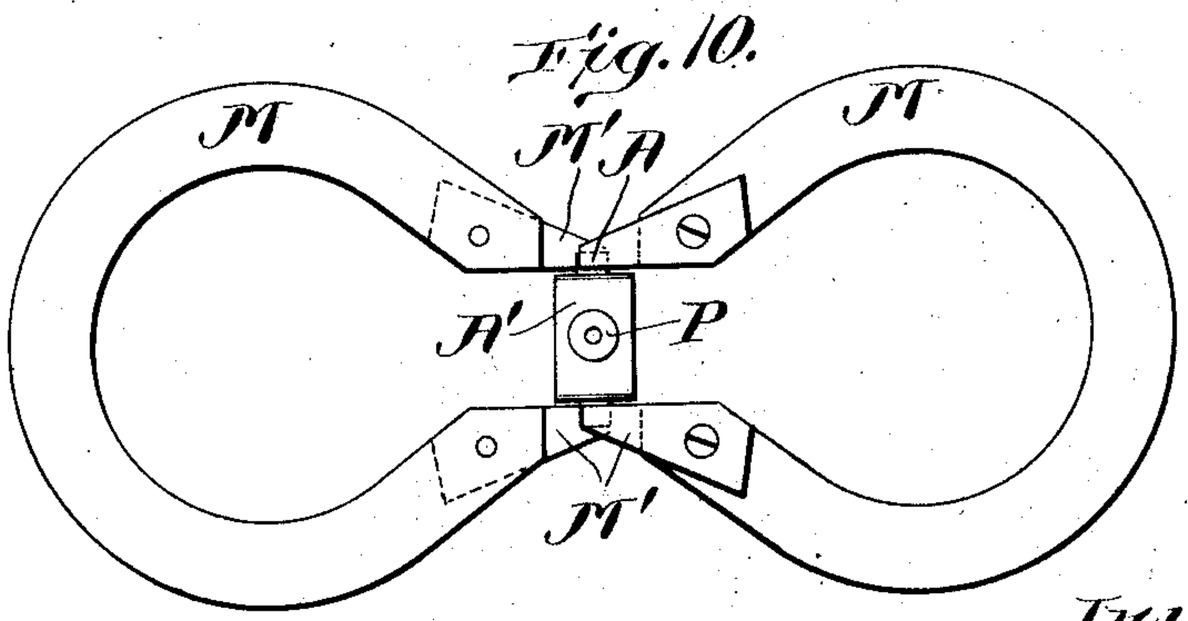


Fig. 10.



Witnesses:
Joseph T. Brennan.
Charles S. Wadkeley

Inventor:
John Trowbridge
by Roberts & Mitchell
Attorneys

UNITED STATES PATENT OFFICE.

JOHN TROWBRIDGE, OF CAMBRIDGE, MASSACHUSETTS.

TELEPHONIC RELAY.

No. 814,411. Specification of Letters Patent. Patented March 6, 1906.

Application filed July 14, 1905. Serial No. 269,628.

To all whom it may concern:

Be it known that I, JOHN TROWBRIDGE, a citizen of the United States, and a resident of Cambridge, in the county of Middlesex and State of Massachusetts, have invented new and useful Improvements in Telephonic Relays, of which the following is a specification.

My invention relates to the art of transmitting electrical undulations; and its object is to so improve the construction of telephonic relays or repeaters as to eliminate from the transmitted undulations the disturbing influences which are manifested audibly at the receiver in the form of crepitations which confuse and sometimes suppress entirely the intelligible articulations of speech wherewith the telephonic current is primarily excited or undulated.

My improvements, presently to be described in detail, are adaptable to many forms of telephonic relays and have demonstrated their capacity to eliminate the undesirable vibratory and percussive disturbances wherewith the operations of most telephonic relays have been impaired. A description of these improvements as they may be associated with one form of telephonic relay will, however, suffice to instruct those skilled in the art in the essentials of their structure and operation so that they may be applied to other forms of relay without the exercise of more than the skill expected of persons trained in the practice of telephony and the manufacture of telephonic instruments.

