

No. 709,740.

Patented Sept. 23, 1902.

A. M. BULLARD & M. C. RORTY.

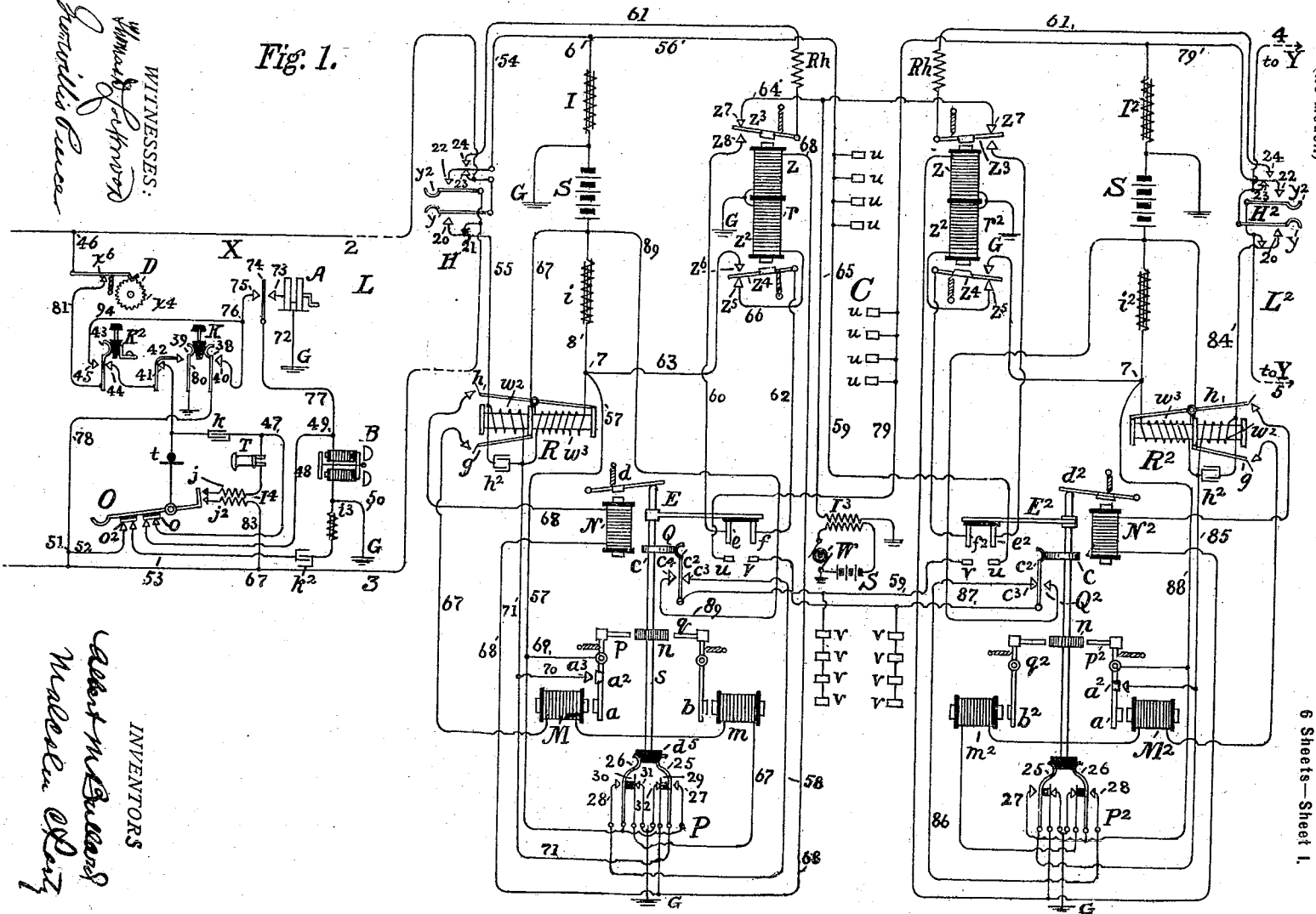
AUTOMATIC TELEPHONE EXCHANGE SYSTEM AND APPARATUS.

(Application filed Aug. 28, 1901.)

(No Model.)

6 Sheets—Sheet 1.

Fig. 1.



THE MORRIS PATENT CO., INC., DALLAS, TEXAS, U.S.A.

INVENTORS
A. M. Bullard
M. C. Rorty

WITNESSES:
Wm. H. Fisher
J. H. Fisher

No. 709,740.

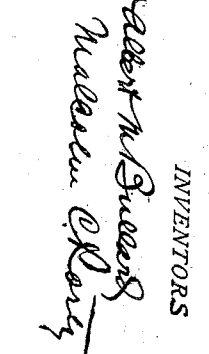
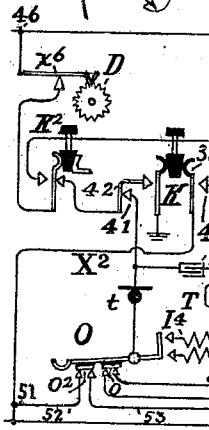
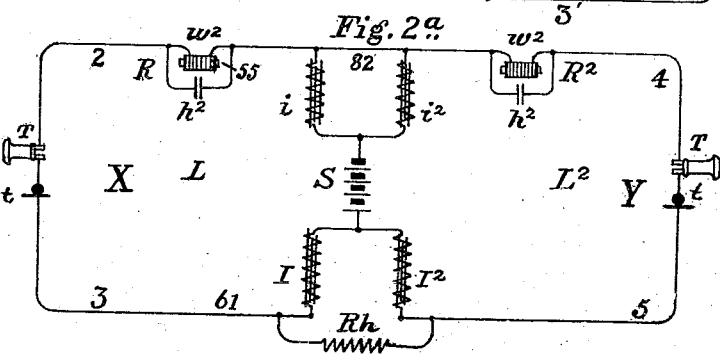
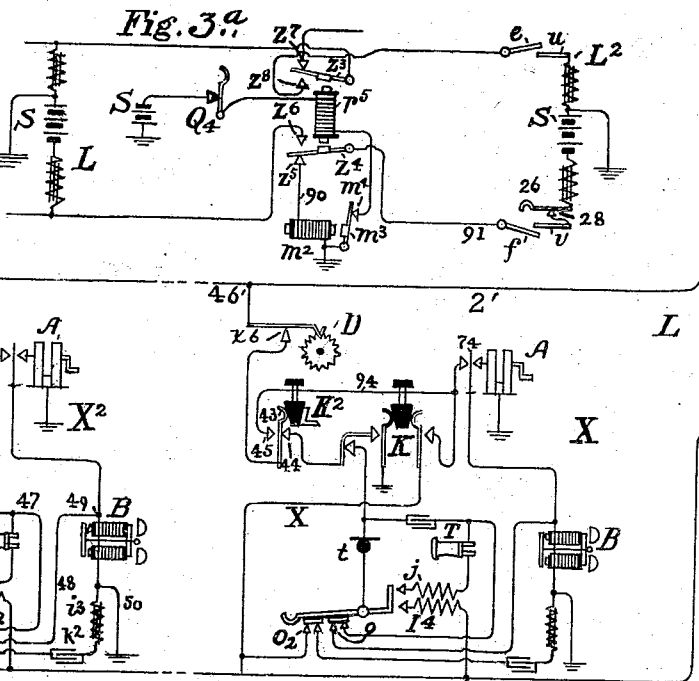
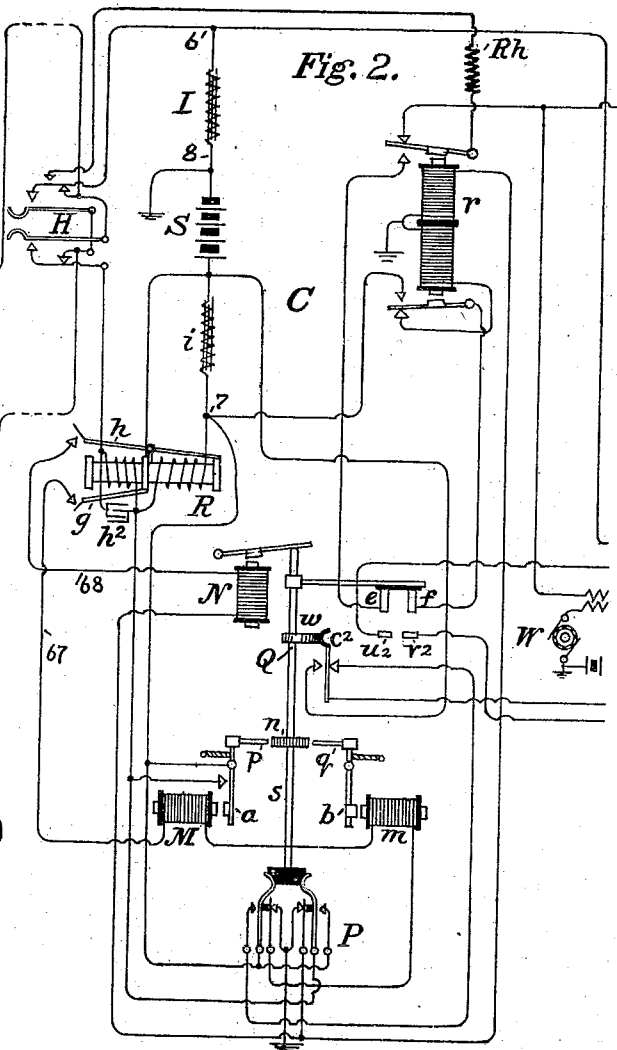
Patented Sept. 23, 1902.
A. M. BULLARD & M. C. RORTY.

AUTOMATIC TELEPHONE EXCHANGE SYSTEM AND APPARATUS.

(Application filed Aug. 29, 1901.)

(No Model.)

6 Sheets—Sheet 2.



WITNESSES:
Thomas J. Sullivan
Harold J. Rice

INVENTORS
Albert M. Bullard
Mabel C. Rorty

No. 709,740.

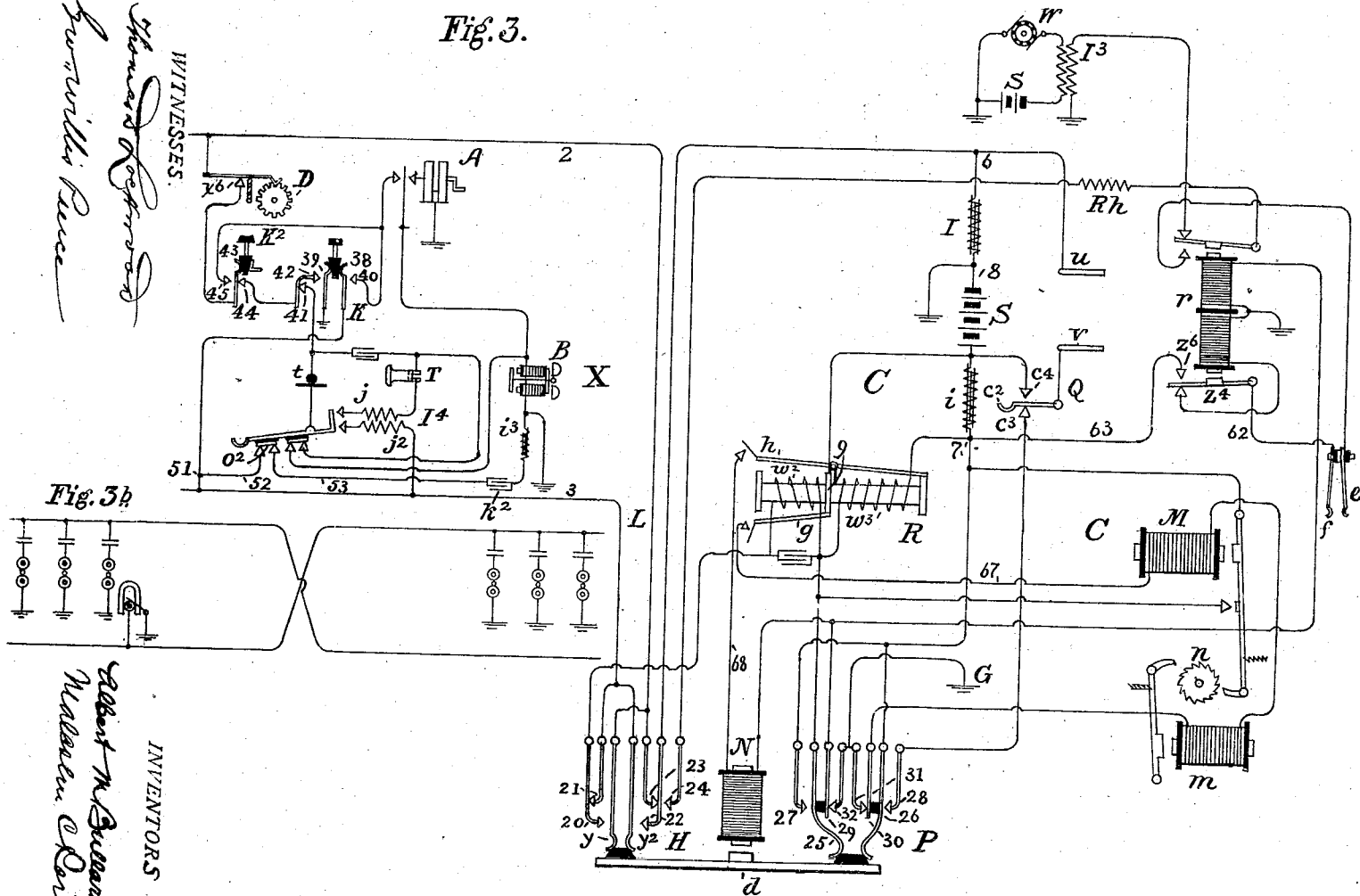
Patented Sept. 23, 1902.

