TELEPHONY

A MANUAL OF THE
DESIGN, CONSTRUCTION, AND OPERATION
OF TELEPHONE EXCHANGES

IN SIX PARTS

PART VI

SWITCHBOARDS AND THE CENTRAL OFFICE

WITH ILLUSTRATIONS

BY
ARTHUR VAUGHAN ABBOTT, C.E.

NEW YORK
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PREFACE.

THE Central Office is the brain of the telephone exchange. From it the wire plant, a complicated ganglion of nerves, radiates in all directions. In it originates that mysterious electric energy that, thrilling over the circuits, animates and operates the whole. Within a decade central office practice has been twice revolutionized. The branch terminal switchboard has displaced the series multiple, and it in turn has been driven forth to make way for the common battery automatic signal board. So rapid have been these changes that one can scarcely catch breath to cry, *What next!* Just now the perfection attained by the common battery board has, at least for the moment, halted the march of invention, and seizing this opportunity, the author is endeavoring to place before his readers a brief account of the central office and its various organs as it exists to-day. The central office consists of four parts. The terminals, the switchboard, the battery plant, and the building; to each of which a section of the volume is assigned. There is no end to circuit possibilities, and the author knows of but one complete collection of the successful devices of the day, so it is hoped that the chapter on Common Battery Boards will place in the hands of the student a more comprehensive view than is to be found elsewhere. Similarly with traffic. There are few statistics of operators' work outside of the inaccessible archives of operating companies, and the author trusts that the chapter dealing with this topic will be of value in stimulating good operating.

ARTHUR VAUGHAN ABBOTT.

NEW YORK, June, 1905.

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CHAPTER I.

INTRODUCTION.

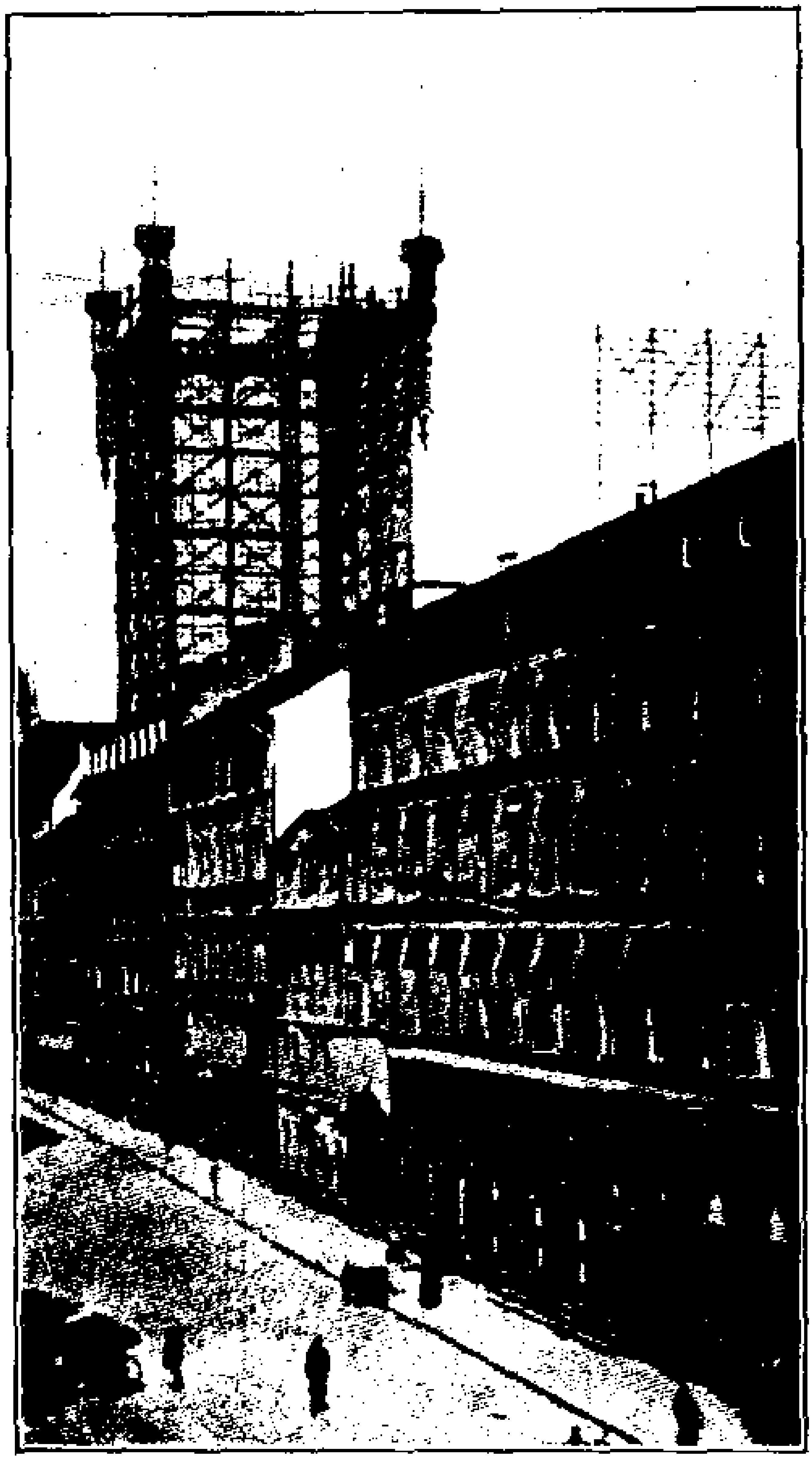
In the first volume it was shown that to permanently connect every substation with all others gave rise to an impossible complexity of circuits. But if each substation is not so joined, means must be provided whereby temporary connections can be established whenever desired, in order that each subscriber shall enjoy the ability to communicate with all others. Hence the switchboard, and hence the necessity of converging all the wire plant to some central point whereat the operation of connecting one line to another on demand can be carried out. Primarily, therefore, the central office is merely the place at which the switchboard is located, and to which all circuits converge. As the advantages of the telephone became more and more widely known, both the number of subscribers, and the amount of business which they desired to transact, rapidly augmented, until to-day in the United States alone there is a steady annual average of three hundred messages per second. To handle such an enormous traffic even when diffused through some five thousand systems, requires the exertion of the keenest inventive ability to devise ways and means whereby it should be accomplished with reasonable speed and expense, and thus the telephone switchboard has evolved into one of the most highly specialized pieces of machinery now in existence. Despite the most persistent endeavors to make the operation of the switchboard more and more automatic, the exchanges of this country to-day use nearly 70,000 employees, while with the advent of the common battery it became necessary to provide centralized power plants dealing with quantities of electrical energy of no mean proportions. To properly house the switchboard and the power plant, to provide adequate accommodations for the operators and other employees, and to care for a converging network of wires to be counted by tens of thousands, gives rise to problems in design of the highest order, that cover the entire range of electrical and mechanical engineering and architecture. As the business grew, there was a corresponding increase in capital invested, and the necessity for a similar development in the organization required to administer the affairs of the company, so that the modern telephone company has become one of the most complex of business aggregations. For such an organization proper offices must be supplied, and in order that the various officials should be in the closest touch with the plant it was natural to select the operating office as the business headquarters, and the central office must, in addition to requisitions already catalogued, be an office building of the most modern type, with sufficient capacity to serve the needs of a large corporation. Taken as a unit, the design of the central office must ... First, such an arrangement of the wire plant as will properly bring all the lines to the switchboard in such a manner that they may always be readily accessible for repair and rearrangement. Second, the provision of an adequate switchboard that shall include the necessary apparatus whereby lines may be connected and disconnected in the quickest and cheapest manner. Third, a power plant, capable of supplying all the electrical energy needed to operate the exchange. Fourth, the design of such a building as shall properly house the elaborate and expensive apparatus.