The difficulty which has heretofore attended the operation of telephonic receivers is attributable in large measure to the practice of placing the transmitter of the relay upon or in direct contact with the receiver-diaphragm which is adjusted to the magnetic portion of the field, thus loading the diaphragm at the very point where loading has the most detrimental effect upon it. On the other hand, in order to transfer to the transmitter of the relay all the articulate vibrations of the receiver it would seem that direct contact between the two was indispensable. I have discovered, in connection with tests and experiments with telephonic relays, including the relay described in my United States Letters Patent No. 756,434, dated April 5, 1904, that this seeming dead-lock can successfully be overcome and that the coexistence in a relay instrument of independent adjustability and intimate sound-transferring contact of the transmitter and receiver is quite possible despite the seeming inconsistency of the two conditions.

In the drawings hereto annexed, Figures 1, 2, 3, and 4 are illustrative and explanatory of my invention; and Figs. 5 to 10, inclusive, show an embodiment thereof. Figs. 1 and 2 show diagrammatically an elementary form of relay. Fig. 3 shows the relay as applied to an ordinary telephonic receiver. Fig. 4 illustrates the application of the elementary principle of Figs. 1 and 2 to a relay such as shown in my Patent No. 756,434, dated April 5, 1904. Fig. 5 is a longitudinal elevation; Fig. 6, a vertical longitudinal section of an instrument which comprises a complete embodiment of my invention. Fig. 7 is a right-hand end, Fig. 8 a left-hand end view, and Fig. 9 a plan view, respectively, of Fig. 5; and Fig. 10 is a detail showing the arrangement of reinforcing-magnets and the armature associated therewith. Figs. 1 to 4, inclusive, are addressed to the phase of the problem referable to the difficulties heretofore encountered by reason of direct attachment of the transmitter to the receiver in a telephonic relay. These figures do not illustrate a full solution, but such part thereof as will be illuminating in connection with the complete structure of Figs. 5 to 10.

Referring to Fig. 1, D represents the diaphragm of a receiving instrument, which may be acoustically vibrated in consonance with the undulations of articulate speech. In opposition to this vibrator D there is mounted a supplemental vibrator, shown as a diaphragm D′, which in this instance is secured to the end of a short cone R in such position as to receive advantageously the impact of aerial vibrations from the air in the partially-inclosed space G, whereby the two vibrators are separated. One member of a microphonic transmitter T is secured to or otherwise placed in mechanical contact with the vibrator D′, and the circuit C, with battery B, is connected with the transmitter members in the ordinary manner, the coils I I′ of the usual induction-coil transferring the electrical undulations to the line C′, which proceeds to a distant receiver. (Not shown in the drawings.) My researches and demonstrations have, however, led me to prefer a form of relay wherein the two vibrators are separated by a much thinner gaseous intermediary than that suggested in Fig. 1. Thus in Fig. 2 the supplemental vibrator D′ is shown as a thin diaphragm (which should be

circular in form) provided with a flange or rim turned toward the receiver-diaphragm D; otherwise the arrangement is substantially the same as that illustrated by Fig. 1. If we regard the diaphragm D, Figs. 1 and 2, as the diaphragm of a telephonic receiver and assume the instrument to be in operation, it is obvious that the transmitter T and the receiver may be independently adjusted and that the gaseous intermediary between the diaphragms D and D′, being in free communication with the outside atmosphere, cannot assume a condition of pressure or tension which will impose any load or stress upon either diaphragm. The transmission of articulate speech from D to D′ will thus be free from disturbances such as attend the direct attachment of a transmitter to a receiver-diaphragm; but the amplitude of the articulate vibrations will necessarily be materially diminished in transit from the receiver to the transmitter and the result in the transmitter-circuit consequently enfeebled.