A. M. BULLARD & M. C. RORTY.
AUTOMATIC TELEPHONE EXCHANGE SYSTEM AND APPARATUS.

(No Model.)

(Application filed Aug. 29, 1901.)

6 Sheets—Sheet 3.



No. 709,740.

Patented Sept. 23, 1902.

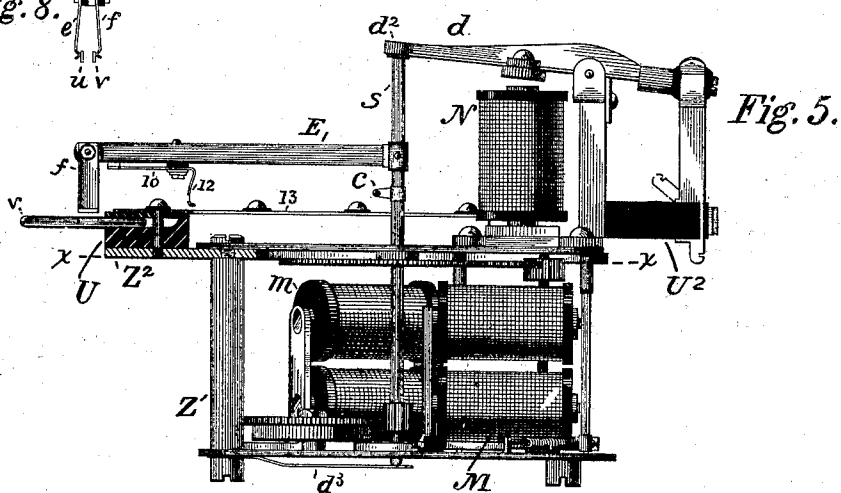
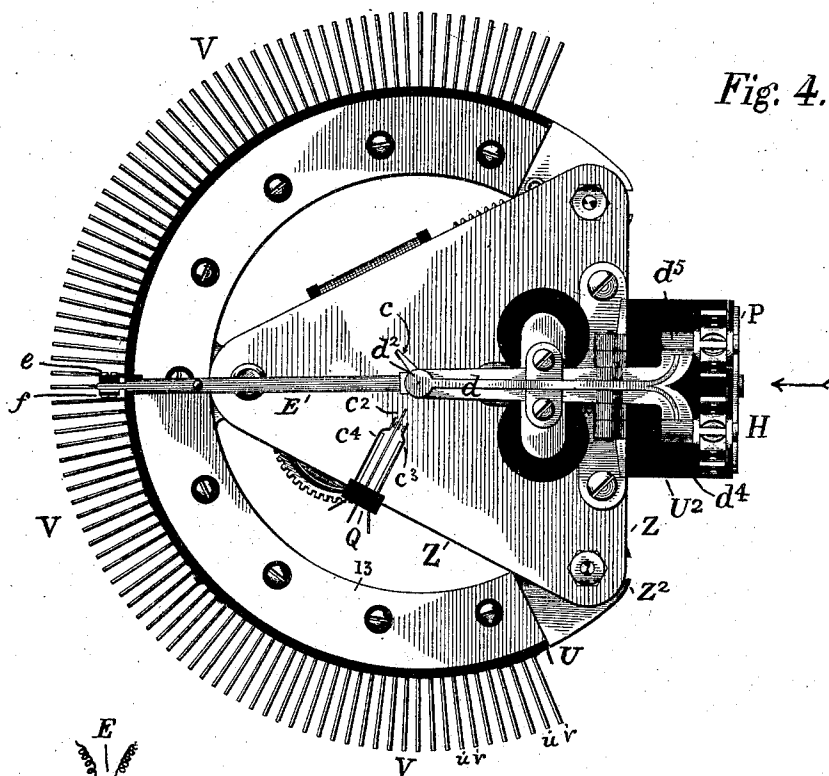
A. M. BULLARD & M. C. RORTY.

AUTOMATIC TELEPHONE EXCHANGE SYSTEM AND APPARATUS.

(Application filed Aug. 29, 1901.)

(No Model.)

6 Sheets—Sheet 4.



Attest,
Thomas L. Reed
Ernest Willis Pierce

Inventors
Albert M. Bullard
Malcolm C. Rorty

No. 709,740.

Patented Sept. 23, 1902.

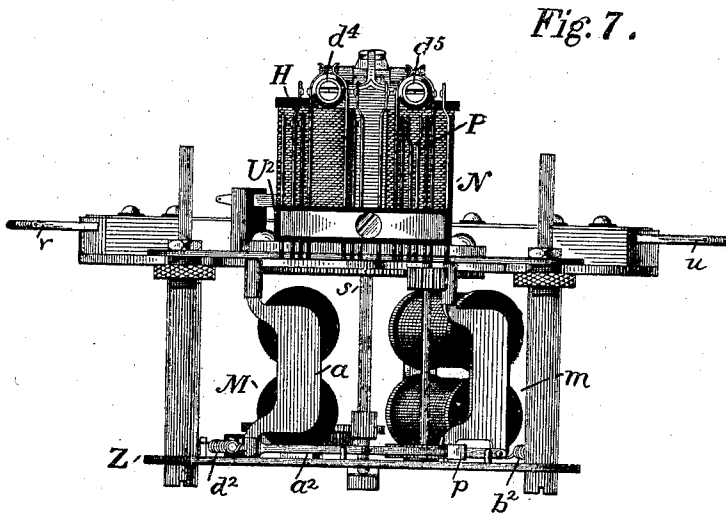
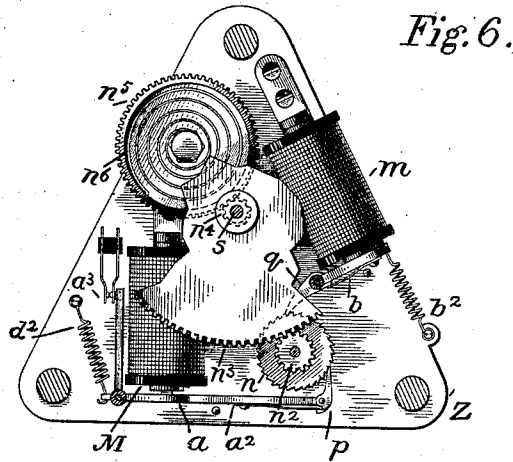
A. M. BULLARD & M. C. RORTY.

AUTOMATIC TELEPHONE EXCHANGE SYSTEM AND APPARATUS.

(Application filed Aug. 29, 1901.)

(No Model.)

6 Sheets—Sheet 5.



Attest.

Thomas L. Greenwood
Notary Public

Inventors

Albert M. Bullard
Malcolm C. Rorty

No. 709,740.

Patented Sept. 23, 1902.

A. M. BULLARD & M. C. RORTY.

AUTOMATIC TELEPHONE EXCHANGE SYSTEM AND APPARATUS.

(Application filed Aug. 28, 1901.)

(No Model.)

6 Sheets—Sheet 6.

Fig. 10.

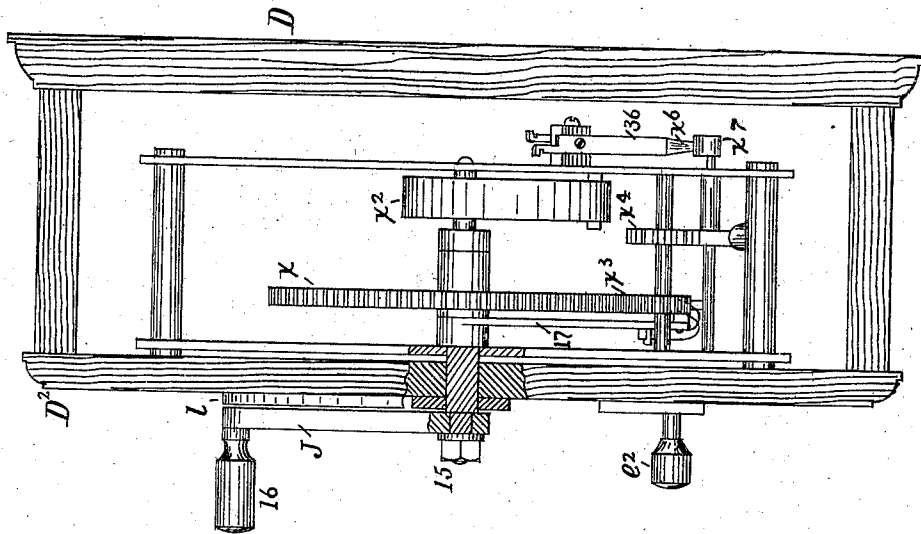
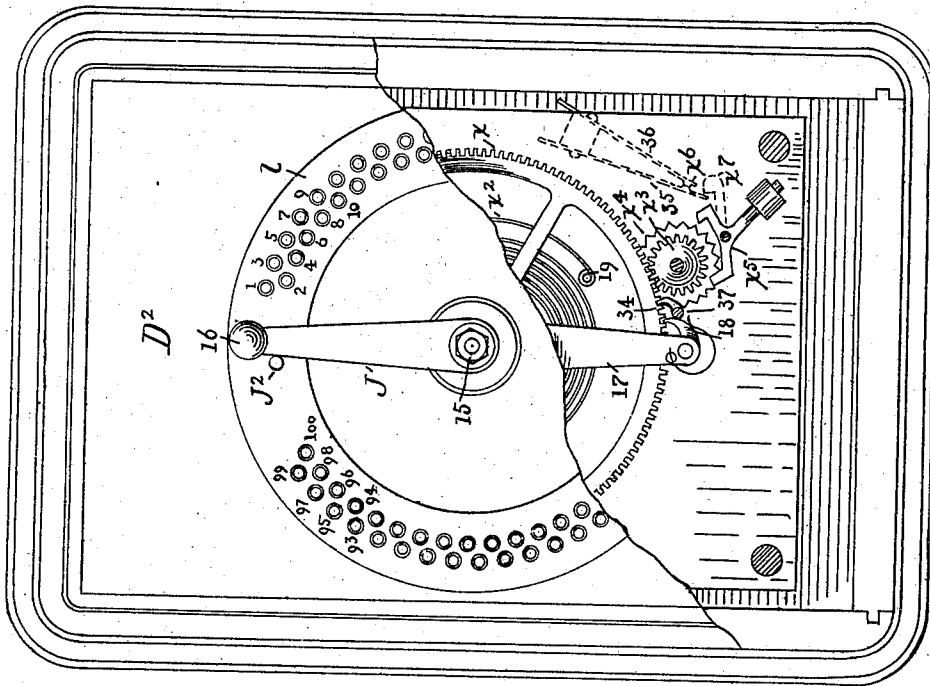


Fig. 9.



WITNESSES.

Howard Lockwood
Geo. Willis Rice

INVENTORS

Albert M. Bullard
Maurice C. Rorty

UNITED STATES PATENT OFFICE.

ALBERT M. BULLARD, OF SOMERVILLE, AND MALCOLM C. RORTY, OF DEDHAM, MASSACHUSETTS, ASSIGNORS TO THE AMERICAN BELL TELEPHONE COMPANY, OF BOSTON, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS.

AUTOMATIC TELEPHONE-EXCHANGE SYSTEM AND APPARATUS.

SPECIFICATION forming part of Letters Patent No. 709,740, dated September 23, 1902.

Application filed August 29, 1901. Serial No. 73,742. (No model.)

To all whom it may concern:

Be it known that we, ALBERT M. BULLARD, residing at Somerville, in the county of Middlesex, and MALCOLM C. RORTY, residing at Dedham, in the county of Norfolk, State of Massachusetts, have invented certain Improvements in Automatic Telephone-Exchange Systems and Apparatus, of which the following is a specification.

10 This invention constitutes an improvement in automatic telephone-exchange apparatus and circuits, and has especial reference to automatic telephone-exchanges designed to supply facilities for intercommunication in small communities where all of the possible subscribers may be accommodated by a small number of substation-circuits, some or all of which may be party or polystation circuits.

15 In organizing an effective automatic telephonic-exchange apparatus it is necessary to provide electrical or electromagnetic mechanisms and appropriate circuit arrangements at the central or switching station controlled for the exercise of their various functions by coördinate operative devices at the subscribers' stations and combined for the orderly performance of the several distinct suboperations involved in the general work of the exchange. These suboperations in all such organizations comprise the selection by a substation of the line of any other substation with which communication is desired, the testing of such line to determine whether it is at liberty or is already engaged, the connection of the two substation-circuits if the one wanted is found to be disengaged, the transmission of call-signals to the wanted substation, the establishment of intrusion-forestalling devices in association with both of the two united substation-circuits, whereby a third substation desiring to communicate with either is prevented from establishing the requisite switch connection and from interrupting the operations of either of the engaged circuits, the associating of a potential "busy" or "engaged" signal with a line or lines already in use and enabling the same to become active and manifest itself to a third circuit desiring interconnection with such

line or lines, thus indicating that for the present the desired line is engaged and that access cannot be had thereto, and, finally, the disconnection and restoration to the normal condition of two lines which have been connected with one another.

Furthermore, in automatic exchanges comprising party-lines or polystation-circuits it is likewise necessary to provide facilities whereby any station may "ring up" or send call-signals to the other stations on the same circuit, means for protecting any such polystation-circuit from intrusion while any two stations thereof are communicating and whereby such a circuit when tested by any other at the central station is made for the present inaccessible, and means for announcing or transmitting the busy signal to the station endeavoring to establish connection therewith as effectually as if the two stations in communication were those of two different circuits switched together at the central station.

