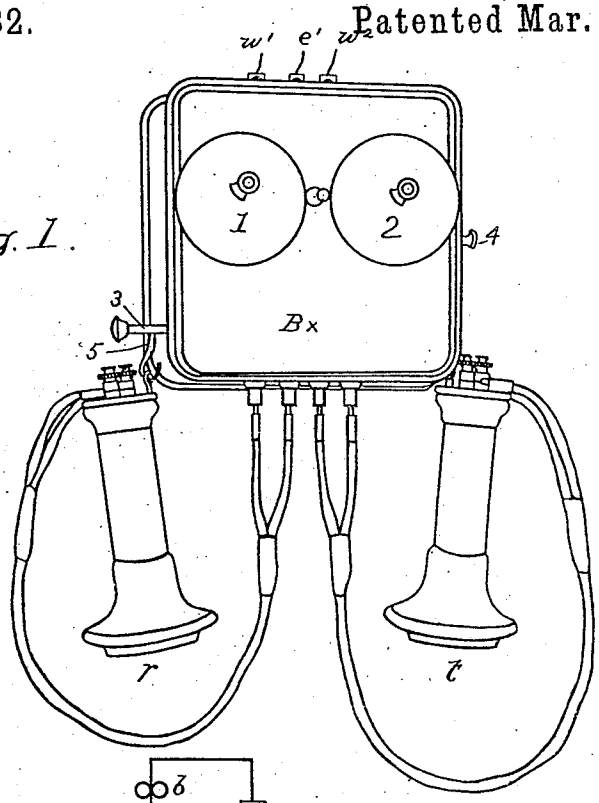
(No Model.) 9 Sheets—Sheet 1.

S. W. HOLMAN.

TELEPHONE EXCHANGE SYSTEM.

No. 536,382. Patented Mar. 26, 1895.

Fig. 1.



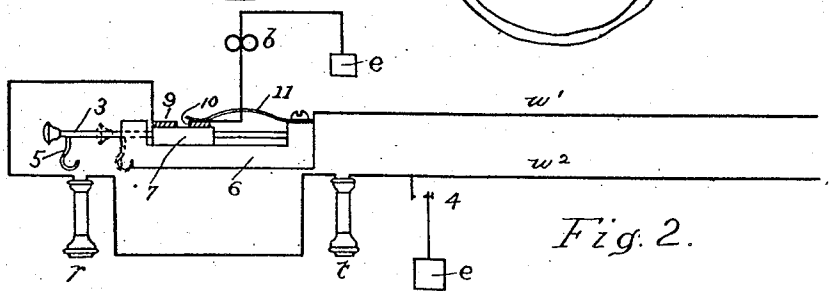


Fig. 2.

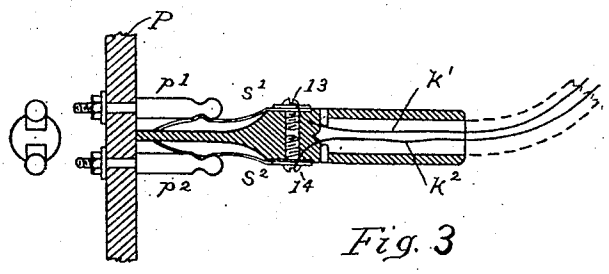


Fig. 3

Witnesses:
Alfred J. Burrow
Thomas J. Cunningham.

Inventor:
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By Reuben L. Roberts,
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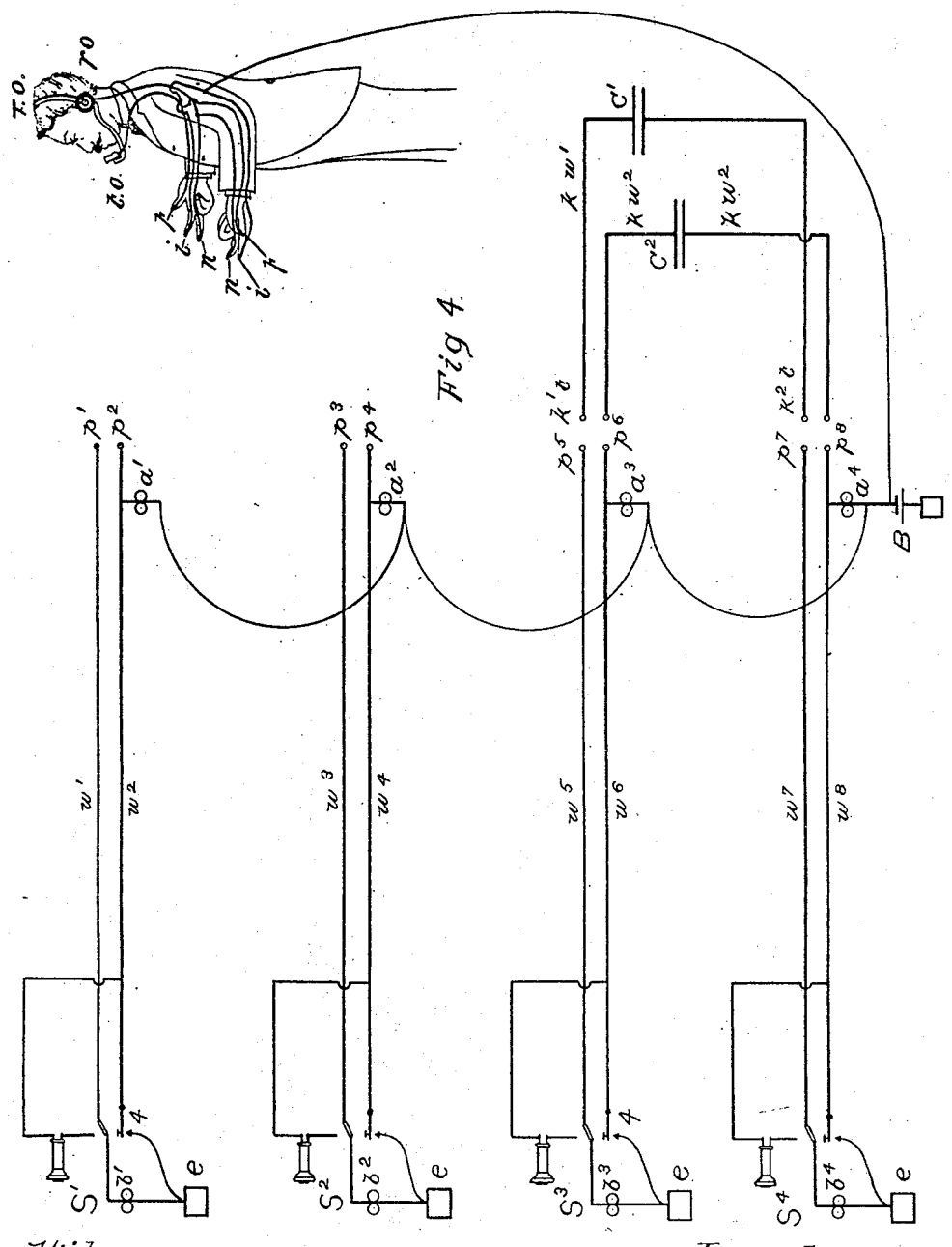

Fig 4.

Witnesses.
a. J. Burrow.
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(No Model.) 9 Sheets—Sheet 8.

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TELEPHONE EXCHANGE SYSTEM.

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Fig. 5.

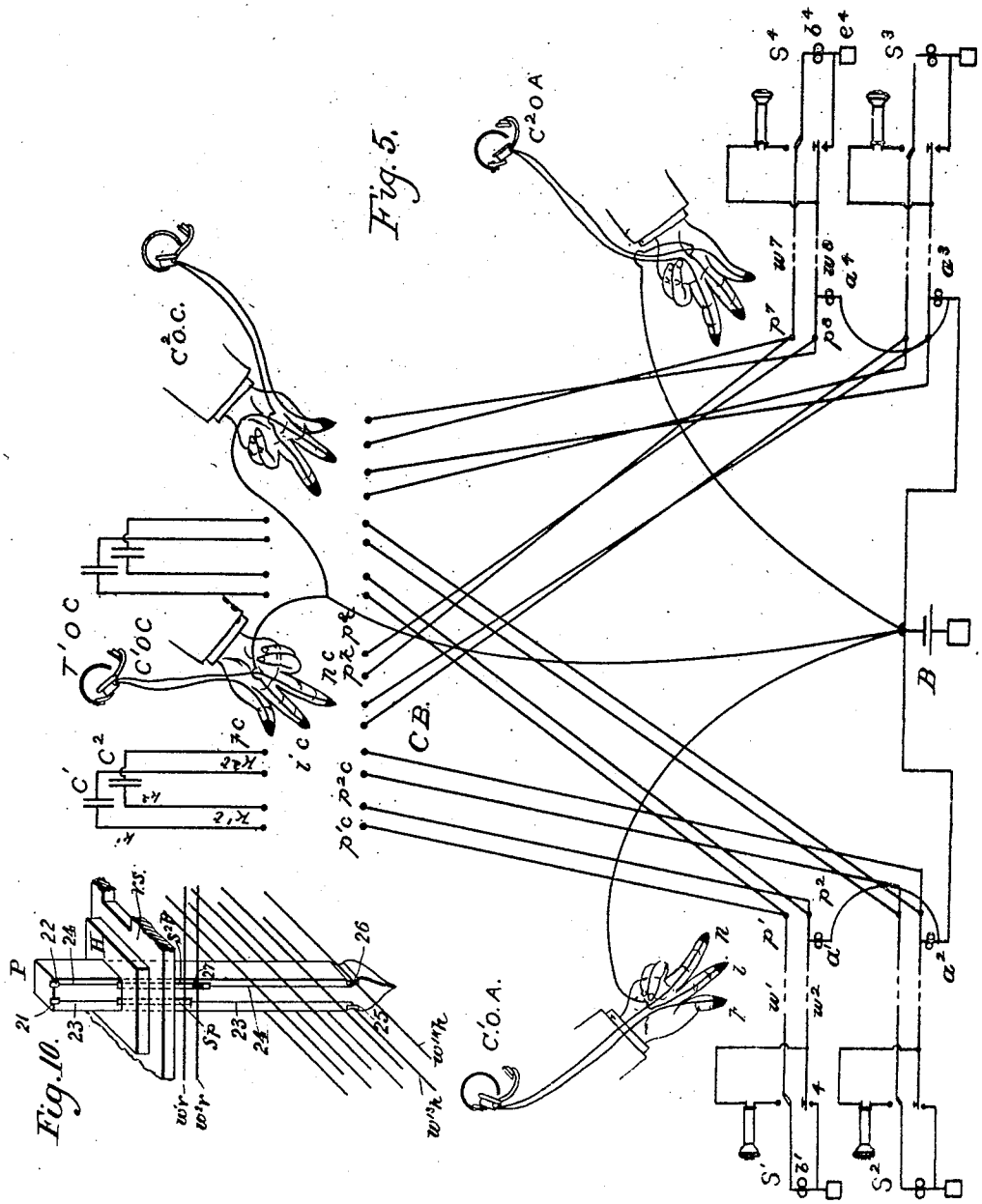

Fig. 10.