In Fig. 3 there is illustrated another mode of securing the benefits of the separation of the receiver-diaphragm from the transmitter-vibrator. The receiver-diaphragm D is mounted in the receiver-shell R′ in the usual way. Secured to the lip L of the receiver the supplemental diaphragm D′ is stretched across the central aperture of the said lip, and the transmitter T is secured or otherwise telephonically connected to the center of the diaphragm D′. In order to insure the freedom of the gaseous cushion G, which separates the vibrators D and D′ from the effects of unbalanced pressure due to confinement and changes of temperature, I recommend that one or two small apertures L′ be provided in the lip L. As before, the transmitter connections to battery-circuit and line are as described with reference to Fig. 1. In the apparatus as shown in Fig. 3 the intervention of the air-gap between the diaphragms D and vibrator D′ quite effectively eliminates the disturbances due in other relays to the direct contact between the receiver-diaphragm and the transmitter, while the solid intermediary provided by the cap L between the diaphragms D and D′ transfers the mechanical vibrations to the transmitter T far more effectively than the air-gap alone, as in Figs. 1 and 2; but although the solid connection illustrated in Fig. 3 is superior to the disconnected arrangement of Figs. 1 and 2 it is nevertheless not all that could be desired, for the reason that the insulating materials of which the commercial receiver-case is composed is not ideally adapted to sound transference.

The forms of relay above described are not so constructed as to reproduce the electrical undulations of the receiver-circuit with enhanced force and amplitude in the transmitter or relay circuit and are for this reason doubtfully effective as relay instruments. Nevertheless the local disturbances which occur in the transmitter and which (if the transmitter were connected directly to the receiver-diaphragm D, as in sundry early forms of telephonic relay) would react upon the receiver undulations and produce the rattling and buzzing noises which have in nearly all relay instruments impaired or obliterated the essential articulate character of telephonic undulations are eliminated by the elastic intervening layer of air, which in the instruments shown in Figs. 1 to 3, inclusive, separate the opposed vibrators D and D′. This gaseous cushion, however, transmits the articulate undulations from the receiver-vibrator D to the supplemental vibrator D′ with unimpaired quality, and the undulations transmitted in the relay-line C C′ correctly reproduce the articulate speech whereby the original sending instrument was excited.

In my United States Letters Patent Nos. 756,436 and 756,437 there are described a method and apparatus whereby telephonic undulations are repeated or relayed from one circuit to another not only without loss in amplitude and force, but with both these qualities enhanced. By means of the magnetically-balanced relay instruments shown and described in the said patents the repetition of telephonic messages can recur indefinitely as additional increments of electromechanical energy are supplied at each station, so that the stations are in truth relays. A full description of this method and apparatus is afforded by the specifications of the said Letters Patent.

In Fig. 4 there is illustrated a mode of applying the air-gap connection shown in Figs. 1 and 2 to a relay instrument of the character shown and described in Letters Patent No. 756,437 and particularly illustrated in Fig. 5 thereof. In Fig. 4 hereto annexed, M M are the magnets which maintain a constant magnetic field in which the armature-coil A is balanced. The armature-coil is mounted between stems P and P′, the stem P being secured to a sustaining-diaphragm D^3 and the stem P′ secured to a diaphragm D, which corresponds (in functional relation to the relaying-transmitter T) to the receiver-diaphragm D of Figs. 1 to 3, inclusive. The receiving-line C^2 contains the armature-coil in circuit, and the undulations of current created in that line by a distant sending instrument react magnetically on the field of the magnets M M. Instead of securing the transmitter T directly to the stem P′, I secure it to the supplemental vibrator or diaphragm D′, which, as in the instruments shown in the previous Figs. 1 to 3, is separated from the vibrator D by an intervening cushion of free or normally inert gas—in this case air. The form of supplemental vibrator is here shown as the same as that of Fig. 2, and the trans-

mitter connections to battery-cir uit, &c., are as in Fig. 1. The effect of th balanced armature A in the field of the magnets M is to enhance the force and effect of the undulations produced in the circuit C^2 as these are transferred to the transmitter T. The effect of the gaseous cushion or layer G, as in the instruments shown in Figs. 1 to 3, is to suppress or absorb the reactionary crepitations liable to be produced by the transmitter T. The intervention of the air-gap in the instrument illustrated in Fig. 4 has the effect of preserving the quality of articulate undulations, though it necessarily diminishes their force and amplitude, and while this diminution is in part compensated for by the peculiar mode of operation of the receiving portion of the relay shown it is obviously preferable to combine the advantages of air separation with those of continuous solid contact, as suggested by Fig. 3. In all cases I believe it to be advisable to maintain pressure balance as between the gaseous cushion and the circumambient gas, so that there shall be no distortion of either of the opposed vibrators. It is also desirable to have the two vibrators quite close together and perfectly parallel as to their opposed surfaces. Concentric arrangement is obviously to be recommended.