In an application for patent, Serial No. 26,441, filed by us August 9, 1900, is described an automatic telephone-exchange system comprehending a number of metallic telephone-circuits extending from substations, respectively, to a central station where is located a common source of electromotive force supplying electrical energy for all requirements of the said circuits. Each circuit at the central station has a movable terminal member and a plurality of fixed terminals, these being so relatively arranged that the movable member of each circuit has within its range one of the fixed terminals of all of the other circuits and may by appropriate operation be brought into contact with any desired one of them, thereby uniting the two lines concerned. In the said system the movable terminal of a circuit is brought into line with the fixed member of another circuit, with which communication is desired, by a series of successive interruptions or intermissions of current corresponding to the number of the line wanted, produced by a suitable periodic circuit-breaker at the substation initiating the call in one of the conductors of the circuit, and is then brought into actual contact therewith by

the establishment of a steady current through both conductors of said circuit, both of these suboperations being carried out by electromagnetic mechanism controlled by relays acted upon by the said interrupted and steady currents, respectively. In the compound talking-circuit thus established the two lines concerned are not in direct conductive connection, but are inductively united through the intermediation of a short local circuit connected with both by repeating induction-coils. The call-signal is automatically transmitted to the station wanted by a reversing-relay, which acts by transposing the relation of the two conductors of the line of said station to the two poles of the common source, and means are provided whereby both lines are made inaccessible to all others while engaged with one another.

The automatic exchange of our present invention employs a central and universal battery or like source of electromotive force furnishing all of the current necessary for the accomplishment of the selecting and connecting processes involved in uniting any two substation-lines for through communication and also the current required as a supply for the telephone-transmitters of the two substations concerned in talking over such a through or compound circuit; but the calling-current is preferably developed by magneto-electric generators at said substations.

In some respects this invention may be regarded as an improvement upon that of the said joint application, since both concern automatic telephone-exchange circuits and apparatus and since some features of the said application are also made use of in this invention. The invention, however, involves certain other features both in circuits and appliances which are different not only from anything disclosed by the said joint invention, but also from anything which, so far as we are aware, has thus far appeared in the art as represented by other inventions of the same general class, while such devices as those to which reference has been made as being employed both in the said joint invention and in the present invention have generally in the latter different circuit arrangements and new coöperative relations with the said different appliances.

Our invention realizes a simple but exceedingly effective and reliable automatic telephone-exchange apparatus for a limited number of main or substation circuits which is particularly well adapted for polystation-lines and which perfectly meets the several requirements hereinbefore recited. Its substation-circuits when arranged for talking are metallic or consist of paired conductors throughout—that is, through the switching mechanisms as well as in the line portions—and the selecting and connecting devices of each circuit comprise two movable or active terminals of said circuit representing, respectively, the two main conductors thereof and adapted to

move into juxtaposition to fixed or passive terminal contact members successively of all other circuits of the exchange arranged in pairs and to make contact with the pair of points constituting the fixed terminal members of the circuit with which communication is desired when that pair is reached. The selective motion of the movable terminals is due to successive interruptions or intermissions of the main-line current acting through appropriate electromagnetic-motor mechanism, the said interruptions being produced by the operation of any suitable periodic circuit-breaker at the substation making the selection, and the connecting motion thereof is dependent upon the operation of other electromagnetic mechanism irresponsive to the selecting-current interruptions, but responsive to the establishment in the circuit of a steady current, which occurs when the circuit-breaker having ceased to operate the circuit is closed through the substation telephone apparatus.

We employ ordinary magneto-generators and polarized bells for sending and receiving call-signals, and at each station provide in association with said generator two keys, which are to be alternatively manipulated according as the bell to be rung is that of another station on the same circuit or is that of a station on another circuit connected through the central station. The call-bells of all stations have their magnets connected in earth branches from one side or conductor of their respective main circuits, a condenser being included in each such earth branch in the usual manner, and the balance of the circuit is maintained by associating with each bell branch a corresponding earth branch from the other side of the circuit containing similarly a condenser and an artificial impedance of like value to that of the bell-magnet.

Our invention also comprises the provision for each circuit of means for balancing on one side of the circuit the resistance on the other of the central-station relays controlling the selecting and connecting magnets and for regulating when two substations of unequal resistance are united to form a through-circuit the amount of current supplied to each.

It comprehends also means whereby when communication has been established through the central station between two substation-circuits the call-generator at the substation which has originated the connection when operated is enabled to ring the bells at the substations of the other circuit without at the same time ringing the bells or operating call-signal devices at the remaining stations of its own circuit.

Another important feature of our invention is an improved means of protecting both circuits concerned in forming a compound circuit for through communication from intrusion or from being interrupted or interfered with by a third circuit during the pend-

ency of such communication, the call-originating circuit receiving such protection from the outset of its selecting operation and the call-receiving circuit as soon as connection with its fixed terminals is established. This means involves the normal detachment of the movable terminals of each substation-circuit from the main conductors of such circuit and their control by a differential testing or discriminating relay which if the desired line be disengaged is excited by the passage of current through but one of its coils and becoming operative acts as an electromagnetic switch to attach the said terminals to their corresponding main conductors, but which should the line wanted be already occupied remains quiescent and inoperative, maintaining the normal detachment of the said movable terminals. Both coils of the relay under such conditions are traversed by currents each acting in opposition to and neutralizing the magnetizing effect of the other on the common core. These non-interference devices are accompanied by means for producing distinctive signaling currents, which traverse the line and produce in the receiving-telephone at the calling-station a sound-signal indicative of the busy condition of the wanted circuit. Moreover, when under the conditions of our present invention any two substation-circuits are united for through communication there is constituted an improved talking-circuit conductively continuous throughout.

The invention includes also various details of improved mechanism and circuit arrangement, hereinafter fully set forth, described, and explained.

In the drawings which accompany and illustrate this specification, Figure 1 is a diagrammatic representation of the central-station connections and appliances of two substation telephone-circuits and the substation apparatus and arrangement of one of them, the same indicating and illustrating the mode of operation of the exchange. Fig. 2 is a diagram of a polystation telephone-circuit shown as extending between two substations and the central station, the complete electrical arrangement of such circuit at the central station and at both substations being indicated in detail. Fig. 2^a is a diagram of the compound talking-circuit formed of two substation-circuits. Fig. 3 is a diagram representing the apparatus and electrical connections of a single substation-circuit at one substation and at the central station, the latter on a somewhat-enlarged scale to illustrate more clearly the mode of operating certain circuit-changing devices employed in the invention. Fig. 3^a is a diagram of a portion of a calling and a wanted circuit, illustrating a modified construction and arrangement of the intrusion forestalling and preventing appliances. Fig. 3^b is a diagram of the calling or ringing circuit formed by the connection at the central station of two substation-cir-

cuits before the telephone at the called station has been removed from its switch-support. Figs. 4, 5, 6, and 7 represent different views of the selecting and connecting or switch mechanism at the central station of a single main circuit, Figs. 4 and 5 being, respectively, plan and elevation views thereof; Fig. 6 a horizontal section on the line *xx* of Fig. 5 looking down, and Fig. 7 an elevational view of the rear or right of Fig. 4 looking in the direction of the arrow. Fig. 8 is a detail of the movable or selecting terminal of the circuit apparatus shown in Figs. 4 and 5. Figs. 9 and 10 are respectively a front elevation, partly broken away, and a side elevation with a portion of the casing removed to disclose the mechanism of a periodic circuit-breaker suitable for use at the substations.

Like reference letters and figures refer to like parts wherever used.

The operation of the invention will be most easily followed and understood by a consideration of the diagram of Fig. 1, aided by occasional reference to the other figures. It is, however, to be kept in mind that the said diagram indicates the second circuit merely by the beginning or central station end of the main conductors thereof.

The circuits are illustrated by Figs. 1, 2, and 3, wherein C represents the central station, and L and L² substation-circuits converging thereto, each from one or more substations. The circuit L is shown as being a party-line or polystation circuit leading by its main conductors 2 3 from two substations X and X². The circuit L² is assumed to extend outward by its main conductors 4 5 to a substation Y, and may of course also be extended to other substations.

Although two circuits only are indicated, it must be understood that in practice a number of such circuits will enter the same central station from substations and that each is there provided with its own individual selecting and switching mechanism, whereby it may by appropriate action taken at any of its own substations select and connect with any other circuit entering the central station. Each circuit for the general purpose of being switched to another is furnished with one set of active or movable terminals, whose function it is to select and connect with fixed terminals belonging to the said other circuit when the switch connection is made in pursuance of its own action and with multiple sets of passive or fixed terminals, one set for and within range of the movable terminals of each and all of the other circuits, so that the said circuit may be selected and connected with by any other, pursuant to the action of the latter.

The movable terminals of each circuit are carried by a bar centered in vertical arbors or journals at one end and capable of revolving or swinging at its other end in a wide arc around said center, and this bar may be termed the "selector-arm" or the "selector."

The fixed terminals of the several circuits may also be termed "fixed contacts" or "fixed points."

Central-station apparatus.—For each substation-circuit there are at the central station two inductance or choking coils, a balancing resistance, a testing and discriminating relay, a controlling-relay, and a selecting and connecting mechanism governed by said controlling-relay and comprising a selecting-magnet, a retaining-pawl magnet, a connecting-magnet, a selector-arm and certain associated switches or circuit-changers, the said selector-arm and switches being under the joint control of said magnets.

Referring to circuit L, for example, I_i represent the said two inductance-coils, which, as shown, are placed one on each side of the central source of electromotive force in a bridge, branch, or terminal loop 8 of the circuit joining the main conductors at points 6 and 7. In accordance with the accepted principles of central and common battery telephone-exchanges the office of these inductance-coils (of which a pair is supplied for each substation-circuit) is to individualize the several substation-circuits or pairs of circuits supplied from the same source and while permitting the ready flow of current from the said source for sufficient transmitter-supply to obstruct and oppose a high impedance to voice-currents which in transit between the transmitter of one station and the receiver of the other would otherwise be liable, at least in part, to be short-circuited through the branch 8 containing the source S, which branch forms an actual bridge or cross-wire between the main conductors of the compound circuit formed of two substation-circuits united for conversation.

R and R^2 are the controlling-relays of main circuits L L^2 , respectively. The controlling-relay, as indicated by the drawings, is preferably such a one as that for which Letters Patent of the United States No. 668,554 were issued to Albert M. Bullard and Louis A. Falk February 19, 1901. It has two armatures of diverse inertia. One of these, the light and quick-acting armature g , controls the local circuit 67, which contains the selecting-magnet and is capable of responding to rapidly intermitting or pulsating currents, and the other is the relatively heavy armature h , which is sluggish in its movement and responsive (by motion to its forward or active position) to a steady or sustained current only and which controls the local circuit 68, containing the connecting-magnet and the exciting-coil of the testing or discriminating relay. In the present instance the electromagnet of the said relay has two end poles and a central pole, the latter serving as the fulcrum or pivot of both armatures. The heavier armature extends in both directions from the said central pole, while the lighter extends to one only of the end poles. The relay is wound with two exciting-coils $w^3 w^3$,

connected in series, together with the battery S, in the substation-circuit. The rearward arm of the sluggish armature h is slightly heavier than the other, and the armature is therefore normally overbalanced in that direction, being thus brought into close proximity to the rear magnet-pole and as far as possible from the forward pole. Thus when interrupted currents pass through the coils the light armature, acted upon by the forward coil only, responds readily to each intermittent current, while the heavier sluggish armature is held in its position of rest by the rearward coil; but, as will be explained more in detail, one of the consequences of the movement of the light armature is the establishment of a short circuit around the rearward exciting-coil. When this occurs, the heavy armature is no longer attracted at its hinder end and yields to the influence of the forward coil and the end pole excited thereby. As long as rapidly-succeeding interruptions occur the transient short-circuitings of the rear coil are so brief that the inertia of the sluggish armature prevents it from moving; but as soon as a sustained current flows through the forward coil the steady attraction of the light armature is promptly followed by the movement toward the forward pole of the heavy and sluggish armature. If desired, two relays might alternately be used—a quick-acting one for selecting the wanted line and a sluggish one for establishing connection therewith. So, also, the selecting and connecting magnets in the local circuits which are controlled by the relay R might be operated directly by the main-line currents. The forward exciting-coil w^2 of the controlling-relays is shunted by a condenser h^2 .

Rh in each main circuit is the balancing resistance thereof. It is concerned with the talking-circuit only, and its position therein balancing in one conductor thereof the coils w^2 of the relays R R^2 and the condensers shunting them in the other is best shown by the diagram Fig. 2^a. For this purpose the said resistance is preferably made substantially equal to the sum of the resistances of the said relay-coils. The said balancing-resistance likewise tends to regulate the supply of battery-current when two main circuits of unequal resistance are interconnected. Each line is supplied with current from the common source through the inductance or choking coils $I I^2 i i^2$, and when one line is united to another each line obtains current through its own inductance-coils and also through the inductance-coils of the other line. It is evident that the introduction of resistance into the circuit between the points where the current-supply connections join their respective component circuits will decrease the amount of current delivered to each through the inductance-coil of the other. The resistance R/h thus becomes a regulator, operating to prevent a substation-circuit of

low resistance from depriving a circuit of higher resistance connected therewith of the current strength requisite for good transmission.