CHAPTER II.

TERMINALS AND DISTRIBUTING BOARDS.

IT is difficult to select the point at which to commence an account of the central office, for all its appliances are so interconnected that it is necessary to postulate some acquaintance with the whole in order to introduce any of the parts. So perhaps the simplest method is to follow the wire plant on its way to the switchboard, thus taking the route of a message as it passes from substation to substation. Time was when the problem of bringing the various lines into the building containing the switchboard taxed the invention of the telephonists, for when all lines were aërial they naturally converged to the roof of the building, and to place thereon a structure capable of resisting the stress of some thousands of lines, so designed as to maintain each in electrical isolation, was a herculean task. Some idea of its magnitude may be gained from Fig. 1 which is the wire tower on the Brunkeberg Exchange, Stockholm, Sweden. The structure is some 75 feet above the roof of the building, is built of Bessemer steel shapes, and cost about $17,000.00, an enormous sum compared to the expenditure for cable entrances of even the most expensive of modern cable ways in the largest of American offices.

Here, all vestiges of such practice have long since vanished with the adoption of the aërial cable and the development of the conduit, for it is essentially true to state that now no open wires are carried into exchange buildings. By the most advanced practice the use of open-wire line is confined to distribution and to toll lines, so that in ex-



changes where no underground construction is used the bulk of the circuits is carried in aërial cable. Even in the smallest installations the open wire is gathered into a cable a few poles away from the office, thus compacting the lines into a small compass and rendering their introduction into the building through a convenient hole in the wall an easy matter. In the larger cities exchanges are located in the more crowded portions and the circuits are universally underground. Hence it is usual to build what is frequently called an "Office Manhole." This is a manhole in the street, to which all conduits converge and in which they end. It is usually made quite spacious, to afford ample room in which to splice and arrange cables. From this manhole to the basement of the exchange building, the cables are carried either in an open tunnel, the method almost universally adopted in the older offices, or by means of a series of short ducts, now the prevalent practice.

The interior of such a tunnel is shown in Fig. 2. It is a passageway some 4 feet wide and 6½ feet high, excavated beneath the street and lined and arched with brick, providing a structure of ample strength to carry the heaviest traffic of a busy street. Into the masonry of the side walls iron supports are built, thus furnishing a series of shelves or racks on which the cables may rest. So far as ease in installing or rearranging cables is concerned nothing can be more desirable, as there is ample space to do anything one pleases. To find room among street structures for such a tunnel is a difficult, often impossible matter, to say nothing of its expense, so by building a short subway of ducts connecting the office basement with the street manhole, both of these objections are avoided. In many cases such a conduit must provide for a very large number of cables, and in order to render all accessible, much ingenuity must be displayed. Usually a broad, flat conduit lends itself most readily to cable installation,

Fig. 2.—Cable Tunnel.

and by fanning out the separate ducts at the basement wall, sufficient room to handle the cables can be secured.

After the cables reach the inside of a building, there is some difference of opinion as to the test method to adopt.

It was formerly the custom to end the cables in iron cable heads carried in a rack attached to the building wall. Such cable heads carried the protective devices, and from them house cables extended to the distributing boards. The iron cable heads are expensive to install, even when carefully connected to the cable can by no means be considered moisture proof, and take up so large amount of space as often to require a room by themselves. As the protector forms the most convenient point at which to test for trouble the cable heads should be placed as near as possible to the switchboard or else much time will be expended in going to and fro. For these reasons it is becoming customary to place the switchboard and distributing board close together on the same floor, as shown in Fig. 3; then the street cables are carried as near as possible to the distributing board, and terminated in pot heads. From the pot heads twenty pair switchboard cables run to the distributing frame. In some cases the street cables have been carried to and laid on the shelves of the distribution board, the individual circuits being extended to the terminals of the board by means of okonite, but the pot head when placed on the shelf of the distributing board takes up so much room as to make this method inadvisable. The neatest arrangement is to set the pot heads on the floor below that occupied by the distributing board, and directly beneath it. Then, by means of a slot in the floor, the cables from the head can run directly to the terminals on the frame. (See Frontispiece, Vol. III.)