Witnesses.

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(No Model.) 9 Sheets—Sheet 4.

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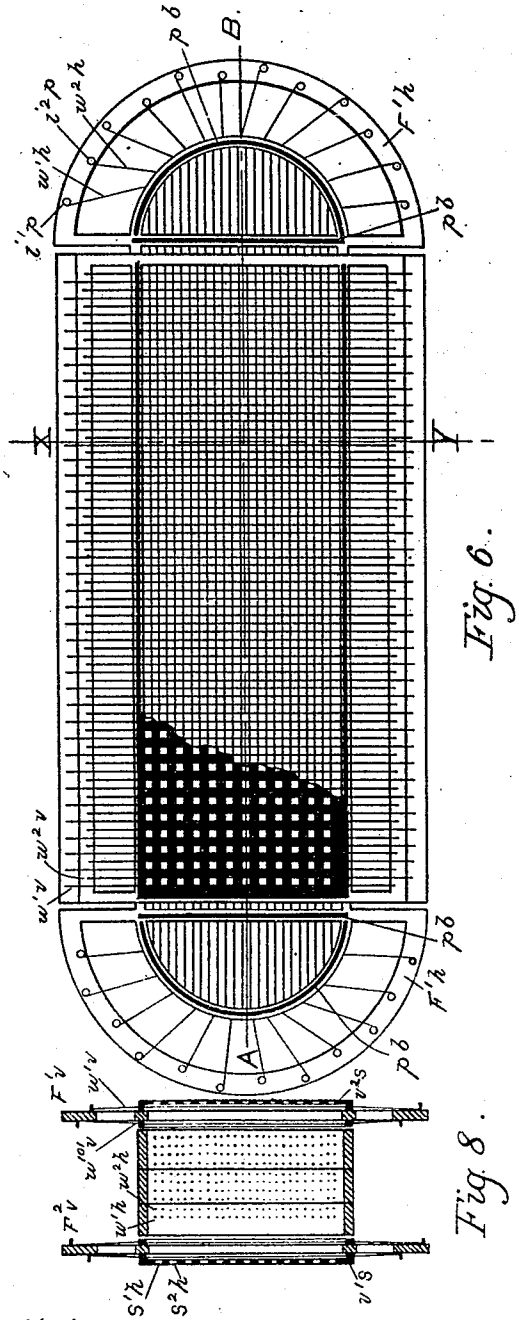

Fig. 6.

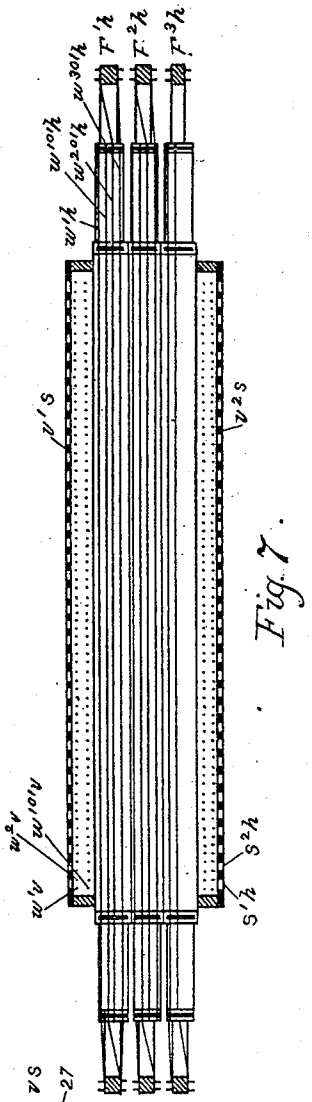

Fig. 7.

Fig. 8.

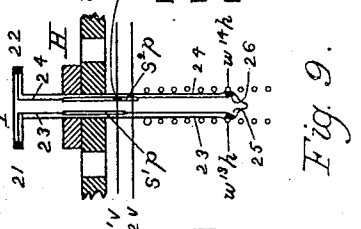

Fig. 9.

Witnesses.

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Inventor

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(No Model.) 9 Sheets—Sheet 5.

S. W. HOLMAN.

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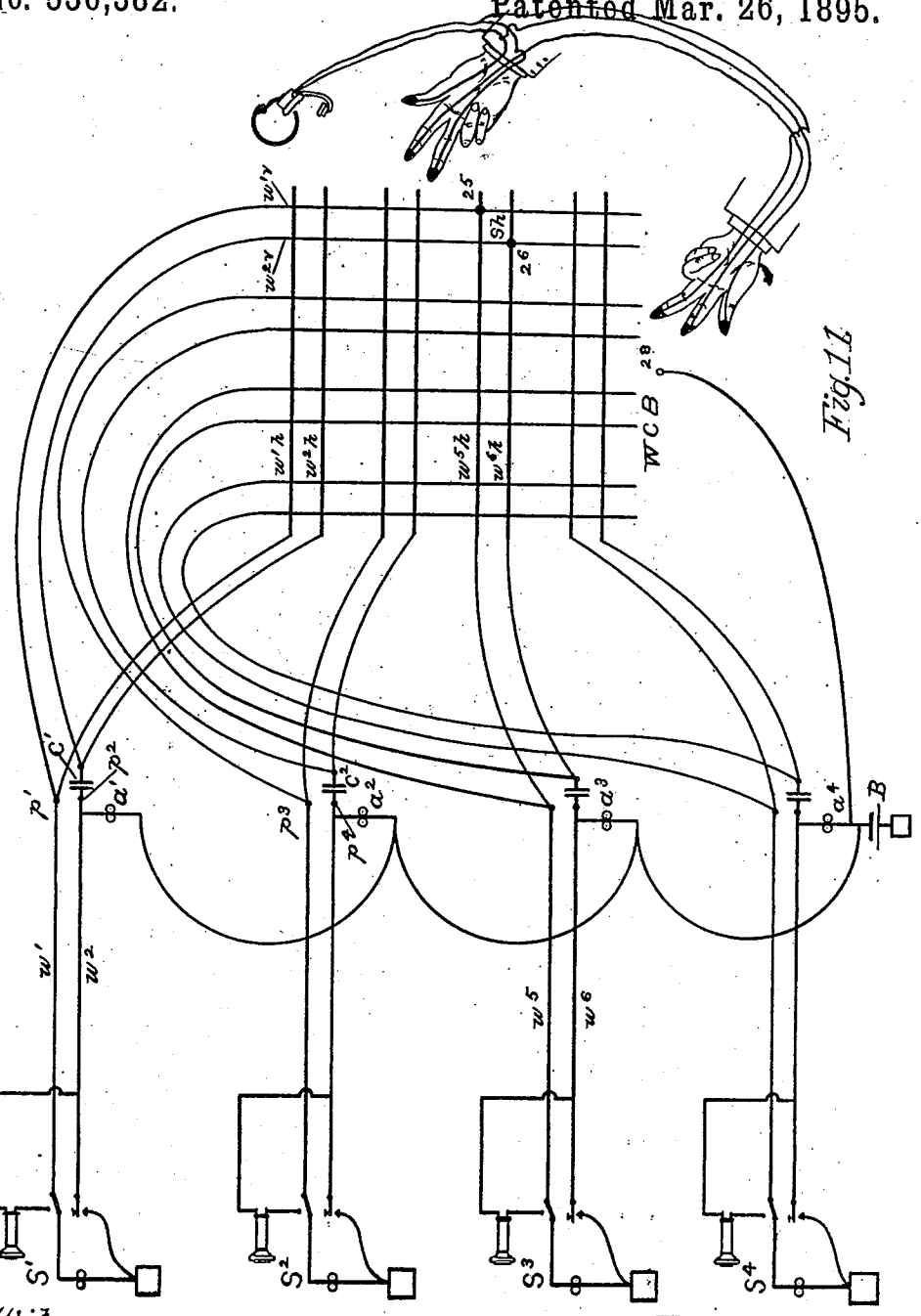

Fig. 1.

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(No Model.) 9 Sheets—Sheet 6.

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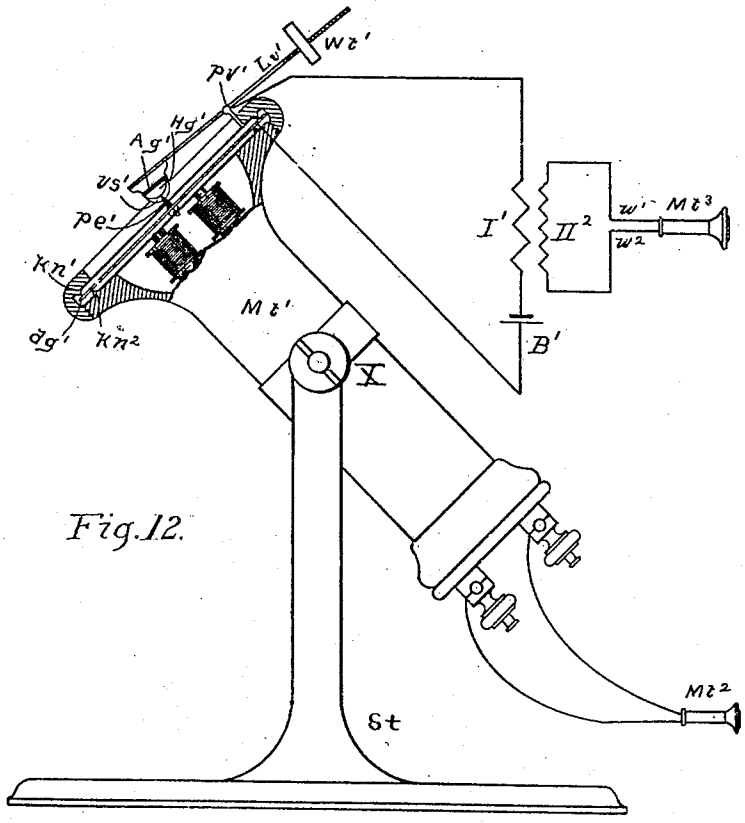

Fig. 12.