5 The electromagnetic motor mechanism for selecting a wanted circuit and for connecting therewith and the associated switches or circuit-changers besides being indicated conventionally by the diagrams Figs. 1, 2, 10 and 3 are shown in mechanical detail in Figs. 4, 5, 6, and 7. There are as many such mechanisms at the central station as there are substation-circuits; but as they are all alike it is sufficient to describe the mechanism belonging to one circuit only. Z is a general framework supporting the several magnets and moving parts of the mechanism. To the plate Z² of said frame is secured an arc-shaped block U of non-conducting material, 20 in which are embedded a number of metallic strips projecting radially from the periphery thereof. These are the passive terminals or fixed contacts of the several other substation-circuits of the system and are arranged 25 in pairs *u v*, each pair representing one circuit, there being for each mechanism at least as many pairs of fixed contact-strips as there are other circuits in the system. In practice for the purpose of avoiding false starts of the selecting mechanism and to provide against the chance of the said selecting mechanism being unduly actuated by incidental operations of the connecting mechanism a space corresponding to two or three steps is allowed at 30 the beginning of the series of strips before the first pair of strips is reached. We may term this block of non-conducting material and the fixed contacts mounted thereon the "switch-plate" V. A vertical shaft *s* is supported 40 generally in the center of the framework. It is capable of revolving in its bearings and also of vertical or longitudinal motion therein and carries a horizontal arm E, termed herein the "selector-arm." (Shown in the several figures and of which Fig. 8 represents an end view.) The arm E extends radially to a point beyond the outer edge of the insulating-block and ends above the several fixed terminals *u v*, so that when the shaft *s* is revolved it moves in the arc of the said block over the several fixed points in succession. At its end are two contact-springs insulated from each other, which on the depression of the vertical shaft slide over, clasp, and make 55 electrical contact with the two members of any pair of the fixed multiple contacts above which they may be at the moment when the shaft descends. These springs are made sufficiently self-centering by having their tips bent outward, so as to jointly form a flare adapted to guide the said tips respectively into contact with the outer sides of the two members of the pair of fixed points or strips, as in Fig. 8. The said springs constitute the 60 movable or active terminals *e f* of the circuit represented by the selector-arm and may be electrically associated with such circuit, one

of them, *e*, through the substance of the horse-shoe or arc shaped insulated metal plate 13, secured to the block U, and the other, *f*, 70 through the selector-arm and the metal framework and mechanism of the selector apparatus. The connection of the spring *e* with the curved plate 13 is made only when the selector-arm is depressed and is formed by an 75 insulated conductor 10 and spring 12, carried on the under side of the selector-arm. The pairs of fixed contact-strips of the several other circuits are electrically connected by conductors attached by soldering or otherwise 80 to their ends with their respective substation-circuit conductors and each pair also with similar pairs of fixed contacts representing the multiple switch-terminals of the same circuit at other selector switch-plates. 85

The revolving motion required for the circular movement of the selector-arm is imparted to the shaft *s* by the selecting-electromagnet M, which by its armature *a*, armature-rod *a*², and pawl *p*, attached thereto, 90 actuates the ratchet-wheel *n*, causing the same to revolve, and by the pinion *n*², carried on the ratchet-wheel axis, and spur-wheel *n*³, engaging therewith, to revolve the said shaft *s*. A retracting-spring *n*⁴ is provided, which in 95 its appropriate time, operating through a reversely-acting spur-wheel *n*⁵ and pinion *n*⁴, restores the shaft *s* and the selector-arm to their resting or zero position. To prevent the undesired exercise of the retracting mechanism, we provide a retaining-pawl *q*, positively actuated by the retaining-electromagnet *m* and engaging with the teeth of the 100 ratchet-wheel *n*.

The selecting and retaining magnets are in 105 series in the same local circuit, the former being a quick-acting magnet arranged or adjusted to respond readily and promptly to rapid successive makes and breaks of the circuit within which it is included, and thus by 110 a step-by-step motion to revolve the shaft *s* and selector-arm in response to and in correspondence with any suitable system of periodic current interruption controlling said circuit. The retaining-magnet, however, is 115 arranged or adjusted by any of the several expedients familiar to those skilled in the art to be sluggish in responding by the retraction of its armature to the momentary cessations of current, and the said armature 120 cannot therefore follow rapid emissions and intermissions of the said current. One said expedient is to provide an electromagnet with long cores and a weak retracting-spring and another is to shunt said magnet, as described in *Culley's Handbook of Practical Telegraphy*, seventh edition, London, 1878, 125 page 288, by "a resistance about equal to its own." We have, however, in practice obtained the required sluggishness by employing a bipolar electromagnet of ordinary construction and dimensions, with the range of 130 its armature so adjusted that the said armature in its forward movement is not checked

by a limiting-stop, but comes into actual contact with the magnet-poles, and having the retracting-spring thereof adjusted so loosely that it can overcome the tendency of the armature under these conditions and the residual magnetism thus encouraged to remain in contact with the magnet-poles only after a considerable and well-defined period of current cessation, during which the said spring has exercised a steady retracting force upon said armature. The first current impulse, therefore, of any series causes the retaining-pawl magnet to attract its armature and to bring the retaining-pawl into engagement with the ratchet-wheel, and the said armature once attracted stays so until the circuit is opened and remains open, when it at length falls back. Thus the said pawl acts as a clutch to maintain each step taken by the shaft *s* and selector-arm until the proper time of release. The selecting-magnet *M* has a retracting-spring d^2 , which retracts its armature *a* on every interruption of current, and the retaining-magnet *m* has a similar spring b^2 , which retracts its armature *b* when the emissions of current cease altogether. The ratchet and spur-gear are so proportioned that for each forward movement of the armature *a* and for each corresponding advance of the ratchet-wheel the selector-arm *E* moves over the switch-plate *V* a distance just sufficient to carry the terminals *e f* from one pair of fixed contact-strips to the next.

Longitudinal downward motion is imparted to the shaft *s* by means of the connecting-magnet *N*, vertically mounted above the uppersurface and at the rear of the switch-plate *V*, and its armature-lever *d*, which extends backward to a fulcrum and then to a forked extension, by means of which it operates the circuit-changers or commutators *H* and *P* and extends forward to an end piece d^2 , which bears against the upper end of the upright shaft *s*. The armature-lever *d* acts to force down the shaft *s* and the arm *E* carried thereby against the upward-pressing force of the spring d^3 , which engages the foot of said shaft. Thus when the selector-arm *E* has been stepped around the switch-plate *V* by the action of magnet *M* to a position where the movable terminals *e f* are opposite the passive terminals *u v* of the line wanted it can be depressed by magnet *N*, which is in a second local circuit, enabling the movable terminals *e f* to grasp and make contact with the said fixed strips *u v*.

In Fig. 1 the movable terminals *e f* of circuit *L*, which for the present may be considered the calling-line, are shown in a position brought about by the movement of the selector-arm in which they may make connection with the appropriate pair of fixed terminals belonging to circuit L^2 , and for convenience in drawing a pair of fixed terminals belonging to line *L* is shown in a similar position with respect to the movable terminals of line L^2 . So in Fig. 2 the movable terminals shown

are those of line *L*, while the fixed terminals are those of L^2 ; but in Fig. 3, which illustrates the central-station arrangement of one circuit only, both movable and fixed terminals are those of line *L*.

H is a key or commutator associated with each line for transposing the relation of the main conductors thereof to those of a second substation-line with which connection is established, and *P* is a similar but slightly more complex commutator arranged to effectuate certain desirable changes in the several circuits. Although both commutators are operated by the action of the connecting-magnet *N*, the commutator *H* is in Fig. 1 shown at a distance therefrom to more clearly indicate its place in the main circuit outside of all of the other central-station mechanisms of said circuit. In Fig. 3 is shown diagrammatically the operative relation of magnet *N* and its armature-lever *d* to both commutators *P* and *H*, and Figs. 4, 5, and 7 illustrate an arrangement highly satisfactory in practice. The commutators *H* and *P* in this relation both consist of a pair of principal contact-springs and several auxiliary contact-springs, the two principal springs of each being arranged to be acted upon mechanically by the arms $d^4 d^5$ of the rearwardly-projecting extension-fork of the armature-lever *d*, which arms, as best shown in Fig. 7, further separate the said springs to alter the contacts when the armature is attracted and allow them to resume their normal condition on the retraction of said armature. All of the commutator-springs are clamped in a manner well understood to the non-conducting base U^2 . In commutator *H* $y y^2$ are the two principal contact-springs, and 20, 21, 22, 23, and 24 are the several auxiliary contact springs or points. Normally contact is established between 20 and 21 and between 22 and 23; but when magnet *N* is operated the springs $y y^2$ are moved farther apart, thus, as clearly indicated in the drawings, causing the original contacts to be disestablished and forming new ones between *y* and 20 and between y^2 , 22, and 24.

The commutator *P* comprises a plurality of circuit-changing contacts grouped in one appliance, so that they may be all worked together and by the same mechanism. The entire appliance involves the two principal springs 25 26, which are acted upon by the fork member d^5 of armature-lever *d* and which impart motion to the several other springs concerned. With these are associated six auxiliary springs or points 27, 28, 29, 30, 31, and 32. Springs 26 and 27 are permanently united, springs 31 and 32 are both connected to ground, and contact normally exists between 30 and 31 and between 29 and 32. When the magnet *N* operates and attracting its armature actuates this commutator, the normal contacts are broken and new ones are formed between 26 and 28 and between 25 and 27. The circuit arrangement and func-

tions of these commutators will hereinafter be explained.

In association with the selector-arm E is another commutator or circuit-changer Q. (Shown in the diagram Figs. 1, 2, and 3 and in Fig. 4.) This consists of a movable member c^2 , two fixed contact-pieces c^3 c^4 , and an actuating cam or finger c , attached to the vertical shaft. When the selector-arm E is at zero, the finger c presses upon the movable contact c^2 , holding it against the fixed point c^3 ; but as soon as the selector-arm is operated and moves away from its zero position the pressure of said finger is removed and the spring c^2 , moving by its own resiliency, breaks contact with c^3 and establishes contact with c^4 . The commutator Q, as will presently be seen, is a portion of the mechanism for preventing intrusion by a third circuit upon circuits already engaged.

The connecting-magnet N is vitalized when the subscriber of the line to which it belongs removes his receiving-telephone from its hook-switch and is deenergized when the receiver is replaced.

It is to be understood that the system described herein requires and, in fact, has but a single central battery or source of current S, although for the sake of avoiding complexity in the drawings it is shown at several places.

W is a tone-producing appliance of any desired character. It is shown as an appliance for rapidly interrupting the current of a local circuit, and thereby producing, by means of the induction-coil I^3 , induced currents in a branch circuit of any line which, seeking to connect itself with a second line, finds such second line already engaged. Under such conditions the induced currents are enabled to act through the intervening conductors on the receiver at the substation where the call was originated, producing a musical tone therein which, as will be understood by the subscriber, indicates that the line wanted is busy.

The testing and discriminating relay r is wound differentially, having an exciting-helix z and a neutralizing-helix z^2 , which when energized by appropriate currents act in opposition to one another, each tending to neutralize the influence of the other upon the core. Both helices are grounded at their inner end, and their remaining circuit connections will presently be manifest. The corresponding relay for subscriber's circuit L^2 is indicated by r^2 . The relay has two armatures whose levers z^3 z^4 work between front and back contact-stops z^7 z^8 and z^5 z^6 , respectively. The relay r is, in fact, an electromagnetic switch, and its function is to establish the connection between the substation-circuit to which it belongs and the movable terminals of such circuit carried by the selector-arm thereof, and this is done when the armatures which constitute switch-levers are in their forward or attracted position; but as long as the said armatures remain unattracted they

are in contact with their back-stops, armature z^4 then forming a part of the intrusion-preventing apparatus and of an incomplete non-intrusion circuit which includes the neutralizing-coil z^2 , and armature z^3 a portion of the tone-test or engaged signal apparatus. Whenever a line wanted is free, the upper or exciting relay-coil z alone carries a current and the armatures work to complete the connection between the two lines; but when a line wanted is already engaged current flows through the lower or neutralizing coil z^2 also, the relay will not work, the desired connection cannot be had, and the engaged signal is transmitted to the calling-substation.

Substation apparatus.—Assuming that all of the main circuits of the exchange are poly-station circuits, or may at any time become so by the installation of additional stations, it may be said that the apparatus at all of the substations of all of the subscribers' circuits is alike. At each station there are the usual call-sending and call-receiving appliances. A is the call-generator, a magnetogenerator developing an alternating current being preferably employed. B is the polarized call-bell, and k a condenser in series with said bell. The bell is grounded on one side and at the other is connected by a branch through the condenser to a particular one of the main-circuit conductors, while the generator, which also has one of its terminals grounded, is normally on open circuit, but is brought into connection when operated with one or the other of said main-circuit conductors as the call is to be sent to a station of the same or of another circuit. The usual transmitting and receiving telephone apparatus and gravity-switch are also employed.

T is the receiving instrument, t the transmitting instrument, I^4 the induction-coil, and O the telephone-switch. The telephone connections are arranged on the standard plan of the central-battery system, the receiver and transmitter being both in circuit with the primary winding j of the induction-coil and with the condenser k , while the secondary winding j^2 is directly in the main circuit. Besides controlling the telephone connection, the switch O, by means of two separate circuit-breakers o o^2 , is enabled to disconnect the bell-magnet ground from the main conductors on both sides of the bell when the receiver is taken from the hook for the purpose of preventing the said ground from affecting the selection-circuits. Certain additional and special apparatus is, however, also required. This comprises a rhythmical or periodic current-interrupter D and two keys or circuit-controllers, one of which, K, is to be depressed during the operation of the call-generator to send a call to a substation of another circuit when the same shall have been connected with the calling-circuit through the central station, while the other, K^2 , is to be operated while sending a call to other stations of the same circuit. Finally, for the purpose

of balancing the branch to earth through the bell-magnet and its condenser k from one side of the main circuit we provide at each station a similar branch from the other side of the main circuit to earth, including the impedance-coil i^3 and the condenser k^2 .