In the Figs. 5 to 10, inclusive, there is shown an apparatus which combines the advantages desirable: first, from air-gap separation, which eliminates disturbances due to load on the receiver and preserves the quality of the articulations; second, from solid continuous sound transferring communication between the receiver and transmitter, and, third, from the enhancement of the force and amplitude of the received undulations in and by the peculiar structure and mode of operation of a receiver such as shown and described in my patent aforesaid. Referring to the drawings, N is a suitable base for the reception and mounting of contact-posts, and N′ is a standard rigidly secured to the base N. Slide-blocks N^2 project from the rear of the standard N′ and engage the slides O, the slide-blocks N^2 and slides O being dovetailed to establish their mutual sliding engagement. Differential screws O′, which are threaded into the slides O and slide-blocks N^2, control the adjustment of these two parts. The magnets M are securely clamped between the plates O^2 and O^3, whereof the former is rigidly secured to the slide O. These parts are all in duplicate, the parts on either side carrying one of the reinforcing relay-magnets M. A block N^3, rigidly secured to the standard N′, is centrally apertured and threaded to receive the shell N^4, between which and the block N^3 the sustaining-diaphragm D^3 is secured. Horizontal posts N^5, secured to the standard N′, support the frame-plate Q, which is provided with lugs Q′ and Q^2. The diaphragm D is secured to a central aperture in the plate Q. The stems P P′ are centrally fastened to the diaphragm D^3 and D, respectively, and carry between them the rectangular frame A′, in which is mounted the armature A. This armature has its coil in circuit with a telephone-line, as described in my aforesaid patents. The diaphragms D and D^3 are preferably constructed of mica. In a circular shallow recess D^4, formed in the plate Q, there is secured the diaphragm D′, which may be a plain plate of sheet-iron, such as used for commercial receiver-diaphragms. The diaphragm D′ constitutes the vibrator for the transmitter T and is separated from the diaphragm D of the receiver by an air-space, the diaphragm of the receiver and transmitter vibrator being opposed to each other, preferably parallel, and as close together as the convenience of construction will allow. At or near the margin of the receiver-diaphragm D the ring Q^4 is inserted, which serves in the instance shown both as the clamp for the margin of the receiver-diaphragm and also as the solid continuous sound-transferring connection between the diaphragms D and D′, the diaphragm D′ being brought into sufficiently continuous and intermittent contact with the ring Q^4 by means of the clamps or spring-fingers K and K′. The ring Q^4 in order to obtain satisfactory results should be of metal and be brought into intimate contact with the receiver-diaphragm and the transmitter-vibrator. This contact, however, is not inconsistent with a practically free ventilation of the air-space between the diaphragms D and D′. This free communication between the air of the space between the diaphragms and the surrounding atmosphere is of value in that the pressure balance between the inner space and the outside air precludes the production of stresses upon the receiver-diaphragm itself or upon the vibrator of the transmitter, if that, as in the instance shown, be also a continuous circular diaphragm. The diaphragm D′, Fig. 6, is considerably larger in diameter than the diaphragm D, the effective diameter of the latter measured from the inside of the ring Q^4 being somewhat less than half the diameter of the former. The ring Q^4, bearing upon the periphery of the diaphragm D, does not interfere appreciably, probably not at all, with the responsive vibrations of the receiver-diaphragm D. This ring bears upon the larger diaphragm D′ well within the periphery thereof, and consequently imparts to the diaphragm D′ the vibrations manifested by the diaphragm D, so as to make their effect felt emphatically at the center of the diaphragm D′, whereon the contact-point of the transmitter T is made to bear. Specifically, it is believed that this proportion and arrangement of the sound-transmitting parts is decidedly effective in transmitting the vibrations of the receiver-diaphragm to the transmitter. Upon