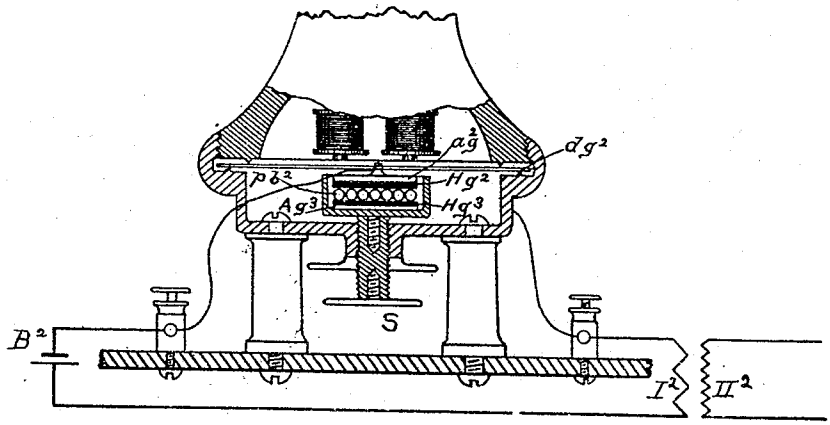

Fig. 13.

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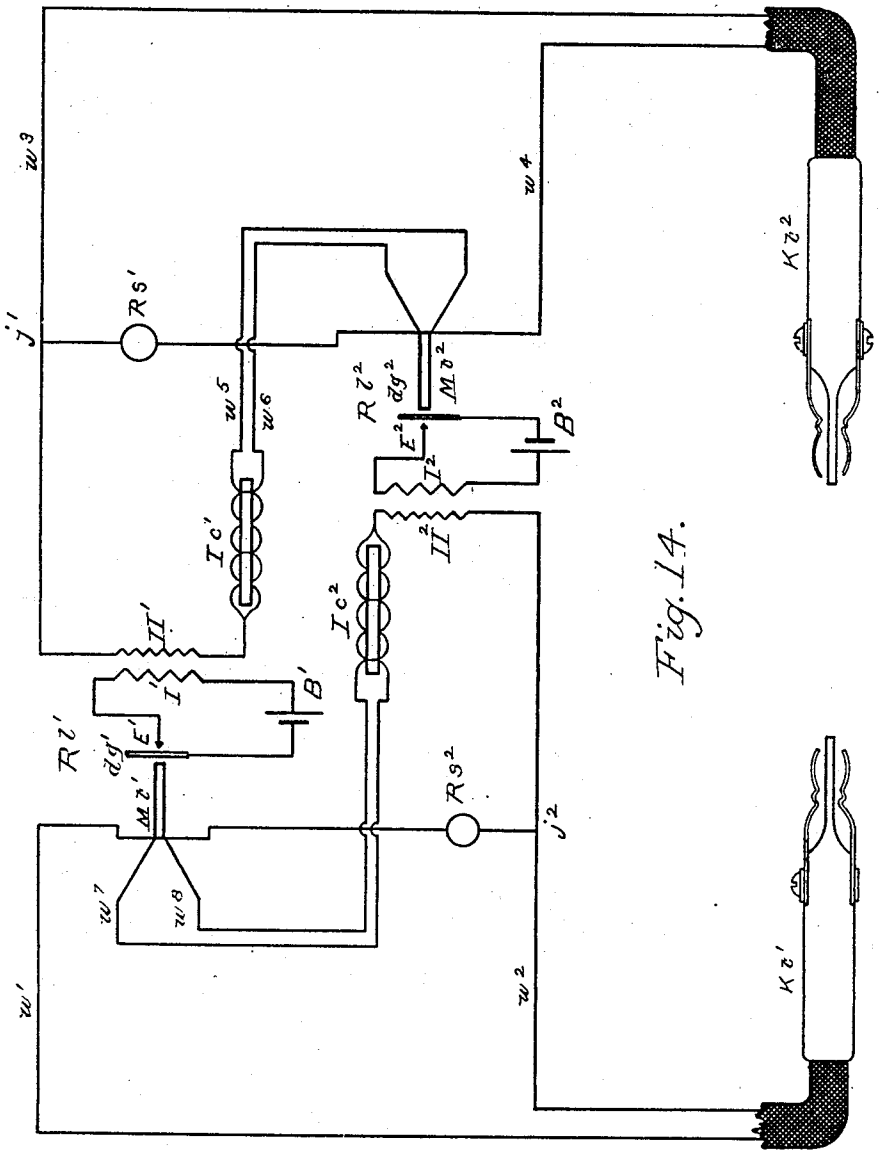

Fig. 14.

Witnesses.

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(No Model.) 9 Sheets—Sheet 8.

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TELEPHONE EXCHANGE SYSTEM.

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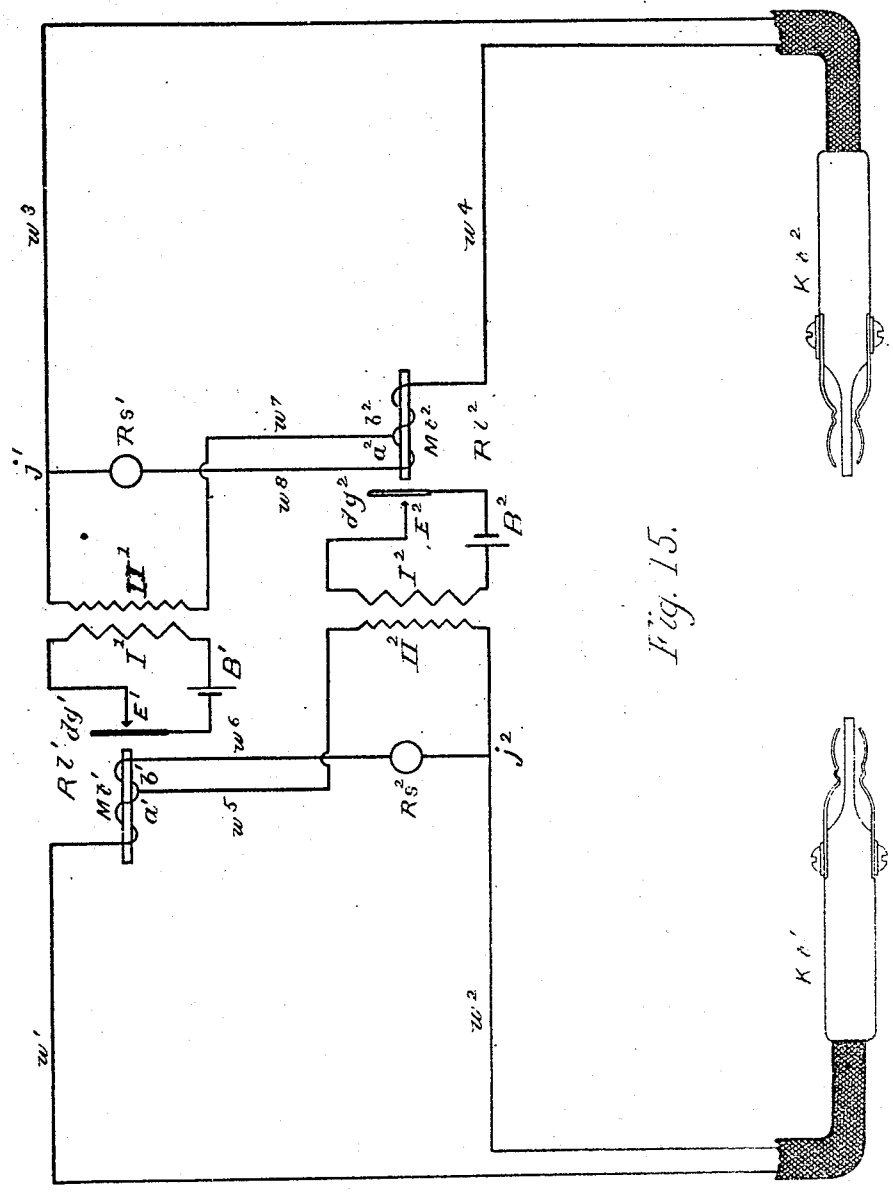

Fig. 15.

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(No Model.)