A form of periodic interrupter D which we have found convenient is particularly illustrated by Figs. 9 and 10. The inner mechanism is mounted upon the inside of the cover D² of the case, and on the outside of said cover are an arm J, rigidly attached to the central shaft 15 and having a handle 16, a numbered and perforated circular plate 1, and a peg e^2 for insertion therein. Within the box is a second arm 17, also rigidly attached to the shaft 15. Upon the extremity of arm 17 is a pawl 18, which engages with a spur-wheel x , loosely mounted upon shaft 15. A spiral spring x^3 has one end attached to shaft 15 and the other end to post 19. A pinion x^3 meshes with the wheel x and turns a star-wheel x^4 , with which engages the weighted escapement x^5 , whose oscillations are utilized to separate and unite the contact-points at x^6 by the arm x^7 . When this instrument is operated at the substation of any circuit for the selection at the central station of another circuit and for connection therewith, the pin or plug e^2 is first inserted in the numbered hole of the wanted subscriber's line, as 10. The arm J is then moved by its handle 16 in a clockwise direction until it is stopped by pin e^2 and in moving winds up spring x^3 . The manipulator thereupon releases the handle 16, and the arm J, impelled by the power thus stored in said spring, returns to zero. Now when the arm J was moved to the pin, as just described, the inner arm 17, rigidly attached to the shaft 15, moved also and through an arc of precisely the same degree as that of arm J. In the movement of arm 17 its pawl 18 slipped backward ineffectively over ten of the teeth of the wheel x , which remained stationary, being steadied and held by the stop-pawl 34. When the shaft 15 begins its contraclockwise rotation, the arm 17 by means of pawl 18 now engages and turns the wheel x and also pinion x^3 and star-wheel x^4 , whose escape x^5 retards and regulates said return movement. The arm x^7 , secured on the same shaft as the escapement, successively separates and reunites the contact-springs 35 and 36, thereby opening and closing the circuit wherein the said springs are included a number of times corresponding to the hole in which the pin e^2 was placed—in this instance ten times. The return motion of shaft 15 is stopped by pawl 18 coming against stop 37 and by the arm J striking against post J².

Wherever the peg e^2 is set, the arm 17 and pawl 18 pick up the spur-gear x and move it through a distance always the same for a given peg-hole, each hole in the plate 1 representing one tooth of the gear x and of the pinion x^3 , and hence of the star-wheel x^4 , which has the same number of teeth as the pinion x^3 .

The key K has two principal and three auxiliary contact springs or points. 38 and 39 are the principal ones, and the others are indicated by the numerals 40, 41, and 42, respectively. Of these, 38 is in permanent union with the main conductor 3 and 39 with the ground; but neither is in normal electrical contact with any of the others. The points 41 and 42 are normally in contact. When the key is depressed, the points 41 and 42 are separated, while contact is made between 38 and 40 and between 39 and 42.

The key K² has a movable contact member 43 and two complementary contact-pieces 44 and 45. Normally the points 43 and 44 are in contact; but when the key is depressed the said points are separated and the movable member 43 makes contact with the fixed point 45. Both keys resume their normal condition when they are no longer pressed.

Circuits, electrical connections, and operation.—The electrical arrangement of the several substation-circuits is identical. To describe X will therefore answer for all. In the resting state of the circuit all of the paths through the substation X between the main conductors 2 3 are conductively discontinuous. The branch through the bell B is, however, made receptive to ringing-currents by the interposed condenser k . This in every case (as indicated in Fig. 2, which shows the arrangement of two substations) is in an earth branch from conductor 2. The said branch leads from point 46 on the said main conductor 2, through the closed resting contacts of the interrupter D and the two keys K² K, to the condenser k , and from thence through the circuit-breaker o of switch O by conductors 47 and 48 and by way of the point 49 to the bell-magnet B and ground connection 50. To aid in maintaining the circuit balance against inductive disturbance, there is a similar but dummy branch from main conductor 3 at 51, passing through conductors 52 and 53, the circuit-breaker o^2 , condenser k^2 , and impedance-coil i^3 to earth. Passing toward the central station C the normal path of the substation-circuit may be traced by conductor 2 to the resting contact 23 22 of commutator H and from thence to the other main conductor 3, through conductor 54 and the bridge 8, extending between points 6 and 7 on the main conductors, respectively, and including the source of current S and the impedance-coils $I i$, and then through the two exciting-coils $w^3 w^2$ in series of relay R, conductor 55, and the closed resting contact 20 21 of key H. The said source is grounded at its pole nearest to main conductor 2. By following the extension 56 of conductor 2 from the bridge-point 6 it will be seen that it passes to the multiple fixed terminals or points u of the circuit, one for the movable terminal of each other circuit. That which is associated with the selector-arm E² of substation-circuit L² is shown in place; but the others are merely indicated to show their circuit relation. In like manner the

fixed terminals v of the other side of the circuit are arranged to connect with an extension of main conductor 3, passing from point 7 of the bridge by conductor 57, the normally separated contacts 26 28, conductor 58, commutator-contacts c^3 c^2 , and conductor 59. The movable terminal e of the circuit connects with conductor 3 at contact 24 of key or commutator H after the said key has been operated by way of conductor 60, front and armature contacts z^8 and z^9 of relay r , resistance R/h , conductor 61, and the contacts 24 22, and y^2 of said key, and the movable terminal f , representing conductor 2 of the circuit L, in like manner unites with said conductor 2 by way of conductor 62, armature z^4 of relay r , front contact-point z^6 and conductor 63, conductor 57, contacts 27 25 of commutator P, conductor 71, condenser h^2 , conductor 55, and contacts 20 and y of the key H. Thus the said movable terminals or selectors are normally detached from their circuit-conductors and only become attached thereto when after selection has been made and the said movable terminals have been brought into contact with the fixed terminals u v of the wanted line, and when also after the commutator H has been operated the relay r becomes excited and attracts its armatures z^3 z^4 . The resting-contact z^5 of armature z^4 is united by conductor 66 through coil z^2 of relay r to ground, and the resting-contact z^7 of armature z^3 connects by conductors 64 and 65 with the apparatus for producing the "busy" tone-signal currents.

Separable contacts a^2 a^3 , associated with the armature-lever and its forward-limit stop of selecting-magnet M, constitute a short circuit around the exciting-helix w^3 of relay R, and when closed permit the sluggish armature h of said relay to swing over to the forward pole thereof.

In the commutator P, operated by the vertically-moving selector-shaft s , the contact made between members 25 and 27 thereof supplements the foregoing short circuit and when the shaft descends maintains the same, even though the armature of the selecting-magnet shall have been retracted. The contact made under like conditions between members 26 and 28 of said commutator constitutes a circuit-closer to connect the fixed terminals v of a line with the source of current, thus raising the potential of said terminals to furnish a test-current for use in protecting a busy line from the intrusion of a third circuit. The normal contact between members 30 and 31 of the commutator is directly in the circuit 67 of the selecting and retaining pawl magnets, which circuit extends from the battery S through the frame and armature g of relay R, the helices of said magnets M and m , to and through said contact to ground. Its purpose is to open the said circuit on the operation of the connecting-magnet N and the consequent depression of shaft s , and the contact normally established between mem-

bers 29 and 32 of commutator P is in an earth branch of the connecting-magnet circuit 68, extending from the grounded battery S and through the frame and armature h of relay R by the same route as local circuit 67 and continuing through the exciting-coil of connecting-magnet N and the upper winding z or exciting-coil of the differential relay r , the said earth branch and its contact members 29 and 32 being placed intermediately between the magnet N and relay r to shunt the latter during the first part of the operation of said magnet, thus making the current available for said magnet stronger than it could otherwise be. When, however, the said magnet has operated and the shaft s has been depressed, the contact between 29 and 32 is broken and current is admitted to the relay-coil z to excite the said relay.

The commutator Q, which has resting contact between its members c^2 and c^3 , operates as soon as the selector-arm to which it belongs is moved from zero, and breaking the said resting contact establishes a new one between c^2 and c^4 , by means of which a substitute and more direct path for test-current from the source S to the fixed terminal v of a calling-line is provided by way of conductor 89, which previously was open at point c^4 , the first path through contacts 26 and 28 of commutator P being open during selection.

It will be understood from what has been stated that normally every exchange-circuit is conductively continuous through the battery S and both coils of its own relay R at the central station C and conductively discontinuous at the substation, and that consequently by closing it at the substation the relay R may be operated.

In the operation of this system let us assume that a subscriber—for example, No. 20-3 of substation X on circuit L—desires to communicate with substation Y of circuit L², whose number, we will say, is 37-2. He first removes his receiver T from the switch-hook O and listens to assure himself that his own line is not already in use by some other station. This action closes the circuit of the source S at the substation and current flows through both windings of relay R and through the telephone apparatus at the substation. The preliminary route of this circuit between the two poles of the source is as follows: impedance-coil i , the relay-coils w^3 and w^2 , conductor 55, commutator H, main conductor 3, point 67, the induction-coil secondary j^2 , switch O, transmitter t , the two substation-keys, the resting contacts of the periodic interrupter D, point 46, main conductor 2, transposing-commutator H, conductor 54, point 6, and impedance-coil I. The current now flowing is steady and sustained and is consequently responded to by both armatures of relay R. At this moment, however, though the selecting and connecting magnets M and N are both operated by the closure of their respective circuits 67 and 68

and though the shaft *s* is depressed and operates the commutators H and P, these movements are with one exception incidental and do not involve the exercise of any useful function. The exception is that by the depression of shaft *s* and the consequent operation of the commutator P the normally separated switch members 26 28 are brought into contact, thereby connecting the ungrounded pole of battery S by way of point 7 on battery-bridge 8, conductor 57, contacts 26 28, conductor 58, resting-contacts $c^3 c^2$ of commutator Q, and conductor 59 to the multiple fixed terminals *v* of the main circuit, whereby the potential of said terminals is raised to prevent intrusion in the initial stage of the operation by another calling subscriber, as will presently be explained. Moreover, though the selecting-magnet M will in this initial closure actuate its pawl and possibly move its selector-arm one space over the switch-plate it will not thus be thrown out of its proper position to begin the selecting operation, for the operation of magnet N and the depression of shaft *s* follow so promptly that the local circuit of magnets M and *m* is at once opened at the contacts 30 31, and these magnets then lose control of the ratchet-wheel *n*, whereupon the shaft *s* and selector-arm E, if they have been moved, swing back to zero. Finding the circuit disengaged, subscriber No. 20 at X revolves the arm J of his current-interrupter D to No. 37, representing the desired line, the pin e^2 having been placed in the hole adjacent on the face of the apparatus to such number, and then releases it. The return of the arm and the revolution of the gear-impelled star-wheel open and close the main circuit in rapid succession a number of times corresponding to the number of the line wanted, and each time the circuit is closed the lower or quick-acting armature *g* of relay R responds and is attracted forward, falling away again with each break. The local circuit 67 of the selecting-magnet is by the said armature movement correspondingly made and broken, and the said selecting-magnet M is intermittently excited, the attractions and retractions of its armature *a* copying those of armature *g* and actuating the selector mechanism, hereinbefore described, to move the selector-arm E around the switch-plate V until the movable terminals *e f* of the circuit are directly opposite and above the fixed terminal contact-strips *u v* of the line wanted—No. 37. The local circuit 67, controlled by the light armature *g* of relay R, after passing through the winding of the selecting-magnet continues through that of the retaining-pawl magnet *m* and through the normally united contacts 30 31 to the ground or return connection. The said retaining-magnet (which, as previously explained, is sluggish in its discharge and reaction) attracts its armature *b* with the first impulse of the periodic series produced by the interrupter, and thus brings the retaining-pawl *q* into engagement with the actuating ratchet-wheel to secure the same and the selector mechanism from falling back during the intermissions of current when the selecting-magnet armature is attracted for a further stroke; but the said armature *b*, having once moved, is not retracted by said intermissions, but remains attracted with its pawl in engagement until the connection is completed. In this way the retaining-pawl is brought into engagement with the ratchet-wheel and caused to remain there during the work of selection, acting as a clutch to hold each step advanced by the selector shaft and arm. The heavier armature *h* of relay R, which was attracted by the steady current when the circuit was first closed, falls back to its normal position, with its rear end close to the rear magnet-pole, as soon as the periodic interruptions of the circuit begin and retains its retracted position as long as the said interruptions continue, the cumulative lag of the armatures *g* and *a*, the current in winding w^3 of said relay, and the slight overbalancing of the armature *h* cooperating to that end, for although the armature *a* has an associated circuit-closing device comprising the armature-contact a^2 and fixed contact a^3 and tending to short-circuit the said winding w^3 through the conductors 57, 69, 70, and 71 with each pulsation of current the frequency of interruption in the main circuit, and consequently of separation of the points $a^2 a^3$, is so high that the resistance of the shunt around the winding w^3 is too great to drain much of the current therefrom. When, however, the substation-interrupter has returned to zero position and selection of the desired line is completed, the current again becomes steady, and the lighter armature *g* of relay R is steadily attracted and held in its forward position, thus closing the local circuit 67, and thereby causing the selecting-magnet M in turn to steadily attract and hold its armature. The short circuit through $a^2 a^3$ around the winding w^3 is then effectively established, the exciting-current through the said winding is drained therefrom, and the heavier and slow-acting armature *h*, no longer held back by its rear pole, is permitted to yield to the influence of the front pole, excited by coil w^2 , and swings over to a position wherein its front end is brought close to the front pole of the magnet. The circuit 68 of the connecting-magnet N is closed by the forward attraction of armature *h*, and a current flows from the ungrounded terminal of the battery S to the frame of relay R and contacts of armature *h* and through the local conductor 68 and connecting-magnet N, returning to the other pole of the battery at this stage of the operation through the contact 29 32 of commutator P. The connecting-magnet is thereby actuated and operates to depress the shaft *s* and selector-arm E, and the movable terminals *e f* of the circuit, which by the selecting process have been moved to a point immediately above the as-