the lug Q′ there is firmly secured a plate-spring T^3, which sustains the adjusting-bar T^2, whereby the transmitter T is adjusted in relation to the diaphragm D′, with which the contact-piece of the transmitter makes contact. The transmitter T is suspended upon a leaf-spring T′, which is secured to the upper end of the adjusting-bar T^2. This adjusting-bar is inwardly inclined at its lower end T^4, and the sloping surface of this inwardly-inclined portion is engaged by the end of an adjusting-screw Q^3, which is threaded into the lower lug Q^2 of the plate Q. Spring-clamps K K′ hold the diaphragm D′ in position in the recess D^4. The magnets M have pole-pieces M′, which slightly overlap each other as viewed horizontally, Fig. 10, so that the ends of the armature A lie between the overlapping pole-pieces M′.

By means of the apparatus above described the receiving and transmitting members of the relay are independently adjustable. The magnets M are adjusted by means of the differential screws O′, which may be operated singly or together, as desired, in order to produce a perfect balance of field around the armature A. The transmitter T, on the other hand, is independently adjusted by means of the screw Q^3, which presses the adjuster-bar T^2 inward or allows it to swing outward under the tension of the spring T^3. The mode of hanging and pivoting these adjusting devices results in what is in substance a parallel-motion adjustment for the transmitter T, the radial action of the spring T′ compensating for the radial action of the spring T^3.

As I have hereinabove stated, in some of the telephonic relays heretofore constructed the contact-piece of the transmitter has been placed in direct contact with or has been secured to the diaphragm of the receiver. This arrangement has stood in the way of the obtainment of satisfactory results, because the securement or contact of the transmitter unduly loads the receiver-diaphragm and it is impossible to make adjustments in the transmitter without undesirably affecting the receiver. Moreover, all the disturbances and crepitations due to the operation of the transmitter are directly transferred to the receiver, and the articulate speech originally transmitted by the line is confused, or it may be wholly suppressed. By separating the vibrator which is in connection with the transmitter from the vibrating diaphragm of the receiver by a thin layer of air between the directly-opposed portions of the vibrator and diaphragm the consequences of too direct an intimate contact between the transmitter and the receiver-diaphragm are avoided, and either instrument may be adjusted independently of the other. Furthermore, by constructing the instrument so that the communication of vibrations from the receiver-diaphragm to the transmitter are through a path of solid continuity, as through the ring Q^4 and the diaphragm D′, the transmitter is put into communication with the receiver just as effectively, for all practical purposes, as it is when it makes its contact directly with the receiver-diaphragm. All of the articulate vibrations of the receiver-diaphragm are passed to the transmitter, whereas by reason of the air separation between the vibrator and the diaphragm the inarticulate disturbances of the transmitter are not communicated to the receiver. The securement of the diaphragm D′ leaves a circumferential clearance which is not air-tight, so that the pressure balance between the air in the cushion G and the surrounding atmosphere is maintained.

One feature which I regard as practically of great importance is the independent adjustability of the receiver and transmitter members of the relay. As these two members are separated by a layer or cushion of air, it is quite obvious that the adjustment of one can be carried on entirely independently of the other, whereas in those instruments whose structure involves mechanical contact or other mechanical connection between the receiving and transmitting members of the relay the proper adjustment of one is very liable to affect the adjustment of the other, and very nice compromises of adjustment have consequently to be resorted to. Moreover, the vibrating portion of the relay, which is set in motion in the magnetic field by the undulations of the current to be relayed, is entirely relieved of the load or restraint of the transmitting-microphone or other transmitting device.