It is usual to place the operating rooms of large offices on the top floors. In many cases this necessitates a long vertical run in the building. It is impractical to suspend

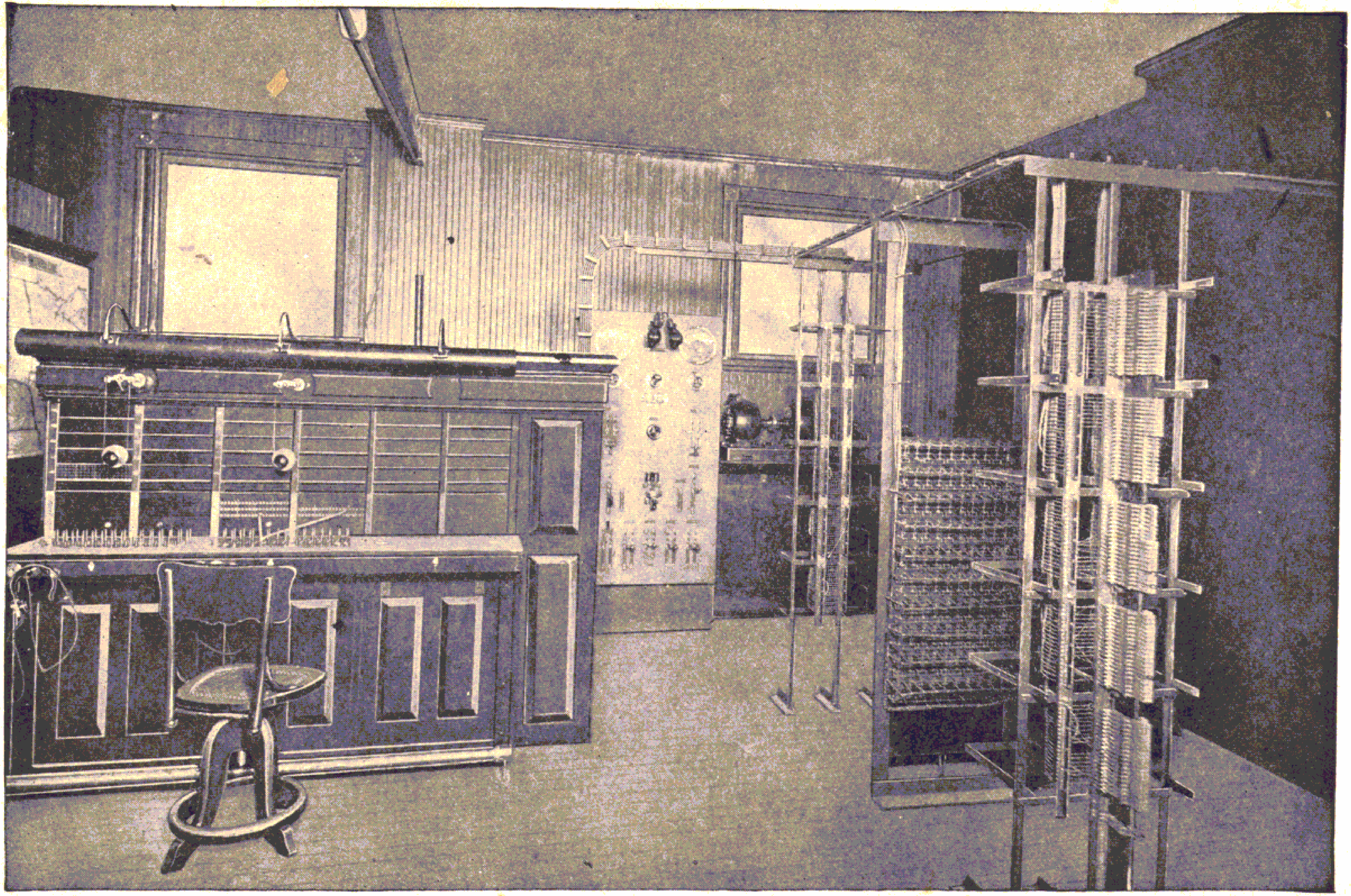


Fig. 3.—General Relation of Switchboard and Distributing Board.

the cables from one end, as the lead sheath is so soft that the weight of but a few feet would pull the sheath apart. So a shaft must be designed to provide a cable support every few feet. Where one wall of the building is free from windows it is convenient to build the shaft only deep enough to take one cable, and as wide as may be necessary to accommodate the desired number. Fireproof doors are provided on each floor to give access to the shaft, and as often as every ten feet the cables are supported by clamps in the wall.

When pot heads are used, protectors must be provided for, and it is now usual to place them on the switchboard side of the distributing frame. The advocates of the pot head claim that its use affords a surer protection against the entrance of moisture than the cable head, that it takes up much less space, costs less to install, and that less protection of a cheaper and more accessible form can be used on the distributing board. Those that favor cable heads, while admitting the advantages cited for the pot head, believe that the difference in cost is more than repaid by the better opportunity that the cable head affords for testing and rearranging circuits when a cable is spliced, and by the fact that protection on the heads guards *all* the wiring inside the building, while if it be placed on the switchboard side of the distributing frame the jumpers in the frame are entirely unprotected, thus leaving unguarded a spot where a little fire may do much injury. This objection, weighty in the days of wooden boards and paraffined wire, now loses much of its force with the employment of iron frames and flameproof wool-covered jumpers, and so the pot head is on the whole the favorite method. In order to combine the merits and omit the defects of both, the plan of using pot heads for the street cables and placing the protection on a special frame in cabinet set between the pot head and the distributing board, is sometimes adopted. This plan involves placing the protectors on long strips, so mounted as to be easily accessible from all sides, and inclosing a sufficient number of strips in a cabinet, as shown in Fig. 4.