sociated fixed terminals uv of the line wanted, are thus pressed down upon and grasp the said fixed terminal strips, respectively, establishing contact therewith. Moreover, the depression of the shaft s by the connecting-magnet N also operates the keys or commutators H and P . The operation of the key P dissolves the contact normally existing between its members 30 31 and 29 32 and establishes new ones between 26 and 28 and between 25 and 27. The separation of 30 and 31 opens the circuit containing the selecting and retaining magnets and permits these magnets to release their armatures, so that the actuating-pawl p and retaining-pawl q are both disengaged from the ratchet-wheel n . The selector-arm E does not, however, now under the influence of the recovery-spring n^6 , return to its starting-point or zero position, being held in place by the movable contact-terminals $e f$, which clasp the fixed terminal strips uv of the wanted line. The separation of 29 and 32 removes the intermediate ground connection or cut-off from the local circuit of the connecting-magnet N . The object of this initial ground connection through contact-points 29 32 was to reduce the resistance of this circuit by short-circuiting the upper winding or exciting-coil z of the differential relay r , thus producing maximum current in the local circuit 68 for the operation of magnet N , while the latter is performing the work of forcing the shaft s down; but the short circuit being now removed the said relay-winding z is introduced into the circuit 68 in series with the connecting-magnet N . The contact established between members 25 and 27 of commutator P closes a new short circuit around winding w^3 of relay R , that through the circuit-closing points $a^2 a^3$ being opened by the disexcitement of magnet M pursuant to the opening of its circuit at the commutator-contacts 30 31, and since this new short circuit remains intact as long as the communication between the calling and called line continues it is evident that the winding w^3 of relay R is excluded from the talking-circuit during conversation, and the contact established between members 26 and 28 of commutator P , which, on original depression of the shaft s supplied a testing potential through contacts $c^2 c^3$ of commutator Q to the fixed terminals v of the calling-line, is of no consequence at this point of the operation, for the reason that the movable member c^2 of said commutator Q was detached from its contact with c^3 on the first rotary movement of shaft s , the said movable member being suffered to make contact with the back contact c^4 , and thus to form a circuit-closer acting to establish a testing potential in connection with fixed terminals v , but under different conditions, whereby the line is guarded from intrusion during the time required by the selecting process and subsequent thereto. We have seen that the connection between the movable terminals $e f$ of the calling-cir-

cuit and the fixed terminals uv of the wanted circuit was effected immediately upon the depression of shaft s by the connecting-magnet N . This operation, however, does not establish communication between the said two circuits, for the reason that the said movable terminals are normally detached from the main circuit they represent. Tracing back from the said terminals, it will be found that neither of them leads directly to its own circuit-conductor and that to attach them to their respective conductors it is essential that the relay r shall attract its armatures. We have also seen that the depression of shaft s was followed by the introduction of winding z of relay r into circuit 68, so that the current flowing through such circuit would also flow through said winding. If a substantially equal opposing current should now flow through the other coil z^2 of the relay, the said relay will remain inoperative and the attachment of the movable terminals to their circuit would not be effected, and this is, in fact, what occurs if the line wanted be already busy; but we have assumed the said line to be disengaged and that a current flows through coil z only. The circuit of said coil beginning at the battery S is traceable through conductor 67, the metal frame of relay R , armature h , connecting-magnet N , conductor 68, and through winding z of relay r to ground. The relay r is excited and attracts its armatures $z^3 z^4$ to their forward positions, establishing connection between the main conductors 3 and 2 and the movable terminals e and f , respectively. At this juncture the main circuit L of subscriber No. 20 is connected by its two movable terminals with the corresponding pair of fixed terminals of the main circuit L^2 of subscriber No. 37; but the talking-circuit between the two substations X and Y remains uncompleted until the said wanted subscriber No. 37 lifts his receiver from his switch-hook. There is, however, a single-conductor earth-return circuit between the said stations over which call-signals may be transmitted.

To ring or send a call from station X to station Y after the selecting and connecting operations described, the subscriber at X actuates his call-generator A , at the same time pressing the key K . The generator may be fitted with the usual automatic controlling device to close its circuit and to connect itself with the line by uniting the points 73 75, the connection in this instance being made through the intermediate piece 74, a branch 77 being led therefrom to earth through the home bell, so that a ring may be produced at the transmitting as well as at the receiving station. The circuit through which the ringing-currents developed by the generator reach the bell at Y is particularly shown by Fig. 3^b and is as follows: from the grounded call-generator A through conductor 76, contacts 40 38 of key K , conductor 78, main conductor 3, contacts y^2 , 22, and 24 of commutator H ,

(which, it is to be remembered, has been operated to transpose the relation of the main conductors 2 and 3 with their continuations 55 and 61 at the central station,) conductor 5 61, resistance Rh , armature z^3 , and front stop z^3 of differential relay r , conductor 60, movable terminal e of selector-arm E , fixed terminal u of substation-circuit L^2 , conductor 79, contacts 22 23 of commutator H^2 , (which has 10 not been operated to transpose its several conductors,) main conductor 4 of circuit L^2 , and at the substation Y from said conductor at 46 through the interrupter D , the resting-contacts 43 44 and 42 41 of the keys K^2 and 15 K , respectively, and the condenser k to the bell B and ground. These appliances and connections at station Y are not shown; but the arrangement is exactly the same as at station X . At the same time a second ground 20 return-circuit is closed by the ringing-key K through the forward exciting-coil w^2 of relay R , maintaining the attraction of armature h of said relay, and thereby, through the intermediation of connecting-magnet N , maintaining the depression of shaft s and the engagement of the selector-springs $e f$ with the selected multiple contacts $u v$. This circuit 25 leading from the ground connection 80 of said key continues by way of contact-points 39 42, the resting-contacts of key K^2 , conductor 81, resting-contacts x^6 of interrupter D , main conductor 2, closed contacts y 20 of commutator H , conductor 55, winding w^2 of relay R , the shunt-circuit 71 57 of the winding w^3 of said 35 relay, point 7 of battery-bridge 8, and through the impedance-coil i and battery S to ground. This effectively prevents any undesired motion or trembling of the selector-arm while the generator at substation X is being operated and also frees the other main conductor 40 3 and its continuation 61 from the battery-current.

The commutator H of line L has it two principal contact-springs y and y^2 always electrically united to the main conductors 2 and 45 3, respectively, of said line. Conductor 2, however, normally connects through the other points or springs 23 and 22 with the multiple fixed terminals u of its own main circuit and with the grounded pole of the battery S , while conductor 3 in like manner connects 50 through points or springs 21 and 20 with the multiple fixed terminals v of its own circuit and with the other pole of battery S , although said connection is normally broken at the 55 contacts 26 28 of commutator P . When the commutator H is operated, the contacts 20 21 and 22 23 are disestablished and new ones are formed of spring y , representing main 60 conductor 2 with point 20, and of spring y^2 , representing conductor 3 with points 22 and 24. This can only occur when the connecting-magnet N of the line in question is operated and attracts its armature d , one of the 65 branches of the forked rearward extension of the lever d^2 then acting to push farther apart the springs $y y^2$, and thus produce the above-

described changes. The effect of this operation is that the main conductor 2 of circuit L instead of being switched to the corresponding conductor 4 of circuit L^2 will be connected 70 to conductor 5 and that conductor 3 of circuit L will be united to conductor 4 of circuit L^2 . Now the bells B at the two substations $X X^2$ of line L are both, Fig. 2, connected with condensers in earth branches of 75 main conductor 2; but the call-generators A at the same substations are in normally open earth branches, which may be connected with either main conductor. Moreover, such also 80 is the case for all of the main circuits of the system L^2 , for example, having its substation-bells similarly connected to the particular main conductor 4, which in that circuit corresponds to the said conductor 2 of circuit L , while in each case by manipulating 85 the key K the generator will be connected with the other main conductor. It follows that when pursuant to the establishment of connection between any two lines L and L^2 90 the commutator H of the connection-actuating line is operated the conductor 3 of the said line with which the call-generator A at substation X is associated by key K is united to conductor 4 of the wanted line with which 95 the call-bells of the said wanted line are associated. Thus by the transposition of conductors effectuated by commutator H the subscriber is enabled to ring the bells of the wanted line without ringing any of the bells 100 at other stations of his own line. A suitable code of signals is of course to be employed, and though all stations of the wanted circuit hear the ringing each will answer only to its own code-signal. When subscriber No. 37 at Y answers by removing his receiver from the hook, 105 his main circuit is closed and his relay R^2 becomes active, causing the connecting-magnet of that line also to depress its selector-shaft s and to operate its commutators $H^2 P^2$. No selection having previously been made, the movable terminal springs of line L^2 do not engage any fixed terminals of any line. Therefore the connecting-magnet of a called line acts merely 115 as a means of actuating the circuit-changers $H^2 P^2$, the former incidentally transposing the line conductors and the latter making the several changes of the circuits, which, in reference to circuit L , have already been described, only one of which, however, is of 120 importance—namely, the short-circuiting of winding w^3 of relay R^2 , that it may not be an impedance in the talking-circuit. Since the operation of calling was previously performed, the incidental transposition effected by H^2 is 125 without significance. The complete talking-circuit between X and Y is thus fully established, and its character and arrangement are well indicated by the diagram Fig. 2^a, wherein the battery S is shown as being bridged at the 130 junction of the two component circuits $L L^2$ to supply current through the impedance-coils $i i^2$ to each independently for a transmitter-supply, while the voice-currents developed

by each transmitter pass over the main conductor straight to the distant receivers, on one side through the non-inductive resistance Rh and on the other through the link conductor 82. The relay-coils w^3 being short-circuited while the circuits are connected for talking are not shown and the relay-coils w^2 are shunted by the condensers h^2 , through which the voice-currents easily pass.

More in detail, the talking-circuit may be thus traced: from secondary winding j^2 of transmitter induction-coil I^4 at station X of circuit L and passing through branch conductor 83, main conductor 3 to spring y^2 and contacts 22 24 of commutator H, conductor 61, resistance Rh , armature z^3 of relay r , front stop z^8 thereof, conductor 60, movable terminal or selector spring e , fixed multiple contact u of line L^2 , conductor 79, contacts 22 y^2 of commutator H^2 of line L^2 , and main conductor 5 of that circuit to substation Y, and at such station through the secondary of the transmitter induction coil, the switch-hook O, the transmitter, the keys K K^2 , and the interrupter, thence returning by way of main conductor 4, contacts y 20 of commutator H^2 , conductor 84, the winding w^2 of relay R^2 and its shunting-condenser h^2 , conductor 85, contacts 25 27 and 26 28 of commutator P^2 , conductor 86, resting-contacts c^3 c^2 of the test-current commutator Q^2 , conductor 87, fixed terminal v of line L^2 , movable terminal spring f of line L, conductor 62, armature z^4 , and front contact z^6 of relay r , conductor 63, shunt-conductors 57 and 71, winding w^2 of relay R and its shunting-condenser, conductor 55, contacts 20 and y of commutator H, main conductor 2 of circuit L, and reaching substation X through the interrupter D, the resting-contacts of keys K^2 and K and transmitter t back to the secondary coil of said transmitter. The two stations are now in full communication and may converse. At the close of the communication both subscribers replace their receivers on their respective switch-hooks. When X hangs his receiver on the hook, the relay R of line L releases its armatures g and h , causing the connecting-magnet to relax its pressure on the shaft s , which thereupon rises, being pressed upward by the spring d^3 beneath its heel. As soon as the selector-springs e f are raised above the fixed terminal strips u v , with which they have been in engagement, there is nothing to hold the selector-arm, and, impelled by the recovery-spring n^6 , it promptly swings back to its initial position and is ready for another call. Of course the normal condition of the commutators H, P, and Q is also brought about by the return vertical and circular motions of the shaft s and arm E. In like manner the replacement of the receiver at Y causes relay R^2 to lose its excitement and to release its armatures, whereupon shaft s of line L^2 is elevated, restoring the initial condition of commutators H^2 and P^2 , and this line also is now ready for further business.

We shall now describe the operations whereby intrusion upon or interruption of engaged lines is prevented and whereby a subscriber desiring to connect his circuit with an engaged line may be informed that it is already occupied. The differential relay r of each line, the movable terminal f , united with the lower armature z^4 of said relay, the commutator Q, the contact members 26 28 of commutator P, and the musical-tone signal apparatus W, with its induction-coil I^3 , are concerned in these operations.