With respect to the transmission of articulate speech as yet no instrument has attained such perfection as the microphonic transmitter. This transmitter in the usual commercial "solid back" form is provided with its diaphragm for the reception of articulate sound-waves. In my improved relay I employ just such a transmitter and subject it to conditions which closely resemble, if they do not exactly reproduce, the usual conditions present when a person speaks to the microphonic transmitter. The vibrator of the receiver reproduces with accuracy the articulate sound-waves emitted by the human voice into a distant transmitter, and the receiver vibrator or diaphragm emits this articulate vibration, setting the objects immediately in contact with it into exactly similar undulations. The transmitter vibrator or diaphragm is subjected to the sound-waves which impinge upon it as effectively as when it is spoken to in the ordinary way. Where, as in the instrument described in my patent aforesaid, a relay-station is provided with an instrument which enhances the force and amplitude of the articulate vibrations of

the telephonic circuit, so that the receiver of the relay may speak not only intelligibly but loudly, the vibrator of such a relay is enabled to speak to the vibrator of a transmitter with exactly the same force and effect as though the person originally sending the message spoke directly into this transmitter.

What I claim, and desire to secure by Letters Patent, is—

1. In a telephonic relay, a receiver, its diaphragm, a vibrator opposed to the receiver-diaphragm, an air layer between the vibrator and diaphragm, in free communication with the circumambient atmosphere, a transmitter in connection with the vibrator, and continuous solid sound-transmitting connections between the vibrator and the diaphragm.

2. In a telephonic relay, a receiver, its diaphragm, a vibrator opposed to the receiver-diaphragm and spaced therefrom, a transmitter in connection with the vibrator, and a close metallic connection between the vibrator and the diaphragm.

3. In a telephonic relay, a receiver, its diaphragm, a vibrator opposed to the receiver-diaphragm and spaced therefrom, a transmitter in connection with the vibrator, and a close metallic connection between the vibrator and the diaphragm at the margin of the latter, to insure sound communication and to permit mutually independent adjustment of the transmitter and receiver, and means to adjust the transmitter independently of the receiver.

4. In a telephonic repeater, the combination of a receiving instrument and a transmitter, each provided with a diaphragm, the diaphragms arranged parallel and opposed to each other, separated by an intervening layer of air which is in free communication with the surrounding atmosphere, the transverse area of said air layer being substantially at least coequal with the area of the smaller diaphragm, and solid sound-transmitting connections from the edge of one diaphragm to the edge of the other.

5. In a telephonic repeater, the combination of a receiving instrument and a transmitter, each provided with a diaphragm, the diaphragms arranged parallel and opposed to each other, separated by an intervening layer of air which is in free communication with the surrounding atmosphere, the transverse area of said air layer being substantially at least coequal with the area of the smaller diaphragm, and solid sound-transmitting connections from the edge of one diaphragm to the edge of the other, and means to adjust the receiver and the transmitter independently.

6. In a telephonic repeater, the combination of a receiving instrument and a transmitter, each provided with a diaphragm, the transmitter-diaphragm of larger effective superficial area than that of the receiver, and a solid sound-transmitting connector which bears upon the periphery of the receiver-diaphragm and upon the transmitter-diaphragm between the periphery and the center thereof.

7. In a telephonic repeater, the combination of a receiver and a transmitter, each provided with a diaphragm, the transmitter diaphragm of substantially greater superficial area than that of the receiver, the two diaphragms separated by an intervening layer of air which is in free communication with the surrounding atmosphere, and a solid sound-transmitting connector bearing upon the receiver-diaphragm at the periphery thereof and upon the transmitter-diaphragm between the periphery and center thereof.

8. In a telephonic repeater, the combination of a receiver and a transmitter, each provided with a diaphragm, the transmitter-diaphragm of superficially greater area than the receiver-diaphragm, the two diaphragms concentrically arranged and in parallel opposition, and a ring of solid sound-transmitting material interposed between the diaphragms and bearing upon the periphery of the receiver-diaphragm and upon the transmitter-diaphragm at a region between the center and periphery thereof.

Signed by me at Boston, Massachusetts, this 13th day of July, 1905.

JOHN TROWBRIDGE.

Witnesses:

JOSEPH T. BRENNAN,

CHARLES D. WOODBERRY.