From the end of the street cable, however terminated, the circuits must be extended through a longer or shorter run to the distributing board. As such a run is inside the office building, and may be kept reasonably dry, house cable is adopted. If pot heads are employed, it is considered necessary to splice to the street cable a length of rubber-covered wire. This idea is founded on the theory that all the fibrous materials (cotton, etc.) used as insulators are composed of microscopic tubes which it is impossible to hermetically seal; hence if such cable were used moisture would sooner or later reach and destroy the paper cable. Prolonged experience has shown that such fear is largely unfounded, for there are many hundreds of potheaded cables to which silk and cotton switchboard cable, either leaded or unleaded, have been spliced, and in which no deterioration of insulation has been noticed. Lead-covered wool insulated cable has also been used because wool is both less hygroscopic and less inflammable.

The distributing board is one of the most important, yet often least comprehended pieces of apparatus; its object is to afford an easy method of changing the relation of the wire-plant circuits and the switchboard circuits; in theory it is exceedingly simple, in practice somewhat

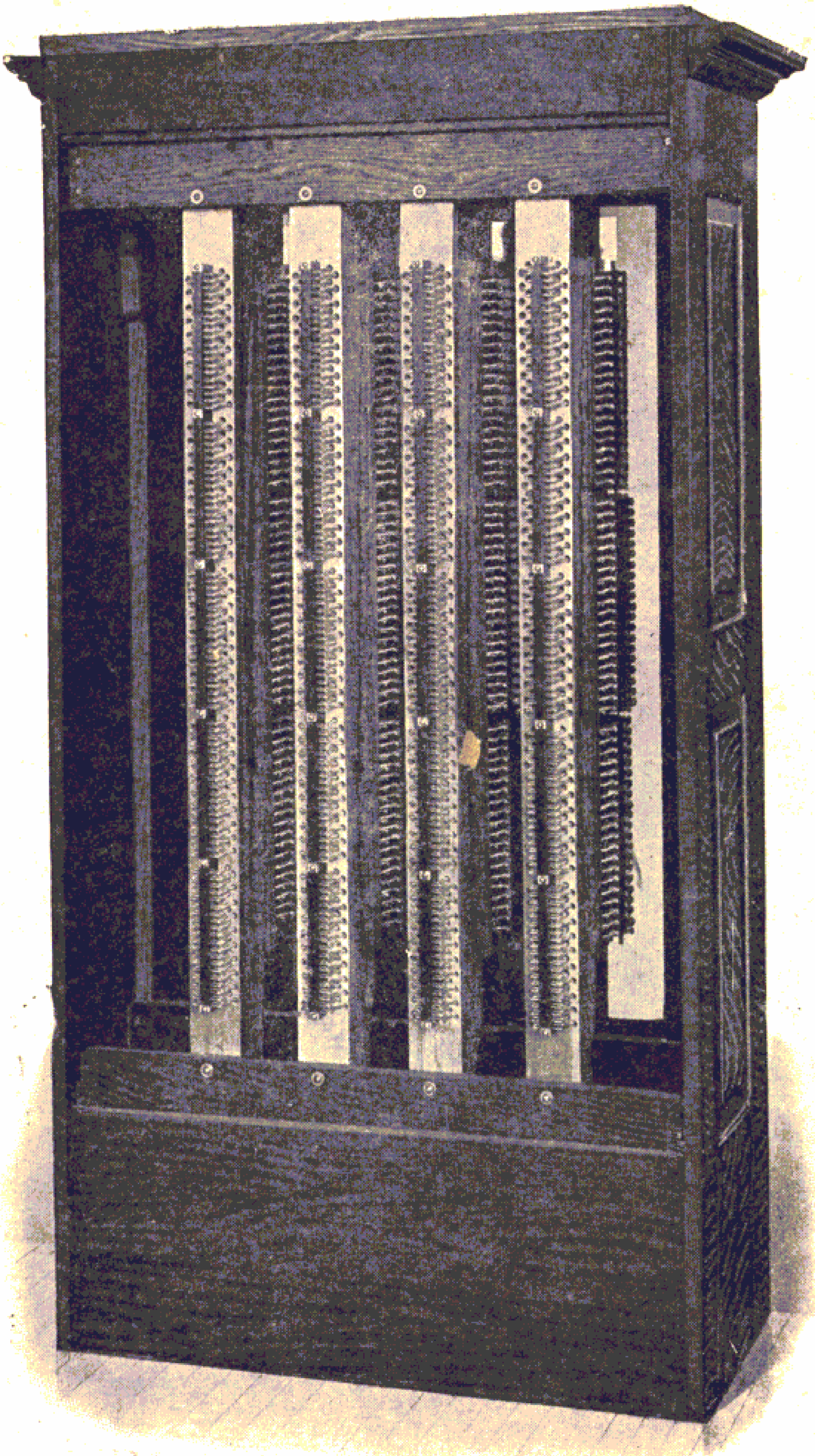


Fig. 4. —Protector Cabinet.

complicated. Referring to Fig. 5, suppose *A B* to be a street cable, having its ends fanned out and each circuit connected directly to the line signals in the switchboard. Such a diagram illustrates an office without a distributing board. It is easy to imagine a thousand causes that will render it desirable to change a cable circuit from one line signal to another. According to the arrangement of Fig. 5, it would be necessary to cut the wires from the cable to the board and splice in new pieces. Such practice would in a short time destroy the best, installed plant. Now suppose that in Fig. 6 the street cable wires be extended to a strip on which a number of binding posts are placed, and that each wire be soldered permanently to its post. Also that the switchboard circuits be similarly extended to and terminated on a second strip supplied with binding posts, placed a short distance away from the first. Evidently any line in the cable can be quickly connected to any one in the switchboard, by simply running a piece of flexible wire between the respective binding post to which the wires are attached. Neither cable nor switchboard circuits are disturbed, there is no cutting or patching, simply the loosening and tightening of a couple of screws, and neither line need be open more than a few seconds. Such is the distributing board. In very small offices the *cross connecting board*, as it is often called, is nothing but a strip of varnished wood, carrying two rows of binding posts, or even two rows of metal pins to which the subscribers' circuits and switchboard circuits are attached, and between which the flexible wire jumpers run.