9 Sheets—Sheet 9.

S. W. HOLMAN.

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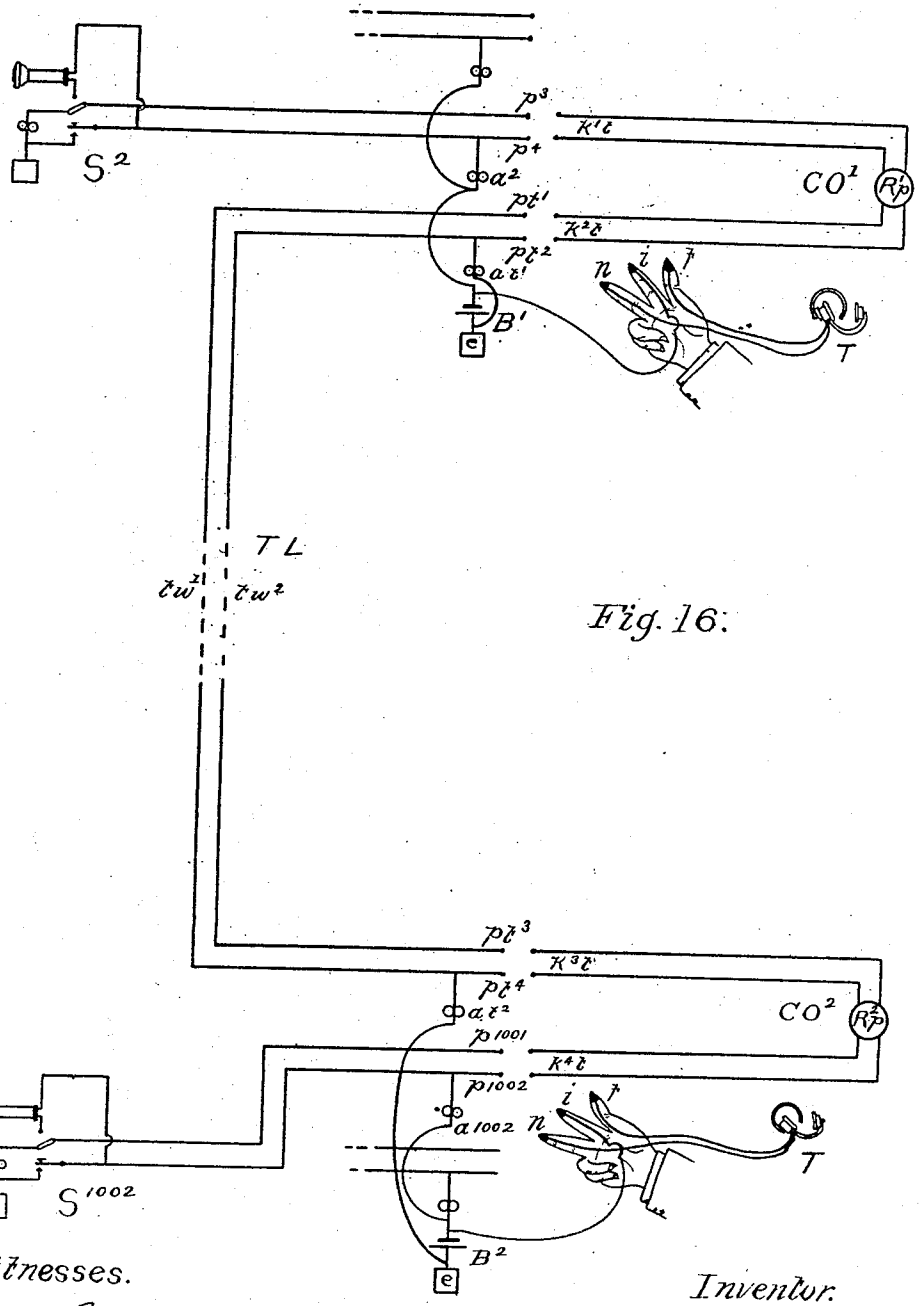

Fig. 16.

Witnesses.

A. J. Burrow.

T. J. Cunningham.

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UNITED STATES PATENT OFFICE.

SILAS W. HOLMAN, OF BOSTON, MASSACHUSETTS.

TELEPHONE-EXCHANGE SYSTEM.

SPECIFICATION forming part of Letters Patent No. 536,382, dated March 26, 1895.

Application filed March 24, 1894. Serial No. 504,965. (No model.)

To all whom it may concern:

Be it known that I, SILAS W. HOLMAN, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented certain Improvements in Telephonic-Exchange Systems, of which the following is a specification.

The object of my present invention is to provide a simple, inexpensive, convenient, reliable, efficient and speedy mechanism and method by which any telephone subscriber may be placed in telephonic communication with any other telephone subscriber, whether connected directly with the same central office or with another central office.

While telephone exchange systems are now in use by which the subscribers connected with one central office may converse with each other with more or less facility, and by which some of the subscribers connected with one central office may converse with some of the subscribers connected with another central office, it is believed that even these systems are unnecessarily complicated and expensive in construction and unnecessarily cumbersome, unreliable, inefficient and slow in operation.

Some of the salient features of my present system are:

The use at the subscribers' stations of magneto telephone transmitters and receivers, such as are described in my Patent No. 496,224, though efficient battery transmitters may be used, and I sometimes make use of the liquid transmitter described in my Patent No. 505,917.

When the distances separating any two subscribers is very great, or when particularly loud conversation is desired, my system contemplates the introduction into the circuit, at one or more intervening central offices, of relay telephones, whose purpose is to increase the loudness of the telephone conversation so that I may give to each subscriber the advantage of long distance lines without the expense and complication of a long distance outfit. Two wires usually extend from each subscriber's station to the central office, one of which is equipped with apparatus by means of which the subscriber may signal the central office, while the other is equipped with apparatus by means of which the central office may signal the subscriber and the two wires may be used together as a metallic circuit. By this device the signaling and switching apparatus is greatly simplified, the subscriber or operator may each signal the other at any time whether the lines are in use or not, and every subscriber has all of the advantages of a metallic circuit. The line wires, so far as they are not carried in cables, are supported upon a peculiar insulator, by means of which they are protected from cross-talk and disturbing noises, and the cables are so constructed as to secure a minimum of electrostatic capacity, self induction and mutual induction, as described in my Patent No. 491,109, of February 7, 1893. By these devices loud, clear and distinct transmission of speech is attained and the telephone circuits are protected from cross-talk and other disturbing noises. At the central office each circuit terminates in one or more branch terminals, to which connecting, signaling or testing mechanism may be conveniently attached either momentarily or during the life of a conversation, as may be required. Annunciators by which the operator receives the signal from a subscriber are permanently connected from one wire of each subscriber's circuit through a battery to the earth. These annunciators are so constructed as to be readily permeable to signaling currents, but impermeable to telephone currents.

The cords or equivalent commutators used in connecting one subscriber's circuit to another are so constructed as to be readily permeable to telephone currents and yet absolutely impermeable to the signaling currents. An advantage of this kind of commutator is that there is no confusion between signals passing between the central office and one subscriber, and those passing between the central office and the other subscriber, in case the two subscribers be connected together. Other advantages of this arrangement will appear.

Attached to each operator and, as it were, made part of his person, is a simple piece of mechanism by which he may signal any subscriber, converse with any subscriber, tell whether any subscriber's line is busy or not, tell when a called subscriber has answered his telephone, tell whether a satisfactory conversation is being carried on, and if not, afford such assistance as is necessary, tell when the

conversation is finished and perform various other useful services which will appear hereinafter.

When the number of subscribers centering in one central office is not very large, say not over one thousand besides the necessary trunk lines to other offices, each subscriber's circuit terminates in a pair of metallic pins that project from the face of the switchboard. The operations of signaling, conversing and testing by the operator are performed by making momentary contact between the apparatus attached to his person and these pins. For conversation between two subscribers, the two pairs of pins are connected together either by a peculiarly constructed flexible cord or by a peculiar form of commutator, both of which are presently to be described.

When the number of subscribers centering in one central office is very large, I make use of two switchboards, one of which, called in this specification the "annunciator-board," is equipped merely with an annunciator and a pair of pins for each subscriber, while the other board, called the "connecting-board," is equipped with a pair of pins for each subscriber, and as many of my flexible cords as there are conversations going on through the office at any one time. Two operators or sets of operators are employed, one of which answers calls at the annunciator-board, while the other makes connections at the connecting-board, and both are equipped with personally attached apparatus for performing the various other desired services. Means are provided for conveying orders mechanically from the annunciator-board to the connecting-board, as will be hereinafter fully described. By thus providing the two radically different kinds of work between two different sets of operators, I attain an enormous advantage in simplicity and cheapness over the multiple board now so generally in use, first, in that fewer operators are necessary, and, second, that each operator is provided merely with such mechanism as he needs to use, whereas it is well known that in the multiple board, each operator is necessarily provided with cumbersome and expensive mechanism of which he uses only a very small part at any one time, and much of which he never uses at all, yet I retain the advantages of the multiple board and secure many others which this and no other form of board in use or described possesses, as will fully appear hereinafter.

As an alternative form of connecting-board, I sometimes make use of an upright frame having stretched across it in a horizontal direction as many pairs of wires as there are circuits entering the office and the same number of wires stretched across it in a vertical direction. A pair of horizontal wires and a pair of vertical wires are legged on to each subscriber's circuit. Both the horizontal and vertical wires may be arranged in several planes, and I am thus enabled to secure in a small space and at small expense an apparatus in which every wire is, at some point, contiguous to every other wire, so that by the insertion of one peculiarly constructed pin, I may connect any subscriber's circuit to that of any other subscriber. By touching the apparatus with which the person of the operator is equipped to proper terminals provided at the head of the pin, the operator may perform all of the necessary acts of signaling, conversing, testing, &c., as above enumerated. Although I have assumed the frame to be upright, because this possesses advantages of accessibility from both sides, the frame could of course be placed in any position.

The above are some of the salient features of my invention. These features and the methods and apparatus by which they are attained will be fully described later in the specification.

It will be convenient in describing my invention to first enumerate the successive steps whereby any two persons at different subscribers' stations are placed in speaking communication with each other for so long a time as they may wish to converse, and whereby the connection is then dissolved. I will then, with the aid of drawings, describe in detail the methods and apparatus I use for attaining this end.

The successive steps whereby communication between any two subscribers' stations may be effected and subsequently dissolved, are, first, the subscriber signals the central office that he wishes to communicate and, being answered, tells the central office with what subscriber he wishes to communicate; second, the central office must ascertain whether the subscriber wanted is or is not using his telephone; third, if, or as soon as, the subscriber wanted is not using his telephone, the circuits from the two subscribers must be telephonically connected together, the calling subscriber signaled that the connection is completed, and the called subscriber signaled that he is wanted at his telephone; fourth, when conversation between these two subscribers is concluded, the fact should be made apparent at the central office, so that the connection may be dissolved; fifth, in addition to these operations, the central office operator should be able to determine whether a party called has answered his signal, whether satisfactory conversation is being carried on, and, if not, to afford such assistance as may be necessary; the subscriber should be at all times able to signal the central office, whether his line is connected to that of some other subscriber or not; sixth, when the distance separating two subscribers' stations is considerable, or when particularly loud conversation is required, it is desirable that the central office operator shall be able to connect into the line joining together two subscribers' stations, a relay telephone by means of which the loudness of the conversation is augmented and each sub-

scriber given the advantages of a long distance telephone without the expense and complication of a local long distance outfit; seventh, the communication may be dissolved by removing the commutator.