From what has been stated it is manifest that the armatures of the differential testing or discriminating relay r must be attracted into their forward positions before the connection between a calling and a wanted substation-circuit can be completed. If currents of appropriate strength and direction pass through both coils of the differential relay, the said relay remains quiescent and will not attract its armatures into the said necessary position. Conversely, if a current of appropriate strength passes through the upper coil z only, the said relay becomes active and does attract its armatures. Since the lower relay-coil z^2 is in direct connection with the lower armature z^4 and conductor 62 with the movable terminal f of its own line, in order to forestall or prevent intrusion it is only necessary to provide that the moment any line becomes busy all of its fixed terminals shall be brought into connection with the ungrounded pole of the battery. Then when any third circuit endeavors to connect itself with the said busy line a circuit for the battery-current will be formed as soon as the movable terminal of the seeking line touches the fixed terminal of the wanted line, and as this circuit leads through the lower coil z^2 of the relay r of the third line endeavoring to establish connection it is clear that the said relay of such line will remain unoperated. The third line accordingly is unable to connect itself with the line desired. Thus the mere act of lifting a receiver from its hook at any substation at once establishes a battery potential at the fixed terminals of the line of such substation, and it is no longer in the power of any other line to connect with that circuit, for this act closes the main circuit and operates relay R, which in turn actuates the connecting-magnet N, causing the depression of shaft s and the operation of commutator P, and when performed at the substation which is making the call it is therefore effective to protect the line of such station from intrusion when at the outset of the operation the attendant removes the receiver from its support before making selection. The members 26 28 of the said commutator P are brought into contact, and all of the multiple fixed terminals v of the circuit concerned are at once brought into conductive union with the ungrounded pole of the battery. The potential non-intrusion circuit of line L from the battery to said terminals v thus provided is traceable from the ungrounded pole of the

battery by conductor 57, circuit-closing members 26 28 of commutator P, conductor 58, contacts $c^3 c^2$ of commutator Q, and wire 59, thence continuing to all of the fixed terminal points v of the circuit. The points v may be regarded as busy-test points; but in the case of a subscriber's line which has called for and has proceeded to select another circuit this testing-circuit is insufficient, for during the act of step-by-step selection the connecting-magnet is not excited, and therefore the contact members 26 28 of the key P are separated, and, secondly, even though a way should be found to unite these contacts the operation of testing by a third subscriber would tend to interfere with the proper operation of relay R of the calling-line, for the test-circuit of the intruding subscriber forming a low-resistance shunt about the said relay is liable to withdraw current therefrom to such an extent as to make its work in selection untrustworthy. To avoid these difficulties and provide protection from intrusion from the beginning of the operation concerned in a communication and throughout until disconnection, we unite the fixed terminal test-points of the call-originating subscriber to the battery through a circuit connection independent of the circuit of his relay and talking-circuit and connecting with said battery at a point where the potential is always stable. This, as previously explained, is done by means of the commutator or circuit-changer Q, which on the first step of the selecting mechanism changes the test-circuit of the calling-line from conductors 57 and 58 to more direct conductor 89. Should a third subscriber undertake to establish communication with a circuit—say L—which is selecting or has selected and connected itself with another, the following operation would take place: The fixed testing-terminals v of L have had the potential of the battery imparted to them, as indicated above, and when the movable terminal or selecting-spring f of the intruding subscriber's line descends and engages with the associated point v of circuit L the incomplete test and intrusion-preventing circuit of the said third circuit is closed, the differential relay thereof (whose lower or neutralizing coil is in such circuit) refuses to work, and the subscriber desiring to connect with L is unable to do so. The intrusion-preventing circuit when completed is as follows: from the battery by conductor 89 to members $c^4 c^2$ of commutator Q and by conductor 59 to points v of the engaged line L, then by movable terminal f of the interfering line desiring communication with L to armature z^4 , back contact z^5 and lower coil z^2 of the differential relay r thereof completing the circuit to ground. As current is at the same time also flowing through the upper coil of said relay, the two coils oppose one another, the relay remains quiescent, and the connection cannot be secured.

In the case of desiring to communicate

with a called engaged subscriber's circuit the outcome of the testing operation is the same and is reached generally in the same way, it being essential in this case also that the said circuit shall be protected from intrusion from the moment that it becomes concerned in a connection. This occurs as soon as its passive terminal v is touched by the active terminal f of the original calling-circuit, for f is and consequently v becomes conductively united to the ungrounded battery-pole by way of conductor 62, armature z^4 , and front stop z^6 of relay r , conductor 63, and point 7. It is therefore the action or non-action of the differential relay r of a line seeking to unite itself with another that determines whether or not such union shall take place, and the said action or non-action of said relay depends upon the engaged or disengaged condition of the desired line. If the said line be disengaged, the relay of the seeking line becomes operative and effectuates the union desired by uniting the main conductors of its own circuit with their normally detached movable terminals; but if the line wanted be already in use the relay of the seeking line remains unexcited, because the incomplete non-intrusion circuit has been completed through the neutralizing-coil of the relay and the battery attached to the terminals v of the wanted line and fails to establish such union. At the same time if a wanted line is busy a tone-signal indicating that fact is transmitted over the seeking line and may be heard in the receiver of the substation of said line. This is produced by the constant operation of the tone-producing apparatus W, which rapidly interrupts the circuit of the source of current and by means of the induction-coil I^3 transmits the said tone-producing current to any line-circuit connected through conductor 65 to the secondary of said coil. The operation of the commutator H of any line connects through contact 24 the main conductor 3 or 5 thereof with the said tone-test conductor 65, provided the upper armature or switch-lever z^3 of the differential relay remains on its resting-contact z^7 , as we have seen is the case if the line wanted be busy.

The complete circuit of the busy-signal current from the tone-producing apparatus to the main conductor of any individual substation and thence through the substation-receiver is traceable by conductors 65 and 64, fixed and armature contacts $z^7 z^3$ of the differential relay r , conductor 61, including resistance R_h , contacts 24, 22, and y^2 of commutator H to main conductor 3, point 67 thereof at the substation, conductor 83, induction-coil windings j^2 and j when united by the switch-lever, receiver T, condenser k , and through the key K^2 and interrupter D to main conductor 2 of the substation-circuit at 46. From this point the tone-test circuit continues itself to ground mainly by the line back to the central station, through contacts y and 20 of key H, conductor 55, relay-coil and condensers w^2 and h^2 ,

conductor 71, contacts 25 and 27 of commutator P, conductor 57, point 7, and then through the impedance-coil i and battery S to earth G. A certain portion of the tone-test current leaks to ground on the outward circuit through the impedance-coil I on the other side of the battery by way of contacts 24 22 of key II and conductor 54; but this does not at all interfere with the efficiency of said current or its ability to produce a sufficiently loud and sharp tone-signal in the substation-receivers, since the said current has abundant margin for wastage and distribution.

Fig. 3^a illustrates a modification of the intrusion-preventing apparatus, which may under certain conditions be applicable, although we regard the differential relay as being preferable. In it L is a circuit about to connect itself with L², which may or may not be busy. Both circuits are indicated merely by such portions as are concerned in this part of the operation. S is the common source of current. Q¹ of line L is a contact closed by the operation of the connecting-magnet N, and the contacts 26 28 of the wanted line L² correspond to those similarly marked in the other drawings, being united if L² is occupied and separated if L² is at liberty. A single-coil relay r^5 takes the place of the differential relay r and has armatures z^3 and z^4 , which may contact with front stops z^8 and z^6 , respectively, but normally rest on back stops z^7 and z^5 . From back stop z^5 a conductor 90 to earth is extended and contains a relay m^2 , having an armature m^3 , which rests on its back contact m^4 . The movable terminals of L are marked e and f , as before, v and u being fixed terminals of L². In operation, assuming first that L² is busy, the contact between 26 28, which we may regard as being members of a commutator P, is closed. When by the action of the connecting-magnet and shaft s the movable terminals $e f$ are caused to engage the fixed terminals $u v$ of L², a current will flow from the ungrounded pole of battery S through contact 26 28 and by way of v and f through conductor 91, armature z^4 , its back contact z^5 , and conductor 90 to the relay m^2 and ground. This relay attracts its armature m^3 , which separating from back-stop m^4 opens the circuit from the battery through the magnet-coil of r^5 . The relay r^5 thus remains unexcited and cannot attract its armatures to unite the detached movable terminals to their respective main conductors of circuit L. Thus connection with an engaged circuit cannot be had. On the other hand, if L² be disengaged the contact-members 26 28 will be separated. Under these conditions when e and f engage u and v , respectively, current does not flow through the magnet of relay m^2 , but does flow through that of relay r^5 , which accordingly, acting as an electromagnetic switch, attracts its armatures and brings the movable terminals $e f$ into connection with their main conductors, thus establishing communication with L².

Referring again to the substation apparatus and to Fig. 2, if a subscriber wishes to ring up another station on the same line—that is to say, on his own circuit—he operates the generator A, as before, but this time presses the key K² instead of K, and as it is equally necessary in this instance as when connection is desired with another line to prevent interruption and to notify all subscribers that the line is engaged he also removes his receiver from the switch-hook and listens to determine whether the line is at liberty. This action operates relay R, connecting-magnet N, shaft s , and commutators H and P at the central station and connects fixed contacts v with the battery, thus establishing conditions for preventing intrusion and for transmitting the busy-signal. The pressure upon key K² separates contact-points 43 and 44 and unites points 43 45. The separation of 43 and 44 opens the circuit of battery S through the subscriber's set, which was closed by taking down the receiver, it being advisable that no battery-current shall be on main conductor 2, as the same to some extent acts in opposition to the ringing-current, and the opening of the main circuit causes the connecting-magnet to lose its excitement, permitting shaft s to rise, and restoring commutator H to its normal position. This restores conductor 2 to the grounded side of the battery S, so that the said battery is practically disconnected therefrom. The closure of points 43 45 permits the passage of the ringing-current from the generator over conductor 94 to the conductor 2, and thus to the several other bell branches thereof at other stations, as X², whose bells are then rung, the small portion of the current which passes to the central station and to ground through the impedance-coil I being insignificant and without material effect on the circuit. The several stations of each circuit will each have its own signal, to which alone it will respond. Thus circuit L may have, say, four stations, and a code will be provided under which three successive rings may call one station, four rings another, and so on. When the desired station has been called and the operation of the key K² is discontinued, the current from the battery S again operates relay R, which acting through magnet N and commutator P reestablishes the intrusion, preventing connection between said battery and the fixed contacts v of the circuit, maintaining the same as long as conversation between the parties continues.

It is desirable that a subscriber sending a call shall hear his own bell ring, and to that end it is necessary that a branch to ground through the home bell shall extend from the generator-circuit 94; but if this bell branch were always attached to the said generator-conductor it would sometimes happen on pressing key K² quickly that though the battery-circuit through contacts 43 44 were broken a new one would be formed before the relay R

could be deenergized through the coils of said relay and through the battery, from the battery-ground to the ground of the bell branch, and the battery-current would still flow. To prevent this, we arrange that the bell-branch connection shall be temporary and provide the intermediate connection-spring 74, which is not connected with the generator-circuit conductor 94 until the key K^2 has been operated for an appreciable period of time and not until the operation of the generator is fairly begun.

The circuit-breakers $o o^2$ of the subscriber's telephone-switch O open the bell and balancing earth branches. The path to ground through the bell when the receiver was removed from the switch was found to provide a circuit for the current of battery S, and the said current by tending to hold attached the armatures of the relay rendered the operation of the interrupter untrustworthy and prevented the relay and selecting magnet from being perfectly responsive thereto.

The circuit-breaker o has been introduced for the avoidance of any such irregularity, and the circuit-breaker o^2 is added to preserve the balance while conversation is being transmitted by disconnecting also the ground connection from the main conductor 3.

Having thus fully described our invention, we claim—

1. In an automatic telephone-exchange, the combination of a group of metallic substation-circuits each provided with a pair of movable terminals one for each main conductor and with multiple pairs of fixed contact-terminals associated with and within range of the movable terminals of the other circuits respectively, a selecting and connecting device for each circuit adapted to move the said movable terminals thereof over the pairs of fixed terminals of the other circuits successively to select any desired or particular pair and connect the said movable terminals therewith, a selecting-electromagnet responsive to periodic interruptions of the main-line current and controlling the selecting mechanism of said device, a connecting-electromagnet responsive to a sustained main-line current to actuate the connecting mechanism thereof, and a source of current common to all said circuits, all at the central station, and a periodic interrupting device at each substation adapted to produce the requisite number of current interruptions for the operation of said selecting-electromagnet and then to close the circuit continuously for the establishment of the said sustained current required for the operation of said connecting-magnet, substantially as set forth.

2. A central-station switching apparatus for each subscriber's circuit of an automatic exchange, comprising an arc-shaped switch-plate supporting at its edge a number of pairs of insulated contact points or strips constituting multiple fixed terminals for a corresponding number of other metallic subscrib-

ers' circuits, a central shaft therefor capable of circular and longitudinal motion, a motor mechanism for the circular motion of said shaft consisting of a ratchet-wheel mounted thereon, an actuating-pawl therefor, a quick-acting electromagnet to operate said pawl by successive steps in response to periodic interruptions of the main circuit, a slow-reacting electromagnet controlling a retaining-pawl for the retention and release of said ratchet-wheel, a connecting-electromagnet adapted in response to a sustained current in said main circuit to impart longitudinal motion to said shaft, a selector-arm in electrical connection with one conductor of the main circuit extending radially from said shaft over the said fixed terminals, an insulated contact-plate electrically connected with the other main-circuit conductor mounted concentric with the switch-plate, and two contact-pieces connected with the two main conductors of the circuit through the selector-arm and contact-plate respectively and forming the movable terminals thereof, the said contact-pieces being mounted on said selector-arm over the fixed terminals of said switch-plate and adapted pursuant to the circular and longitudinal motion of said shaft to select and connect with any desired pair of said fixed terminals, substantially as herein described.

3. In the central-station apparatus of an automatic telephone-exchange, the combination with a controlling main-circuit relay having two armatures of diverse inertia and two exciting-coils in series one developing magnetism for the attraction of both said armatures into operative position and the other acting upon the heavier armature only and developing magnetism for the retention and retraction thereof, and two local circuits containing respectively a selecting and a connecting electromagnet the former controlled by the lighter and the latter by the heavier and more sluggish of said relay-armatures, of a normally open short circuit around the said retracting-coil and two circuit-closers therefor actuated by the said selecting and connecting electromagnets respectively, whereby a short circuit may be established around the said retracting-coil by the action of the selecting-magnet, and maintained by the action of the connecting-magnet, as set forth.