When a telephone line becomes inoperative, the diffi-

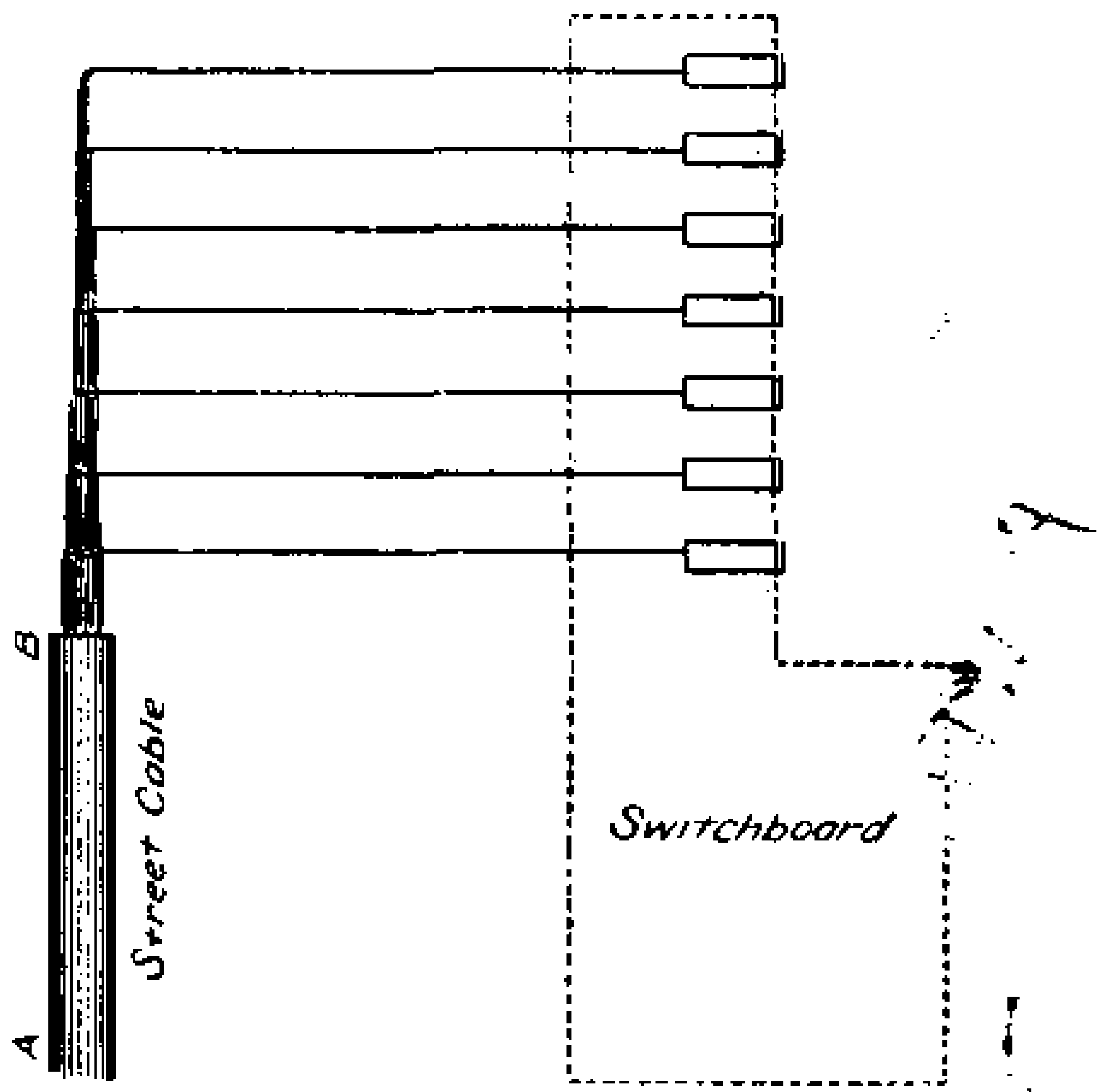


Fig. 5.—Diagram of Switchboard without Distributing Board.