In the drawings: Figure 1 is a perspective view of the apparatus at the subscriber's station. Fig. 2 is a diagram showing the mode of operation of Fig. 1. Fig. 3 is a detailed view of a switchboard cord terminal shown connected to the central office terminals of a subscriber's line. Fig. 4 is a diagram of an exchange as arranged for a small number of subscribers, say one thousand or under. Fig. 5 is a diagram of an exchange as arranged for a large number of subscribers, say one thousand to three thousand. Fig. 6 is a diagrammatic front view of one form of connecting board, by which cords are dispensed with and any one line is connected to any other line by a single pin. Fig. 7 is a horizontal cross-section of Fig. 6 at AB. Fig. 8 is a vertical cross section of Fig. 6 at XY. Fig. 9 is a detailed view of the pin used in connecting two wires of the board shown in Figs. 6 to 8. Fig. 10 is a perspective view of the pin shown in Fig. 9. Fig. 11 is a diagram illustrating the connections and method of operating the connecting-board shown in Figs. 6 to 10. Fig. 12 is a view of a relay which I sometimes introduce at the central office into a circuit connecting together two subscribers, the object of the relay being to increase the strength of the telephonic currents, and thus augment the loudness of the telephonic conversation. Fig. 13 is a view of an alternative form of relay. Fig. 14 is a diagram showing how two relays may be connected together to form a telephone repeater capable of reinforcing telephonic conversation in both directions. Fig. 15 is an alternative method of connecting together two relays for the same purpose. Fig. 16 is a diagram illustrating the method of connecting a subscriber's line terminating in one central office with another subscriber's line terminating in another central office by means of a trunk line joining together the two central offices.

So far as may be the same letters refer in all the figures to like instruments, apparatus, wires, &c., numerals being added to the letters to designate different parts of the same kind, and the letters sometimes being coupled. Thus, T in all cases designates a set of telephone apparatus, the transmitter of which is sometimes designated by t and the receiver by r.

B indicates a battery; w, a line wire, odd numbers being usually affixed to indicate the wire by means of which the central office signals the subscriber, and even numbers the wire by which the subscriber signals the central office.

Numerals are sometimes used independently of letters to indicate parts of instruments, and letters are sometimes used in the description without numerals to refer generally to parts which are particularly designated by the same letter with a numeral attached.

To avoid confusion, so much of the apparatus only is shown in the drawings as will enable the invention and its mode of operation to be understood.

Fig. 1 is a perspective view of the apparatus placed at each subscriber's station, and Fig. 2 is a diagram showing its connections and mode of operation.

B^x is a box within which is an electric tap bell having two gongs 1 and 2, a two point switch operated by the rod 3 and a press-button circuit-closer operated by the press-button 4.

t and r are magneto telephones such as are described in my Patent No. 496,224, one of which is intended to be used as a transmitter and the other as a receiver. They are connected to the box by flexible cords as shown. The telephone r hangs, when not in use, upon the hook 5. This hook forms part of the rod 3 and when this rod is pushed in, slides within the box so that the telephone cannot be hung upon it. When the telephone is on the hook the rod cannot be pushed in. When the rod 3 is pulled out the bell is in circuit, and when the rod is pushed in the telephones are in circuit. The bell cannot, therefore, be put out of circuit unless the telephone is off the hook, and the subscriber, having finished a conversation, cannot hang up his telephone unless he pulls out the rod and thus disconnects his telephone and puts the bell in circuit. Two line wires w' and w^2 from the central office and an earth wire e', enter the top of the box.

Referring particularly to Fig. 2, 6 is a wooden frame in which slides the wooden block 7 by means of the rod 3. 9 and 10 are metal plates secured to this block. 9 is connected through the telephones r and t to the wire w^2 that extends to the central office. 10 connects through the bell b to the earth. The line wire w' terminates in a metal spring 11, which rests on 10 and continues the circuit through the bell to earth when the rod 3 is pulled out, but which rests on 9 and continues the line w' through the telephones and back to the central office by the line w^2 when the rod 3 is pushed in. The spring push-button 4 is connected to the earth and when operated connects the line w^2 to earth, and thus signals the central office as will appear later.

Fig. 3 is a detailed view of a switchboard cord terminal shown connected to the central office terminals of a subscriber's line. k', k^2, are the two conductors of the cord which are joined to terminal springs s', s^2 by screws 12 and 13. p', p^2 are metal pins projecting from the rubber face plate P of the switchboard and forming the terminals of the subscribers' two line wires.

Fig. 4 is a diagram illustrating the connections and mode of operation of my system as applied to smaller offices of say one thousand subscribers or under. S' is a subscriber's sta-

tion, w' and w^2 the line wires, ending at the central office respectively in the pins p' and p^2. As shown, the line wire w' is normally open at the central office and grounded through the bell b' at the subscriber's station. Line wire w^2 is normally open at the subscriber's station and grounded through the annunciator a' and battery B at the central office. S^2, S^3 and S^4 are other similar subscribers similarly connected to the central office switchboard.

An operator is shown at the switchboard having attached to his head a telephone TO consisting of a transmitter *to* and receiver *ro*. Each hand of the operator is equipped at the tip of the thumb, first and second fingers of one or both hands with metallic thimbles *f*, *i*, *n*. A wire extends from the thumb *f* of each hand, through the telephones and back to the tip of the second finger *n*. A wire extends from the tip of the first finger *i* of each hand to the same pole of the grounded battery B to which the annunciators are attached. The telephones attached to the head are wound of very high resistance; in practice sometimes as much as five thousand ohms.

k' *t* is a cord terminal connected by wires kw', kw^2, through condensers C', C^2, with cord terminal k^2t.

The operation of the system is as follows: Suppose subscriber S^3 wishes to telephone to subscriber S^4. He first signals the central office by operating the press-button 4 which allows a current to pass from battery B through annunciator a^3, over line wire w^6 and button 4 to earth. He then takes his telephones off the hooks and moves the switch so that they will be connected in metallic circuit with the central office. The central office operator, seeing the annunciator a^3 fall, touches his thumb and second finger to the pins p^5 and p^6. He is thus in telephonic communication with subscriber S^3 and can ask for and receive the subscriber's order to be connected with subscriber S^4. The operator then signals subscriber S^4, by touching the tip of his first finger *i* to pin p^7, thus allowing a current to pass from battery B through pin p^7, wire w^7, bell b^4 to earth and ringing bell b^4. He then connects the two lines together by placing cord terminal $k't$ between pins p^5 and p^6, and cord terminal k^2t between pins p^7 and p^8. The operator then notifies subscriber S^3 that the connection is completed by touching the first or battery finger of one hand to the pin p^5, which makes a click in the subscriber's telephone if he is listening, and rings his bell in case he has meanwhile hung up his telephone. In practice, as soon as an operator gets an order for a connection, he places the cord terminals in place, one with each hand, and simultaneously signals both subscribers, using the first finger of one hand to call the desired subscriber, and the first finger of the other hand to notify the calling subscriber that connection has been made.

To avoid the necessity of having a cord run from each operator's person to the grounded battery, I sometimes provide the operator with a pocket or local battery, one terminal of which runs to the first finger of the right hand, while the other terminal runs to the corresponding finger of the left hand. By touching the two fingers simultaneously to pins connecting with the subscribers' lines, or by touching one hand to such a pin and the other to an earth plate, any desired signals may be sent.

When a subscriber has finished his conversation, he may send a disconnecting signal to the central office by pressing the button 4 as in first calling. The operator may, however, tell at any time whether conversation is going on over any two connected lines by touching the pair of terminals of either line with his thumb and second finger. He may further tell whether or not either subscriber has hung up his telephone for, when the telephone r' is off the hook, the wire w' will be at the same potential as the wire w^2, since wires w' and w^2 are connected together and to one terminal of the grounded battery B, but are otherwise insulated; and for the same reason if telephone r^2 is off the hook, wires w^3 and w^4 will be of the same potential. If, however, the telephone r' is on the hook, and consequently wires w' and w^2 are not connected together, there will be a considerable difference of potential between wires w' and w^2, which will manifest itself in a loud click at the operator's telephone TO when contact is made with pins p', p^2. The presence of a similar click when the operator touches p^3, p^4 shows telephone r^2 to be on its hook. The very high resistance of the operator's telephone TO does not allow of a sufficient short circuit between pins p', p^2, or p^3, p^4 to operate annunciators a', a^2 or bells b', b^2. This similarity or difference of potential between the two line wires becomes of great use in larger central offices, as will hereinafter appear.

The object of the condensers C' and C^2 is to prevent signal currents between the subscriber and operator on one line, from operating the signaling apparatus of the subscriber and operator of the other line. While the cords are thus impermeable to signaling currents, they are of course readily permeable to telephone currents.

As many operators as are needed to take care of the business may each be equipped with personally attached apparatus and all work simultaneously at the switchboard.

When the number of subscribers centering in one central office becomes large, say over one thousand, I divide the board into two parts different in kind. One of these, called the "annunciator-board," is used chiefly in receiving orders for connections, while the other, called the "connecting-board," is used chiefly in connecting together the lines of subscribers.

Fig. 5 is a diagram illustrating the connec-

tion and modes of operation of my system adapted to central offices having a large number of subscribers, say one thousand to three thousand.

S′ is a subscriber's station equipped as above described and having line wires w' and w^2 extending to the central office. a' is the annunciator which is now more intimately associated with its pins p', p^2. The wires w' and w^2 not only connect to the pins p', p^2, but also branch to the pins $p'c$, p^2c on the connecting-board CB, and to other pairs of pins if desired.

C′OA is a central office operator equipped with personally attached apparatus, as previously shown in connection with Fig. 3. For convenience, only one hand is shown for each operator. C²OA is another similarly equipped operator at another section of the same annunciator-board, for in practice several operators are usually required both at the annunciator-board and at the connecting-board.

C′OC and C²OC are personally equipped operators at the connecting-board. All of the operators, whether at the annunciator-board or the connecting-board, are similarly personally equipped.