4. The combination in an automatic telephone-exchange switch apparatus, of a substation telephone-circuit having its main conductors provided with normally detached movable terminals to select and connect with the fixed terminals of other circuits and also provided with multiple fixed contact-terminals to be selected and connected with by the movable terminals of other circuits, a selecting and connecting device for bringing the said movable terminals into juxtaposition to any predetermined pair of fixed terminals and uniting them therewith, a selecting-electromagnet and a retaining-pawl magnet in a local circuit for operating and maintaining the

operation of the selecting mechanism of said device, a connecting-magnet in a separate local circuit for operating the connecting mechanism thereof; a relay having its exciting-coils in the main substation-circuit together with a source of current, and provided with a quick-acting armature controlling the former and a sluggish armature controlling the latter of said local circuits, and an electromagnetic switch controlling the said detached movable terminals of said first-mentioned main circuit and acting when energized to unite them to their respective conductors, substantially as set forth.

5. The combination in an automatic telephone-exchange system, of a substation telephone-circuit having its main conductors provided with normally detached movable terminals to select and connect with the fixed terminals of other circuits and provided also with multiple fixed contact-terminals to be selected and connected with by the movable terminals of other circuits, a selecting and connecting device associated with said circuit and adapted to connect the movable terminals thereof with the fixed terminals of any other selected circuit, a controlling-relay in the said circuit, a local circuit governed thereby and including a connecting-electromagnet to actuate the connecting magnetism of said device, an electromagnetic switch having its actuating-electromagnet in the said local circuit controlling the said detached movable terminals and acting when energized to unite them to their respective main-circuit conductors, a normally closed short circuit around the said magnet of said switch, and means actuated by said connecting-electromagnet to remove said short circuit, substantially as and for the purposes set forth.

6. The combination in an automatic-exchange system of a substation-circuit having normally detached movable terminals, selecting and connecting apparatus for connecting the said terminals with fixed terminals of another substation-circuit, an electromagnetic switch associated with said connecting apparatus controlling the said detached movable terminals and adapted when energized to unite them conductively to their respective main conductors, and means for preventing the operation of the said electromagnetic switch when the said other substation-circuit is already engaged, substantially as set forth.

7. In an automatic-exchange system, the combination of a substation-circuit having normally detached movable terminals, selecting and connecting apparatus for uniting the said terminals to fixed terminals of another substation-circuit, a testing or discriminating differential relay associated with said connecting apparatus controlling the said detached movable terminals and adapted to become energized by the passage of current through but one of its coils and to unite them to their respective main conductors, but on the passage of current through both coils to

remain quiescent and to maintain the detachment of said terminals, and means for establishing current through one or both of the said coils, substantially as specified.

8. In the central-station switching apparatus of an automatic exchange, the combination substantially as herein described, of a substation main circuit having active and multiple passive terminal contacts, a selecting and connecting mechanism for said circuit, a battery or like source of electromotive force, a normally discontinuous circuit connection between said source and the several passive terminals of said main circuit, and a circuit-closing device operated by said selecting and connecting mechanism to establish the continuity of said connection when said main circuit becomes engaged, whereby an electric potential is imparted to said passive terminals to furnish current for the intrusion-preventing devices of other circuits.

9. In the central-station switching apparatus of an automatic exchange, the combination of a main substation-circuit having active and passive terminal contacts, a selecting mechanism acting to move said active terminals step by step into juxtaposition to the passive terminals of any other selected or wanted main circuit, a source of electromotive force, a normally open direct-circuit connection between said source and the said passive terminal contacts, and a commutator or switch actuated by said selecting mechanism on the first step taken thereby, to close said direct connection and thus to establish a potential on said passive terminals and indicate the engagement of the circuit to which they belong, substantially as and for the purposes specified.

10. The combination in an automatic telephone-exchange central-station apparatus, of two constituent substation-circuits each having one set of active and multiple sets of passive-terminal contacts formed or connected into a compound talking-circuit by engagement of the active terminals of the call-originating circuit with one set of the passive terminals of the call-receiving circuit, a selecting and connecting mechanism for each of the said circuits, and a source of electromotive force, with devices for impressing an intrusion-preventing potential on the vacant passive terminals of both circuits comprising for each a normally incomplete circuit connection between said source and the said passive terminals, and a circuit-closer therefor, the said circuit-closer being operated by the said selecting and connecting mechanism respectively of the call-originating substation-circuit, substantially as set forth.

11. In an automatic telephone-exchange, the combination with a call-originating or calling line, and a call-receiving or wanted line, both having a normally detached movable or active terminal and multiple fixed or passive terminals, and a switching device for each line actuated by selecting and connecting

magnets in separate local circuits and adapted to connect the movable terminals of the calling-line with the fixed terminals of the wanted line, of a source of current having one pole connected to the said fixed terminals of the wanted line when said line is engaged and the other pole connected with the movable terminal of the calling-line to form a testing-circuit adapted to be closed by connecting said terminals, and a differential relay for said calling-line controlling the said detached movable terminals thereof, the said relay having an exciting-coil in the connecting-magnet local circuit and a neutralizing-coil in said testing-circuit, and being adapted to become energized and to attach the said movable terminals to their respective line conductors, and to remain quiescent and maintain their detachment according as the engagement or disengagement of said wanted line may determine the presence or absence of neutralizing-current in the testing-circuit and the neutralizing-relay-coil included therein, substantially as and for the purposes set forth.

12. In the central-station apparatus of an automatic telephone-exchange, the combination of a call-originating or calling-subscriber's line, a call-receiving or wanted subscriber's line, and connecting mechanism for each, with a busy-signal tone current device in a normally open circuit, means actuated by said connecting mechanism of the calling-line for completing said open circuit through said calling-line, a relay-magnet for said calling-line adapted to become excited on the connection of said line with a disengaged wanted line, but to remain quiescent if said line be busy, and a switch-lever controlled by said magnet and adapted during the quiescence thereof to maintain the continuity of the busy-signal circuit, and on the excitation thereof to open the said busy-signal circuit at substantially the same instant at which it is closed by said connecting mechanism, substantially as described.

13. The combination in an automatic exchange system, of a substation-circuit having normally detached movable terminals, switching apparatus for connecting the said terminals with fixed terminals of another substation-circuit, an appliance for producing distinctive busy-signal currents, means actuated by said switching apparatus for connecting the same to the said first-named circuit, an electromagnetic switch associated with said switching mechanism controlling the said busy-signal apparatus and the said detached movable terminals and acting when quiescent to maintain the connection of the said busy-signal apparatus and the detachment of the said terminals, and when energized to disconnect the said busy-signal connection and unite the said terminals to their respective main-circuit conductors, and means for preventing the operation of said switch

when said other substation-circuit is already engaged.

14. In an automatic telephone-exchange, the combination at the central station, with substation-lines having normally detached movable terminals and multiple fixed terminals any of which lines may be a line calling for another or a line wanted by another, and switching mechanism for each line actuated by selecting and connecting magnets in separate local circuits and operating to unite the movable terminals of a calling-line to the fixed terminals of a wanted line, of a battery or like source of current adapted to be attached to the fixed terminals of an engaged line by the normal operation of the switching mechanism establishing such engagement, an incomplete non-intrusion circuit for a calling-line to be completed through the said attached battery and fixed terminals of any engaged line when the movable terminals of said calling-line are connected therewith by the switching mechanism of said calling-line, a normally discontinuous busy-signal circuit and a tone-current-producing apparatus included therein, means actuated by the said calling-line switching mechanism for continuing said busy-signal circuit through said calling-line, and a differential discriminating relay for said calling-line having an operating-coil in the local circuit of said connecting-magnet a neutralizing or operation preventing coil in the non-intrusion circuit and two switching armature-levers adapted each to move between a back contact upon which it normally rests and a front contact and control respectively the non-interruption and busy-signal circuits as well as the connection of the calling-line main conductors with their normally detached movable terminals, the said circuits leading through the said normal contacts, and the said connection leading through the said front contacts, substantially as and for the purposes specified.

15. In an automatic telephone-exchange, the combination of a main telephone-circuit normally open at its substation, central-station apparatus therefor comprising selecting mechanism adapted to bring the movable terminals of said circuit into juxtaposition to the fixed terminals of any desired other circuit, a quick-acting selecting-electromagnet to actuate and a slow-reacting electromagnet to control said selecting mechanism, connecting mechanism adapted to unite the said juxtaposed terminals, a connecting-electromagnet to operate said connecting mechanism, a main-line relay having a quick-acting armature capable of following rapid successive current-interruptions and controlling the said selecting-magnet and a sluggish armature responsive to a steady or sustained current only and controlling the said connecting-magnet, a source of current also in said main circuit, and substation devices comprising a

switch for closing the main circuit through the telephone apparatus for the establishment of a sustained current from said source therein for the responsive operation of both armatures of said main-line relay, and a periodic circuit-breaker for interrupting or intermitting the said current when established, for the responsive intermittent operation of the quick-acting armature only of said relay, substantially as specified.

16. In an automatic telephone-exchange, a call-originating subscriber's circuit and a call-receiving or called subscriber's circuit one or both being a polystation-circuit and each having two main conductors, a switching or connecting device for each at the central station adapted to unite the said main conductors of each to those of the other and thereby constitute a compound or through circuit, electromagnetic call-bells associated one at each substation with the corresponding conductors of the respective circuits, a normally disconnected call-generator at each substation, a key therefor to connect the same with the other or complementary main conductor of each circuit, and a transposing-commutator for the calling-circuit at the central station operated by the said switching device thereof to transpose the conductors of the said calling-circuit, whereby a preliminary-call-signal circuit may be established comprising the said complementary main conductor of the calling-circuit and the bell main conductor of the called circuit and including the bell or bells of the said called circuit, and the generator at the calling-station of the calling-circuit but excluding the bells at all other stations of the said calling-circuit, substantially as set forth.

17. In an automatic telephone-exchange, two main conductors of a metallic circuit extending from a central station to a plurality of substations, an electromagnetic bell at each substation connected with one of said conductors, a magneto-electric call-generator at each of said substations normally disconnected from both conductors, a grounded battery and controlling-relay looped between said conductors at the central station, an individual switching device at said central station adapted to unite the said main conductors with those of other substation-circuits, two keys associated with each said substation-generator one adapted to connect the same with the bell main conductor of the same circuit to operate the bells at other stations thereof, and the other adapted to simultaneously ground said bell-conductor and thereby complete the circuit of said grounded battery and relay therethrough and to connect said generator to the other main conductor to operate the bells of a second circuit connected by said central-station switching device, and a transposing-commutator actuated by said switching device and acting to unite the said other main conductor to the bell-conductor of said

second circuit, substantially as and for the purposes specified.

18. In an automatic telephone-exchange composed of polystation subscribers' circuits each having two main conductors one associated with the call-bells at the several circuit-substations and the other dissociated from said bells and an individual switching device at the central station for each circuit, a temporary signaling-circuit established between a call-originating and a wanted circuit by the action of the switching device of the former, and comprising the call-bell-associated main conductor of the wanted circuit, the station-call bells connected with said conductor each in a ground branch thereof, the said dissociated main conductor of the call-originating circuit grounded at the calling-station thereof, and a call-generator connected therein at said calling-station, substantially as described.

19. In an automatic telephone-exchange, the combination at each station of a polystation-line, of two main conductors, an electromagnetic bell included in a ground branch from one of them, a grounded call-generator in a normally incomplete circuit, two keys associated with said generator and with the said main conductors respectively and adapted to complete the said generator-circuit through their respective main conductors, and a normally open circuit connection extending between the ungrounded terminals of the bell and generator and adapted to be closed during the operation of said generator as a branch circuit thereof including the coils of said bell, whereby the said generator is enabled to ring the bell of its own station when operated in connection with either main conductor, as set forth.

20. In an automatic telephone-exchange, the combination of a compound talking-circuit between two substations formed by uniting the normal circuits of said substations at a central station, and comprising telephone apparatus at the said substations, a bridged source of current connecting through parallel impedance-coils on each side with the two main conductors respectively, and two shunted relays maintaining the connection of said constituent circuits and having their windings in series in one of the said main conductors, with means for balancing in the other main circuit-conductor the said shunted relays, and for regulating the amount of current supplied from said source to the two constituent circuits respectively as set forth.

21. In an automatic telephone-exchange, a compound talking-circuit between two substations formed of two constituent subscribers' circuits switched together at a central station, and comprising telephone apparatus at the said substations, a battery supplying current for said telephone apparatus bridged between the main conductors at the central station, two impedance-coils in series in each

main conductor one on each side of said battery-bridge connection, two connection-maintaining condenser-shunted relays having their electromagnets in series in one of said main conductors, and a low-resistance conductor shunting the impedance-coils in the main conductor which contains said relays, combined with a balancing and regulating resistance shunting the impedance-coils in the other main conductor, substantially as specified.

22. In an automatic exchange, and in combination with the two main conductors of a polystation subscribers' line thereof, apparatus and circuit connections at each substation comprising an electromagnetic bell and condenser in a ground branch from one of the said main conductors, a balancing impedance corresponding to that of the magnet of said

bell and a second condenser in a ground branch from the other main conductor, a switch serving as a telephone-receiver support and operated by the removal and replacement of said receiver, and two circuit-breakers connected respectively in the said bell and balancing earth branches and both controlled by said switch, substantially as described and for the purposes set forth.

In testimony whereof we have signed our names to this specification, in the presence of two subscribing witnesses, this 26th day of August, 1901.

ALBERT M. BULLARD.
MALCOLM C. RORTY.

Witnesses:

GEO. WILLIS PIERCE,
THOMAS D. LOCKWOOD.