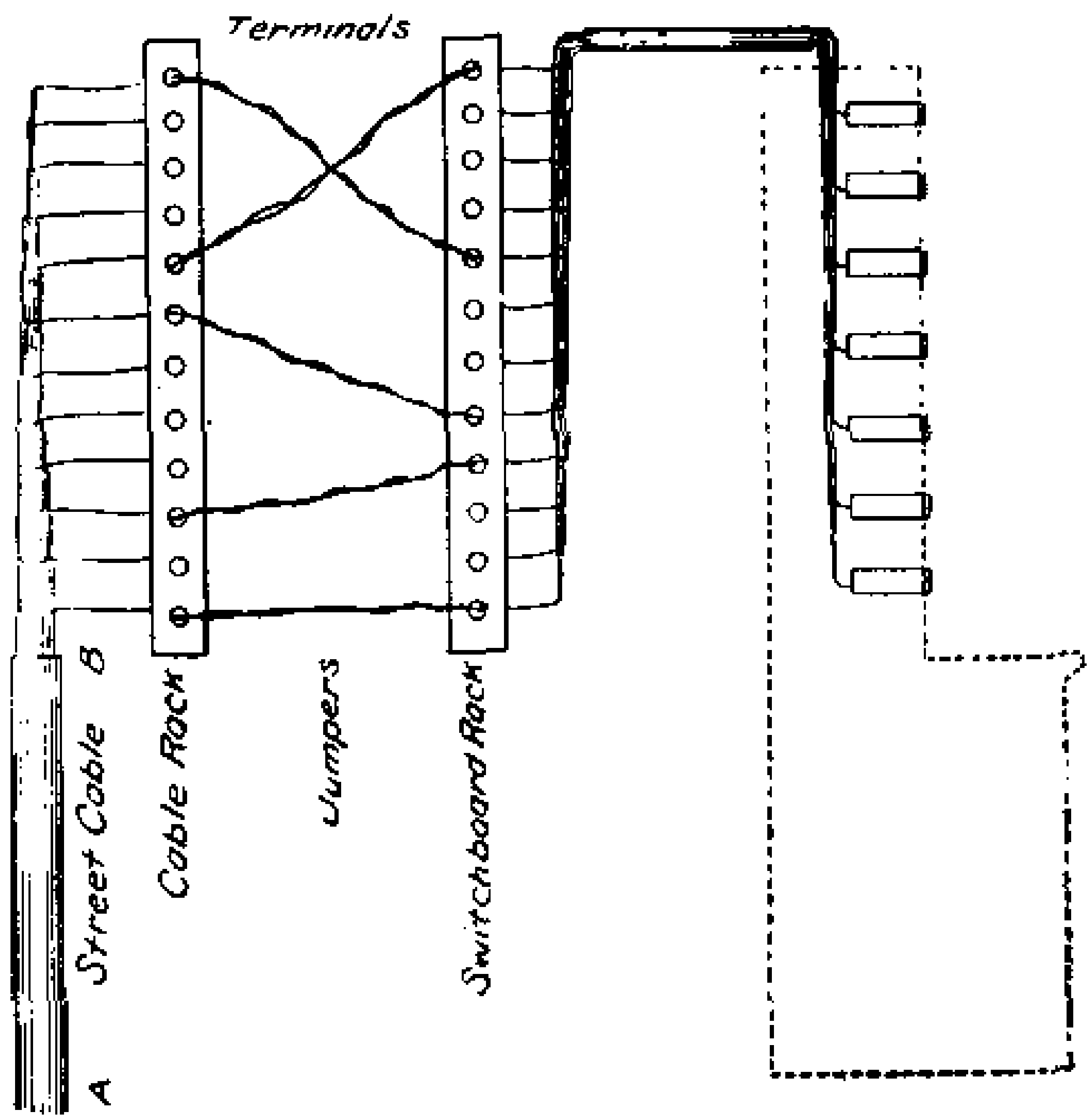


 Fig. 6.—Diagram of Switchboard with Distributing Board.

culty may lie either in the wire plant between the office and the subscribers' premises, or in the switchboard apparatus and its circuits. As the distributing board forms a temporary connection between these two, it logically becomes the point from which the inspector seeks to locate trouble, by opening the jumper and testing out toward the substation, and in toward the switchboard.