The operation of the exchange is as follows: Suppose subscriber S′ wishes to talk with subscriber S^4. He presses the button 4 and the annunciator a' is operated. The operator C′OA sees this signal and places his thumb f and second finger n' upon the pins p' and p^2, replacing the shutter of the annunciator with the same movement of the hand. The operator then asks the subscriber with what other subscriber he desires to converse. The subscriber tells him "with No. 4." The operator C′OA then communicates the number of the two subscribers to the proper section of the connecting-board. For instance, he may write upon a slip of paper the number (1) of the calling subscriber, the number (4) of the desired subscriber and sends it to the connecting-board by mechanism to be described later. The operator C′OC (or, if he is busy, the operator C²OC), looks at the slip and notes that No. 1 desires to be connected with No. 4. He places his thumb fc and finger nc upon the pins p^7c, p^8c, and, if he hears a loud click in his telephone T′OC he knows that the line connecting to subscriber S^4 is not in use. This loud click is due to the fact that the wire w^8 of subscriber S^4 forms an open terminal through a^4 of the grounded battery B, and hence is charged to the potential of that battery, while wire w^7 is connected to the earth at subscriber's station S^4, and is of course of the same potential as the earth. If, however, subscriber S^4 had been using his telephone, it would have been off the hook, the lines w^7 and w^8 would have been connected together through the telephones at S^4, the earth connection at S^4 would have been removed, and the two wires w^7 and w^8 would have been of approximately the same potential. The operator's telephone T′OC is of very high resistance, as before explained, and hence does not operate drop a^4 when shunted across p^7, p^8. It plays the part of a volt meter inasmuch as the operator soon learns to determine differences in strength of click, and thus easily to separate the busy test from accidental differences of potential. It will be noticed that the busy test here provided tells the operator, not merely whether the line of a desired subscriber is connected to some other line, as does the busy test of the system now generally in use, but whether the desired subscriber has his telephone off the hook and therefore in use, or whether it is on the hook and therefore clearly out of use. A subscriber may have finished his conversation and many minutes may have elapsed, and yet his line would show busy by the old fashioned busy test, a fault that is productive of much mischief in practice. Having found the circuit of subscriber S^4 not busy, the operator then connects cord terminal $k't$ with pins $p'c$ and p^2c, and cord terminal k^2t with pins p^7c and p^8c, thereby establishing a telephonic circuit between subscriber's station S′ and subscriber's station S^4. He next touches his signaling finger ic of one hand to the pin p^7c, thereby ringing the bell b^4 of subscriber S^4, and the corresponding finger of the other hand to pin $p'c$, thus signaling subscriber S′, either by ringing his bell or making a click in his telephone, that the connection is completed.

As before stated, signals to or from the central office and one subscriber are not operative of the apparatus of the other subscriber or operator, because of the condensers C′, C² in the cords k', k^2. Thus, when the operator C′OC touches his signaling fingers to pin $p'c$, it does not actuate the annunciator a^4 of operator C²OA, nor does the operation of the press button 4 by subscriber S^4 operate the annunciator a^4 of operator C²OA, even though the two lines are in telephonic communication; yet either subscriber S′ or S^4 may signal his own appropriate operator at the annunciator-board at any time, whether the lines are connected together or not.

When either subscriber, *e. g.*, S′ has finished his conversation and desires to converse with any third subscriber, *e. g.*, S^5, he has only to signal the central office by pressing button 4 and the connection will follow as at first, whether he has been disconnected from subscriber S^4 or not. The operators at the connecting-board may, however, at any moment of leisure, by simply touching the fingers f and n to the proper pair of pins p, p, and noting the presence or absence both of click and conversation, determine whether subscribers so connected are carrying on a conversation or have finished or are simply waiting, and, in case they are having any difficulty in conversing, may help them out. I sometimes make use of one operator or set of operators to make connections, and another operator to watch connections and dissolve them when conversation is finished.

The very great flexibility of the present system as thus far described, as well as its simplicity, convenience, reliability, efficiency and speediness, are in marked contrast to systems generally in use, as will easily be perceived by any one skilled in the art to which this invention pertains.

As an alternative form of connecting board, I sometimes make use of an upright frame having stretched across it in a horizontal direction as many pairs of wires as there are circuits entering the office and the same number of wires stretched across it in a vertical direction. A pair of horizontal wires and a pair of vertical wires are legged on to each subscriber's circuit. Both the horizontal and vertical wires may be arranged in several planes, and I am thus enabled to secure in a small space and at a small expense, an apparatus in which every wire is, at some point, contiguous to every other wire, so that by the insertion of one peculiarly constructed pin, I may connect any subscriber's circuit to that of any other subscriber. Within the board, wires are stretched both horizontally and vertically as shown in Figs. 6, 7 and 8, of which Fig. 6 is a front view of a board with the casing removed. Fig. 7 is a horizontal cross-section of Fig. 6 on the line AB, and Fig. 8 is a vertical section of Fig. 6 on the line XY.

F'h is an iron frame, fanning out at each end as shown. Along this frame, in a horizontal direction, are stretched plated steel wires $w'h$, w^2h, &c., each secured by insulating pins $i'p$, i^2p, at either end, to the iron frame F'h. The wires are supported, wherever necessary, in perforated insulating braces pb, pb, &c. They are everywhere insulated from the frame. Each frame has the wires arranged in four parallel planes, as shown particularly in Fig. 7, $w'h$, $w^{101}h$, $w^{201}h$, and $w^{301}h$, and each plane has as many pairs of wires as may be desired, having due regard to convenience in distance apart of wires and size of frame. In a connecting-board for three thousand six hundred subscribers, I place the wires one-tenth of an inch apart and make the frame F'h about five feet high and fifteen feet long. There may be several similar frames, F'h, F^2h, F^3h, and more if desired, placed similarly but one behind the other. In practice I find three thousand six hundred horizontal wires require three frames which aggregate a depth of three inches.

The wires $w'h$ and w^2h form a pair of terminals for one circuit, which is brought to the frame by wires connecting to these terminals at the pins $i'p$, i^2p. The other pairs are similarly connected.

F'v and F^2v are also iron frames in which vertical wires $w'v$, w^2v, &c., are stretched. Each frame has the wires stretched in two planes $w'v$ and $w^{101}v$. The frames supporting the vertical wires are placed one on either side and parallel to the back of frames F'h, F^2h, &c. Outside the various frames and parallel to them are the vulcanite face plates $v's$ and v^2s, each pierced with square holes $s'h$, s^2h, &c., to allow the insertion of pins to make contact with the horizontal and vertical wires. The vertical wires $w'v$ and w^2v form a pair of terminals for the same circuit, as do the horizontal wires $w'h$ and w^3h. In fact each circuit entering the office terminates in a pair of vertical wires and a pair of horizontal wires in the wire frames.

Fig. 9 is an enlarged view of the pin used, to connect any pair of vertical wires with any pair of horizontal wires. The same pin is shown in perspective in Fig. 10. As many such pins are provided as there are likely to be conversations carried on through the office at any one time. These pins may be inserted from either face of the board.

In Figs. 9 and 10 vs is the vulcanite face place. H is a square block of vulcanite through which is a square hole of the same size as those in the face plate. $s'p$ and s^2p are metal springs fixed to the inside of the block H and adapted to connect with vertical wires $w'v$ and w^2v, when the block H is placed so that its square hole shall match a square hole in the face plate. P is a square vulcanite pin that slides within the hole in H. Near the top of the pin at 21 and 22 are ends of metal strips 23 and 24, which strips are adapted to connect at 25 and 26 with a pair of horizontal wires. In the figure they are in contact with horizontal wires $w^{13}h$ and $w^{14}h$. They would make contact with any pair of wires dependent upon the hole in which the pin was placed and the distance to which it was pushed in. The metal pin 21 has a wire 23 running along one face of the pin P and terminating at 25. It makes sliding contact with spring $s'p$. Similarly, pin 22 has a wire 24 running along the face of the pin P to the terminal 26 and making sliding contact with the spring s^2p. 27 is a bit of vulcanite attached to a spring s^2p and intended to prevent contact between wire $w'v$ and this spring. It will thus be seen that by moving the pin in and out, metallic circuit contact may be made between the vertical wires $w'v$ and w^2v, and any one of the pairs of horizontal wires, *e. g.*, $w^{13}h$, $w^{14}h$.

By choosing the proper hole in which to insert the pin and by inserting it the proper distance, which is determined in practice by the feeling as the pins touch the various successive horizontal pairs of wires, or which might be determined by a scale cut on the pin, I may make metallic circuit between any vertical circuit and any horizontal circuit.

Fig. 11 is a diagram illustrating the connections of a central office equipped with one of these wire switch boards, and which, together with Figs. 6, 7, 8 and 9 shows the mode of operation of the connecting-board. S', S^2, &c., are the subscribers' stations, a', a^2, &c., the annunciators, and $p'p^2$, p^3p^4 the associated pin terminals, all as above described. Subscriber's wire w' branches to vertical wire $w'v$ and to horizontal wire $w'h$ in the connecting-board WCB, and his wire w^2 branches

to vertical wire w^2v and to horizontal wire w^2h; and, generally, each subscriber's pair of wires branches to a pair of vertical and a pair of horizontal wires in the connecting-board. C', C², &c., are condensers inserted between each annunciator and the pair of connecting-board wires associated with its line wire. The diagram shows subscriber S' telephonically connected to subscriber S³. This is done by inserting a pin (Fig. 9) at *sh*, which pin, in the manner shown in Fig. 9, connects $w'v$ to w^5h and w^2v to w^6h. The operator is equipped with personally attached apparatus as before described. He makes his busy test by touching his thumb and second finger to plug terminals 25 and 26, and signals the two subscribers by touching his forefinger to plug terminal 25. As an alternative arrangement of the calling circuit of the operator, I have, in Fig. 11, shown a battery terminating at 28, and a cord joining together the first fingers of both hands. It is evident that, by touching 28 with one hand and 25 with the other, a current will pass from battery B over lines w' and w^5, and ring the bells of subscribers S' and S³. Exactly the method of calling shown in Fig. 4 might, however, be used.

When the distance separating any two subscribers is very great, or when particularly loud conversation is desired, my system contemplates the introduction into the circuit, at one or more intervening central offices, of relay telephones, whose purpose is to increase the loudness of the telephone conversation so that I may give to each subscriber the advantage of long distance lines without the expense and complication of a long distance outfit.

Various forms of relay telephones have been proposed, but all of these, when put in practical use, have been found capable of working only in one direction, *e. g.*, if subscribers S⁴ is connected to subscriber S², the relay may be made to magnify either the talking of S' or of S², but not of both. Practical use, however, shows that my herein described relay is equally operative in either direction, *i. e.*, it magnifies the conversation arising from subscriber S' or subscriber S² or from both simultaneously. The means whereby I accomplish this, as well as the details of construction of my relay, form part of the present invention.

My relay, when applied to a current arising from a magneto telephone transmitter, very greatly increases the loudness of talking due to such current, while preserving all the clearness of articulation for which magneto telephones are proverbial.

By inserting one of my relays in a cord used, at the central office, to connect together the circuits of two subscribers who are equipped with my magneto transmitters, I may insure as loud and much clearer conversation between them than if both were equipped with so-called "long distance" battery transmitters.

By inserting a second relay telephone in series with the first, I may still further increase the loudness of the conversation, and in practice, conversation between subscriber S² equipped with a magneto transmitter and connected with central office CO' and subscriber S¹⁰⁰² equipped with a magneto transmitter and connected with central office CO², the two central offices being connected by a line five hundred miles in length, and both central offices having relays inserted in the line, is carried on with perfect ease.

For convenience in this specification, I will designate a pair of telephone relays so connected together as to magnify conversation in both directions, as a "telephone repeater."

The mechanism of each relay is shown in Fig. 12, and the method and mechanism used in connecting together two such relays to form a repeater, and the method of connecting such repeater into the line are shown in Fig. 14.

In Fig. 13 is shown a multiple contact relay which may be used as an alternative form of the relay shown in Fig. 12; and in Fig. 15 is shown a method of connecting together two relays to form a repeater that may be used as an alternative to Fig. 14.

Referring to Fig. 12, Mt' is a magneto telephone such as is described in my Patent No. 496,224. A distinguishing feature, as set forth in the patent referred to, is the method of mounting the diaphragm *dg'* between two concentric ring-shaped knife edges kn' kn^2 of different diameter, whereby talking uttered into the similar magneto telephone Mt² is repeated in the vibrating of the diaphragm *dg'* of Mt' with great accuracy and amplitude. To the diaphragm *dg'* and projecting upward as shown, is fixed the plumbago electrode *pe'*. *Ag'* is a silver button suspended from one end of a lever *Lv'* which is pivoted at *pv'* and counterbalanced by a weight *wt'*. By moving the weight *wt'* to or from the point of support of the lever, the pressure of *Ag'* upon the electrode *pe'* may be made very delicate, while the inertia of the system *Ag' Lv' wt'* is preserved. The face of the electrode *Ag'* presented toward the electrode *pe'* is covered with a thin film of mercury *Hg'* into which the electrode *pe'* dips slightly. The face of the mercury may be again covered with a thin film of vaseline *vs'*, whose purpose is to prevent the oxidation of the mercury. B' is a battery and I' the primary of an induction coil of which II' is the secondary. The whole relay revolves about the axis X as shown, whereby the pressure between the two electrodes may be varied without varying their inertia.

The operation of the relay is as follows: Talking into the magneto telephone Mt² sets the diaphragm *dg'* of the telephone Mt' into vibrations similar in form to those of the diaphragm of Mt² though of somewhat less am-

plitude. The vibration of the diaphragm dg' immerses the electrode pe' to a greater or less distance into the mercury Hg', thereby allowing a greater or less amount of current to flow from the battery B' and electrode pe', through the electrode Hg' and primary coil I' back to the battery B'. As the vibrations of the diaphragm dg' may be made to vary the resistance between the electrode pe' and electrode Hg' within very wide limits, very great differences in strength of current may be produced in the primary coil I', which in turn induces through the secondary coil II' and upon the line wires w', w^2, an undulating current similar in form to that given out by the magneto telephone Mt^2 but enormously increased in strength. Thus, talking into telephone Mt^2 is heard in telephone Mt^3 much louder than if the relay were not in circuit.

An alternative form of relay telephone is shown in Fig. 13, in which the diaphragm dg^2 carries a silver plate Ag^2 whose face is covered with mercury Hg^2. A second silver plate Ag^3 whose face is covered with mercury Hg^3 is adjustable to and from the plate Ag^2 by means of the screw s. Between the two mercury faces are placed a number of plumbago balls pb^6 as shown. In this instrument the vibration of the mercury surface Hg^2 to and from the mercury surface Hg^3 causes the plumbago balls to dip more or less deeply into both mercury surfaces, and thus vary the resistance of and consequently the strength of current flowing in the circuit B^3, Ag^2, Hg^2, pb^2, Hg^3, Ag^3, I^2, B^2.

It is evident that while such a relay as is shown in Fig. 12 (or Fig. 13) is capable of magnifying the sound uttered in Mt^2 and heard in Mt^3, sound uttered in Mt^3 cannot be heard in Mt^2; *i. e.*, the relay will not work both ways.

It might at first be supposed (and indeed it has been proposed) that two relays might be connected in opposite directions, *i. e.*, the secondary coil of each to the magneto telephone of the other, either in series or multiple. On so connecting two relays, however, I find that the slightest jar will start the diaphragm of one relay of a pair in vibration, and that this will induce a current in the second relay, which will again induce a current in the first relay, and so the cycle of mutual reinforcement is kept up with increasing strength of current until the respective diaphragms are forced to their elastic limits, when both continue to vibrate and give out a loud musical sound determined by the normal time of vibration of the diaphragms, and in no way allowing of the repetition of conversation. I have discovered, however, that the mutual action of each relay of a repeater upon its mate may be prevented, and yet each reinforce the conversation in the desired direction by so arranging the two relays of a repeater that, while the currents arising from the respective line circuits, act each upon the magnet of one relay and cause this relay to impose a magnified current upon the other line circuit; the current given out by each relay shall act differentially upon the magnet of the other relay. One method of accomplishing this is shown in Fig. 14, and an alternative method in Fig. 15.

Fig. 14 is a diagram of a repeater complete consisting of two relays Rl' and Rl^2. The relay Rl' consists of the magneto telephone Mt', having a diaphragm dg', electrodes at E', battery B', a primary induction coil I' and secondary coil II'. Similarly the relay Rl^2 consists of the magneto telephone Mt^2, diaphragm dg^2, electrodes E^2, battery B^2, primary coil I^2 and secondary coil II^2. w' w^4 are conductors of a flexible cord connecting the relay Rl' with the cord terminal Kt', which cord terminal is adapted to connect with any subscriber's or trunk line circuit, say S'. Similarly w^3 w^4 are conductors of a flexible cord connecting the relay Rl^2 with the cord terminal Kt^2, which cord terminal is adapted to connect with any subscriber's circuit, or trunk line circuit, say S^2. One terminal of the secondary coil II' of relay Rl' connects to the line wire w^3 at junction j'. The other terminal of II' connects in divided circuit through a double and differentially wound impedance coil Ic' and wires w^5 and w^6, with both terminals of the magneto telephone Mt^2 of relay Rl^2. Rs' is an adjustable resistance inserted in wire w^6 between junction j' and the magneto telephone Mt^2 of relay Rl^2. Similarly one terminal of the secondary coil II^2 of relay Rl^2 connects to the line wire w^2 at junction j^2, while the other terminal of II^2 connects in divided circuit through a double and differentially wound impedance coil Ic^2 and wires w^7 and w^8, with both terminals of the magneto telephone Mt' of relay Rl'. Rs^2 is an adjustable resistance inserted in wire w^2 between junction j^2 and the magneto telephone Mt' of relay Rl'.

The double wound impedance coil Ic' (or Ic^2) is fully described in a patent for simultaneous telegraphy and telephony, issued to me on December 12, 1893, and numbered 510,508. Briefly it consists of a magnetic core and a wire branching into two equal wires, one of which is wound around the core in a right-handed direction, while the other is wound around the core in a left-handed direction. In practice each wire should have a large number of turns so that alone and without the other, it would present a considerable impedance to a telephone current. If it is desired that the ohmic resistance of the coil shall not be large, wire of large sectional area should be used. In practice, also, the the core should consist of an annular bundle of soft iron wires to increase the impedance. The peculiar usefulness of this coil arises from the fact that it is practically impermeable to telephone currents tending to pass over the two windings in series, and yet readily permeable to telephone currents passing over the two windings in multiple.

The operation of the telephone repeater

shown in Fig. 14 is as follows: Telephone currents arriving from a subscriber's station over the circuit $w'w^2$ pass through the magnet Mt'. (They will not pass over the wires w^7w^8 because, as explained, they cannot pass through the impedance coil Ic^2 in series.) The magnet Mt' actuates the diaphragm dg' and, by varying the resistance at E', varies the comparatively strong current flowing from battery B', through E' and primary coil I'. Consequently a strong telephone current is set up in secondary coil II'. One terminal of this coil sends currents directly into the line wire w^8, as shown, while the other terminal sends two equal and similar currents in multiple (hence without impedance), through the coil Ic' and by wires w^5 and w^6 to both terminals of magneto telephone Mt^2. These two currents, being equal in potential when arriving at the two terminals of Mt^2 have no effect on telephone Mt^2, but one of them passes to line over wire w^4, while the other passes through the rheostat Rs' to junction j' and thence back to coil II'. In order that the currents in w^5 and w^6 shall be equal, the electrical properties of the rheostat Rs' should be equal to those of the line circuit w^3 w^4, but, since in practice it is not necessary to entirely prevent the action of coil II' on telephone Mt^2, no accurate adjustment of such electrical properties is necessary. It may be noted that these circuits form a Wheatstone bridge of which II' is the actuating electromotive force, Mt^2 the galvanometer (or galvanoscope). w^5 and w^6 are two arms of the bridge, Rs' the third arm and the subscriber's circuit w^3 w^4 the fourth arm. Hence it follows that, so long as the well known proper proportions be attained between the wires w^5 and w^6, the rheostat Rs' and the line circuit w^3w^4, the coil II' can have no effect on the telephone Mt^2.

Having thus explained how a feeble telephone current in circuit $w'w^2$ may, by means of relay Rl', induce a strong telephone current on circuit w^3w^4, without affecting relay Rl^2, it is easy to see by simple inspection of the diagram how, in a similar way, feeble currents in circuit w^3w^4 may, by means of relay Rl^2 induce strong currents on circuit $w'w^2$ without affecting relay Rl'. Thus each relay magnifies the current in its own proper direction without affecting the other.

An alternative method of connecting together two relays to form a repeater in which each relay shall act differentially on the other is shown in Fig. 15. As before, Rl', Rl^2 are relays; Mt', Mt^2, the magneto telephones of the relays; dg', dg^2, diaphragms; E', E^2, pairs of electrodes; B', B^2, batteries; I', I^2, primary coils; II', II^2, secondary coils; Rs^2, Rs', rheostats; Kt', Kt^2, cord terminals, and w', w^2, &c., wires. The coil of magneto telephone Mt' is wound in two halves, a' and b', so that a current entering the coil from wire w^5 may, by passing equally through the two halves a' and b', produce no magnetizing effect on Mt'. Similarly the coil of magneto telephone Mt^2 is wound in two halves a^2 and b^2.