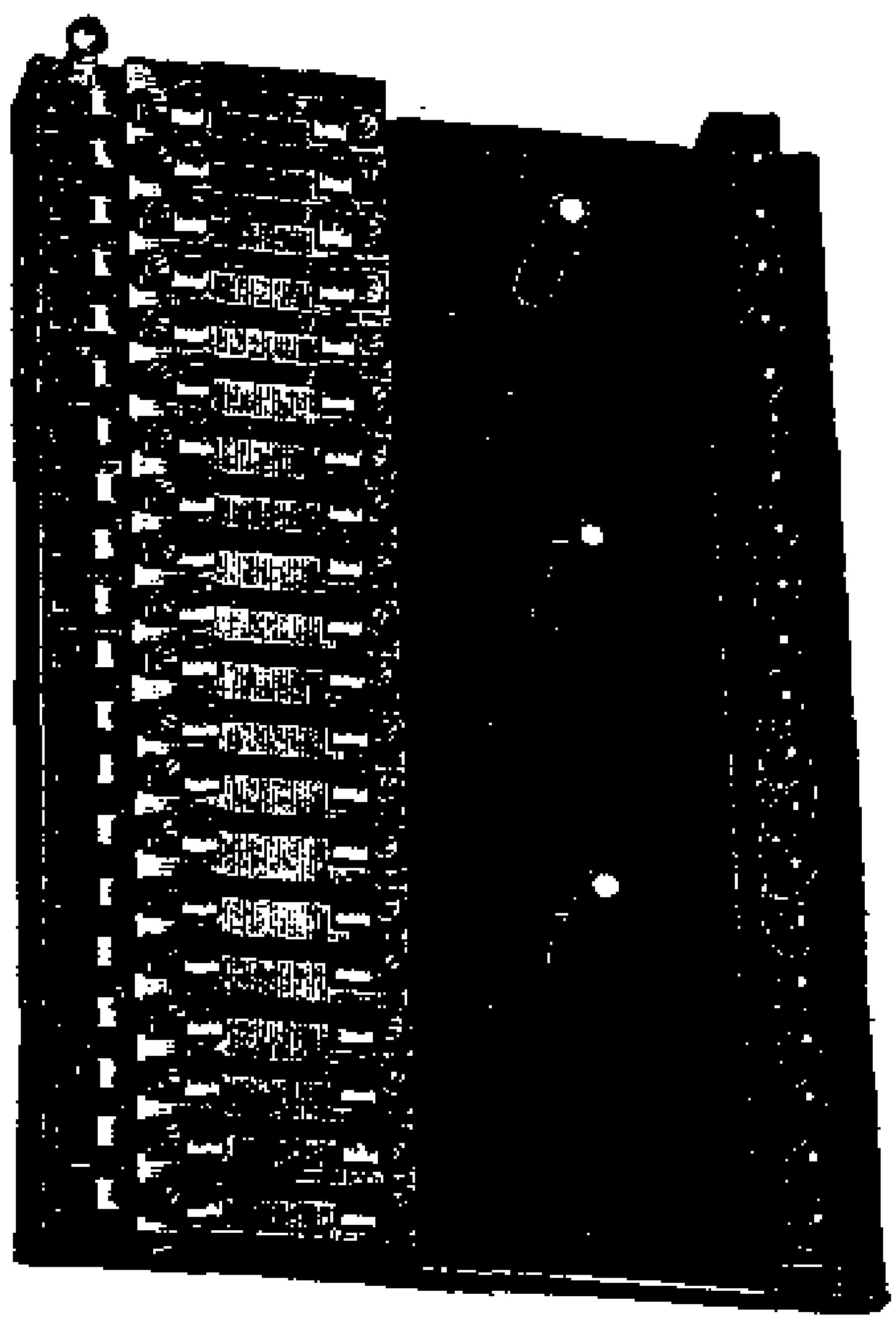


Fig. 7.—Simplest Form of Distributing Board.

As the distributing board is placed at the end of street cables, it becomes the natural location for protective devices. The distributing board therefore must provide for three functions. It must enable a temporary connection to be rapidly and easily made between any wire plant wire and any switchboard circuit. It must lend itself readily to the operations of testing for trouble. It must afford a convenient location for protection. Consider now how the various boards fulfill these requisites. The simplest distributing board is, as is indicated in Fig. 7, literally a "board," usually from 8 inches to 12 inches wide, and 5 feet to 8 feet long, made of hard wood, preferably maple, and thoroughly dried and varnished. Along one edge is a strip of wood carrying binding posts, while on the other edges the protective devices are arranged in a row on about the same spacing as the binding posts.

The cable from the switchboard is usually placed either in the space formed by the strip carrying the posts and the main board, or else directly on the back of the board; each of its wires being soldered to the end of the binding post within the strip, or if the post is supplied with two nuts,

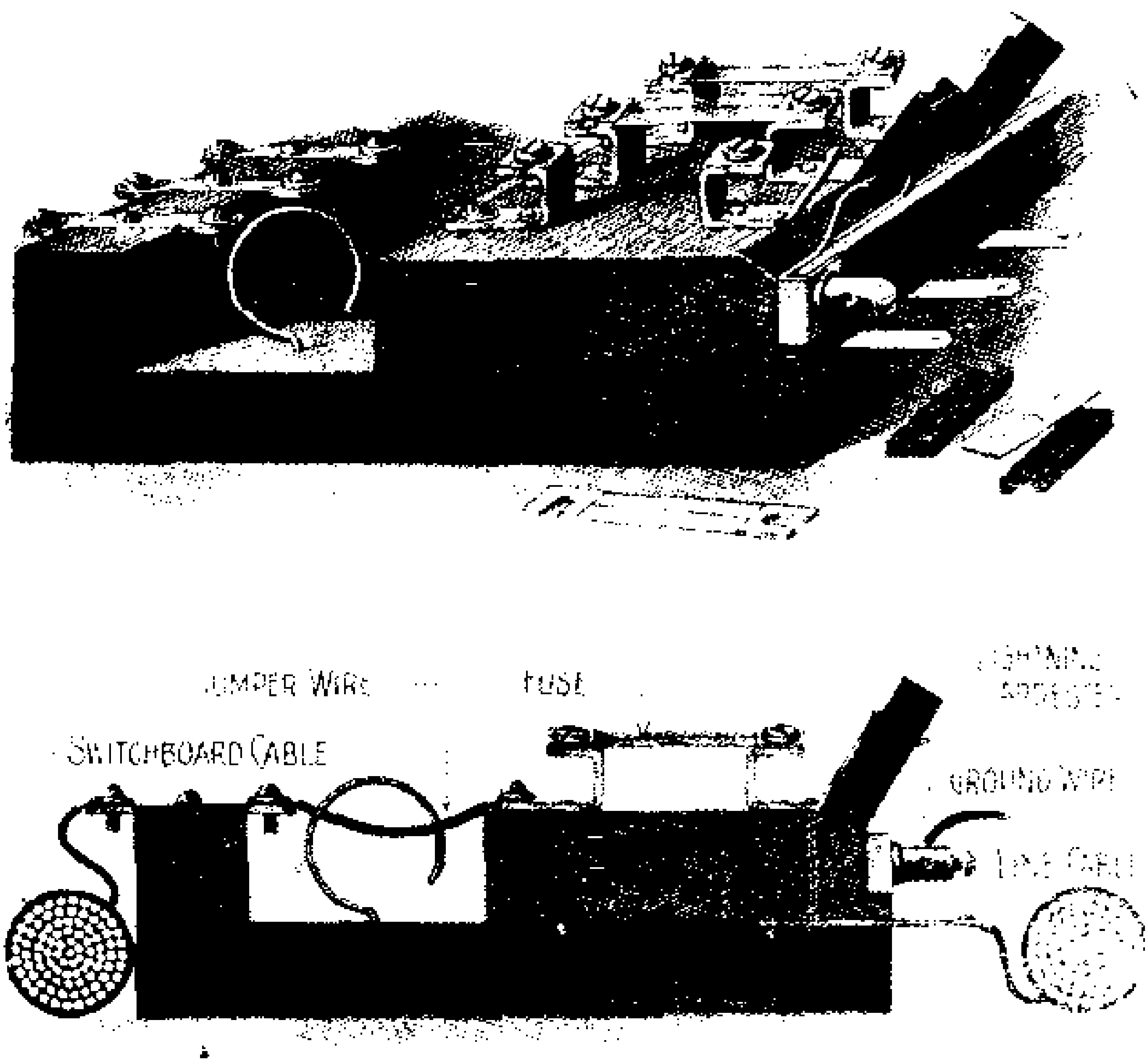


Fig. 2.