The operation is as follows: A telephone current arriving from a subscriber's station (or trunk line) by circuit $w'w^2$, passes through the telephone Mt' in part by the circuit w', a', b', w^6, w^3, and in part by the circuit w', a', w^5, w^2, but in both cases, around the magnet of Mt' in the same direction. As previously described, a reinforced telephone current is, through the action of the relay Rl', set up in the secondary coil II'. One terminal of the coil II' sends a current to line *via* junction j' and wire w^3, while the other terminal sends a current *via* wire w^7 through coils a^2 and b^2, around the magnet of Mt^2 in opposite directions; hence producing no magnetizing effect on Mt^2. The current through b^2 passes to line over w^4, while the current through a^2 passes over wire w^8 and through rheostat Rs', back to the coil II'. By making the rheostat Rs' electrically equal to the circuit w^3 w^4, the coil II' has no magnetizing effect on the magneto telephone Mt^2 of relay Rl^2. Similarly telephone currents arriving at magneto telephone Mt^2 from circuit w^3w^4, may, by means of relay Rl^2 induce reinforced currents upon circuit w' w^2 without affecting magneto telephone Mt' of relay Rl'. Thus each relay may magnify the current in its own proper direction without affecting the other.

Numerous other methods of connecting together the two relays so that each shall act only differentially on the other, will readily occur to any one skilled in the art to which this invention pertains.

The method of connecting a subscriber whose line terminates in one central office with a subscriber whose line terminates in another central office is illustrated in diagram Fig. 16. The line of subscriber S^2 terminates at central office CO' in pins p^3 and p^4 and annunciator a^2 as previously described. Similarly the line of subscriber S^{1002} terminates at central office CO^2 in pins p^{1001}, p^{1002} and annunciator a^{1002}.

R'p is a telepone repeater at central office CO' with cord terminals $k't$, k^2t, and similarly R^2p is a telephone repeater at central office CO^2 with cord terminals k^3t and k^4t. Personally equipped operators are shown at both central offices.

TL is a metallic circuit trunk line, consisting of the two wires tw' and tw^2, extending between the two central offices and terminating at central office CO' in switchboard pins pt' and pt^2 and annunciator at' precisely as a subscriber's line terminates, excepting that the other terminal of the annunciator at' connects directly to earth instead of through a battery. Similarly the same trunk line terminates at central office CO^2 in switchboard pins pt^3 and pt^4 and annunciator at^2.

It will be noticed that trunk wire tw' is normally open at central office CO' and grounded through annunciator at^2 at central office CO^2. Similarly trunk wire tw^2 is normally open at

central office CO^2 and grounded through annunciator *at'* at central office CO'. It follows that when the personally equipped operator at CO' touches his battery finger to pin *pt'*, the annunciator at^2 in central office CO^2 is operated, and when the personally equipped operator at CO^2 touches his battery finger to pin pt^3, annunciator *at'* at central office CO' is operated. The method of signaling to or receiving signals from a different central office is thus exactly like signaling to or from a subscriber.

Connections between a subscriber and a trunk line, at either central office, are made precisely as between two subscribers at one central office, excepting that, when the offices are widely separated, cords in which a telephone repeater is inserted, are used to make the connection at one or both offices. In many cases, however, ordinary cords, as above described, may be used at one or both offices.

In operating the system, subscriber S^2 may ask operator CO' to connect him with operator CO^2, and then ask operator CO^2 to connect him with subscriber S^{1002}, or subscriber S^2 may tell operator CO' with whom he desires to communicate, and leave it to this operator to make up the necessary through connection.

In the light of the various above descriptions, further description of the system as a whole, whether composed of one or many central offices, becomes unnecessary.

I claim—

1. A metallic circuit telephone exchange system consisting of telephonic apparatus at each subscriber's station, and a pair of wires extending therefrom to the central office switchboard and there ending in pairs of open branch terminals, one of each of said pairs of line wires being normally open at the subscriber's station and grounded at the central office through a high impedance annunciator and battery, the other wire being normally open at the central office and grounded through a bell at the subscriber's station; switching mechanism at each subscriber's station by means of which its two wires may be joined together through the subscriber's telephone and, at the central office, a double conductor connecting cord provided with a condenser in each conductor and a double-contact terminal at each end, each of which contact terminals is adapted to make connection with any pair of said branch terminals on the switchboard; an operator's switchboard commutator comprising a transmitting and receiving telephone conveniently adjusted upon the person of the operator and having each terminal connected by a flexible conductor with a metallic thimble placed upon a finger of each hand, and signaling apparatus consisting of a conductor connected to or adapted to be connected to an electric generator and connected by flexible conductors with other metallic thimbles placed one upon a finger of each hand, whereby the operator may, by touching the proper combination of metallically tipped fingers to the appropriate switchboard terminals, send signals to and put himself in telephonic communication with any desired subscriber or pair of subscribers.

2. A telephone operator's switchboard commutator consisting of a transmitting and receiving telephone conveniently adjusted upon the person of the operator and having each terminal connected by a flexible conductor to a separate metallic thimble placed upon a finger of one or each hand, whereby the operator may, by touching the proper combination of metallically tipped fingers to the appropriate switchboard terminals, place himself in telephonic communication with any desired subscriber or pair of subscribers.

3. Signaling apparatus for a switchboard operator consisting of a portable electric generator conveniently placed upon the person of the operator and having each terminal connected by a flexible conductor to a separate metallic thimble placed upon a finger of one or both hands, whereby the operator may by simultaneously touching the proper metallically tipped fingers, each to the appropriate subscriber's or earth terminal upon the switchboard, signal any desired subscriber or pair of subscribers.

4. Signaling apparatus for a switchboard operator consisting of a flexible conductor conveniently placed upon the person of the operator and having one terminal connected to a metallic thimble placed upon a finger of one hand and the other terminal to a metallic thimble placed upon a finger of the other hand, whereby the operator may, by simultaneously touching one metallically tipped finger to the open terminal of a grounded electric generator and the other metallically tipped finger to the appropriate subscriber's line terminal upon the switchboard, send a calling signal to any desired subscriber.

5. A telephone metallic circuit interconnecting board or commutator consisting of two series of parallel conductors, extending across said board at right angles to each other, the conductors in one or both series arranged in groups in different planes, a pair of immediately adjacent conductors in each series constituting the open branch terminals for each telephone circuit in combination with a connecting plug consisting of two parts reciprocally movable, and resilient conductors, which electrically connect said parts, whereby, while one of said parts is in contact with a pair of circuit wires in one plane, the other part is adapted to be placed successively in contact with a pair of circuit wires in each of several other planes.

6. A connecting plug for electric circuits, consisting of two parts reciprocally movable, and resilient conductors, which electrically connect said parts, whereby, while one of said parts is in contact with a pair of circuit wires

in one plane the other part is adapted to be placed successively in contact with a pair of circuit wires in each of several other planes.

7. A telephone relay consisting of a magneto telephone, a carbon electrode projecting from the diaphragm of the magneto telephone, a balanced electrode consisting of a thin film of mercury held contiguous to the carbon electrode, a protecting film of non-oxidizable liquid covering the mercury electrode, a battery and an induction coil, the primary of said coil, the battery and the said electrodes being in circuit.

8. A telephone relay composed of a magneto telephone, an electrode consisting of a thin film of mercury attached to and vibrated by the diaphragm of the magneto telephone, a second electrode consisting of a thin film of mercury supported independently of said diaphragm, carbon granules between the two mercury films and dipping slightly into both, protecting films of non-oxidizing liquid covering both mercury films, a battery and an induction coil, the primary of said coil, the battery and said electrodes being in circuit.

9. A telephone repeater composed of two opposing telephone relays, each relay consisting of a magneto telephone receiver, electrodes actuated by the diaphragm of said receiver, a battery and an induction coil; the magneto telephone of one relay being in circuit with the line wires extending in one direction, and the magneto telephone of the other relay being in circuit with the line wires extending in the other direction, and mechanism connected in the circuit of the secondary coil of each relay to cause the current given out by each secondary coil to act differentially upon the magnet of the opposite relay.

10. A telephone repeater composed of two opposing relays, each relay consisting of a magneto telephone receiver, electrodes actuated by the diaphragm of said receiver, a battery and an induction coil; the magneto telephone of one relay being in circuit with the line wires extending in one direction, while the magneto telephone of the other relay is in circuit with the line wires extending in the other direction, and a double and differentially wound impedance coil in the circuit of the secondary coil of each relay, through which, by a branching circuit, it is connected at one or both terminals with the line wire of the other relay on opposite sides of its magneto telephone, whereby the current given out by each relay acts only differentially on the magneto telephone of the other relay.

11. A telephone repeater composed of two opposing relays, each relay consisting of a magneto telephone receiver, electrodes actuated by the diaphragm of said receiver, a battery and an induction coil; the magneto telephone of one relay being in circuit with the line wires extending in one direction, while the magneto telephone of the other relay is in circuit with the line wire extending in the other direction, and the circuit of the secondary coil of each relay is connected at one or both terminals to the middle of the coil of the magneto telephone of the other relay, whereby the current given out by each relay acts only differentially on the magneto telephone of the other relay.

12. A telephone exchange system consisting of numerous subscribers' stations, each equipped with telephones; wires extending from the various subscribers' stations to the central office, and, at the central office, a telephone repeater composed of two opposing telephone relays, each relay consisting of a magneto telephone receiver, electrodes actuated by the diaphragm of said receiver, a battery and an induction coil; the magneto telephone of one relay being in circuit with the line wires extending in one direction, and the magneto telephone of the other relay being in circuit with the line wires extending in the other direction, and mechanism connected in the circuit of the secondary coil of each relay, by means of which the current given out by each secondary coil acts differentially upon the magnet of the opposite relay.

13. A telephone exchange system consisting of two or more central offices; wires radiating from each central office to subscribers' stations, each equipped with telephonic apparatus; trunk lines extending between the central offices and, at one or more of the central offices, a telephone repeater composed of two opposing telephone relays, each relay consisting of a magneto telephone receiver, electrodes actuated by the diaphragm of said receiver, a battery and an induction coil; the magneto telephone of one relay being in circuit with the line wires extending in one direction, and the magneto telephone of the other relay being in circuit with the line wires extending in the other direction, and mechanism connected in the circuit of the secondary coil of each relay, by means of which the current given out by each secondary coil acts differentially upon the magnet of the opposite relay.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 23d day of March, 1894.

SILAS W. HOLMAN.

Witnesses:
A. J. BURROW,
T. J. CUNNINGHAM.