Fig. 8.—Section and Isometric View of Simple Distributing Board.

held under the lower one. In a similar manner, the wire plant cable is attached to the back of the board on the protector side, each wire being attached to a post or screw that may be seen between the carbon plates and the fuses or heat coils. To connect any wire plant wire to any switchboard circuit, it is only necessary to insert one end of a flexible wire under the screw at the inner end of the fuse, run it longitudinally along the board to the binding

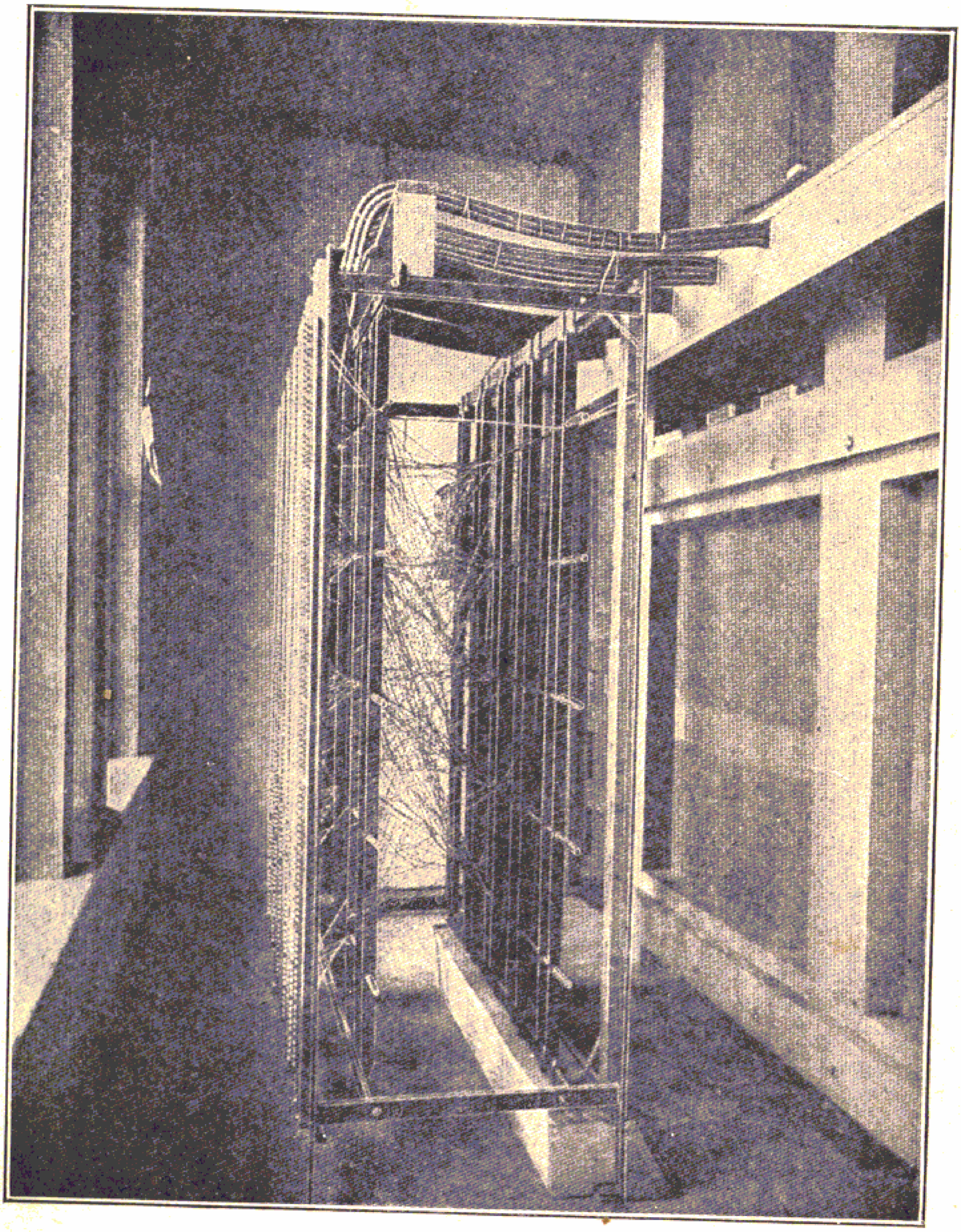


Fig. 9.—An Objectionable Design at Distributing Board.

post of the desired switchboard circuit, and clamp it. Pins are driven into the board about every 6 inches, around which the jumpers may be bent, and thus carried nearly longitudinally throughout their entire course, as shown in Fig. 7. Fig. 8 shows an isometric and sectional view of a distributing board designed on this same general plan, though the details are slightly different in the arrangement of the protectors and use of a ring to guide the jumpers instead of a wood pin.

Supposing the protectors to be set on half inch centers, a hundred lines will need a board 50 inches long; a very convenient size, but for two hundred lines, a length of more than 8 feet would be needed, making the board inaccessible. It is impractical to use two boards and connect from one to the other. To secure greater capacity, the most obvious design is to bring all the switchboard cables to a series of strips, either vertical or horizontal, and all the wire plant cables to a similar set placed a short distance away, say 2 feet to 3 feet, with an open space between them, through which the jumpers can be run. Such a board is illustrated in Fig. 9, which also shows the objection by revealing the inextricable tangle of wires that even the use of a small number of jumpers produces.

The modern iron frame distributing board presents a very neat solution of the problem. As now built, distributing boards consist of a number of panels built of angle iron. Fig. 10 shows a single panel of an approved design. The height is usually regulated by the room in which it is to be placed or the convenience of the wire chief in reaching terminals. The length, as will be presently shown, depends only on the desired capacity, while the width or distance between opposite sides is also a function of capacity. The base is a piece of light $2\frac{1}{2}$ inch by $2\frac{1}{2}$

inch angle, the uprights are $1\frac{1}{2}$ inch or $2\frac{1}{4}$ inch angles, the horizontals $1\frac{1}{2}$ inch to 2 inch by one fourth inch

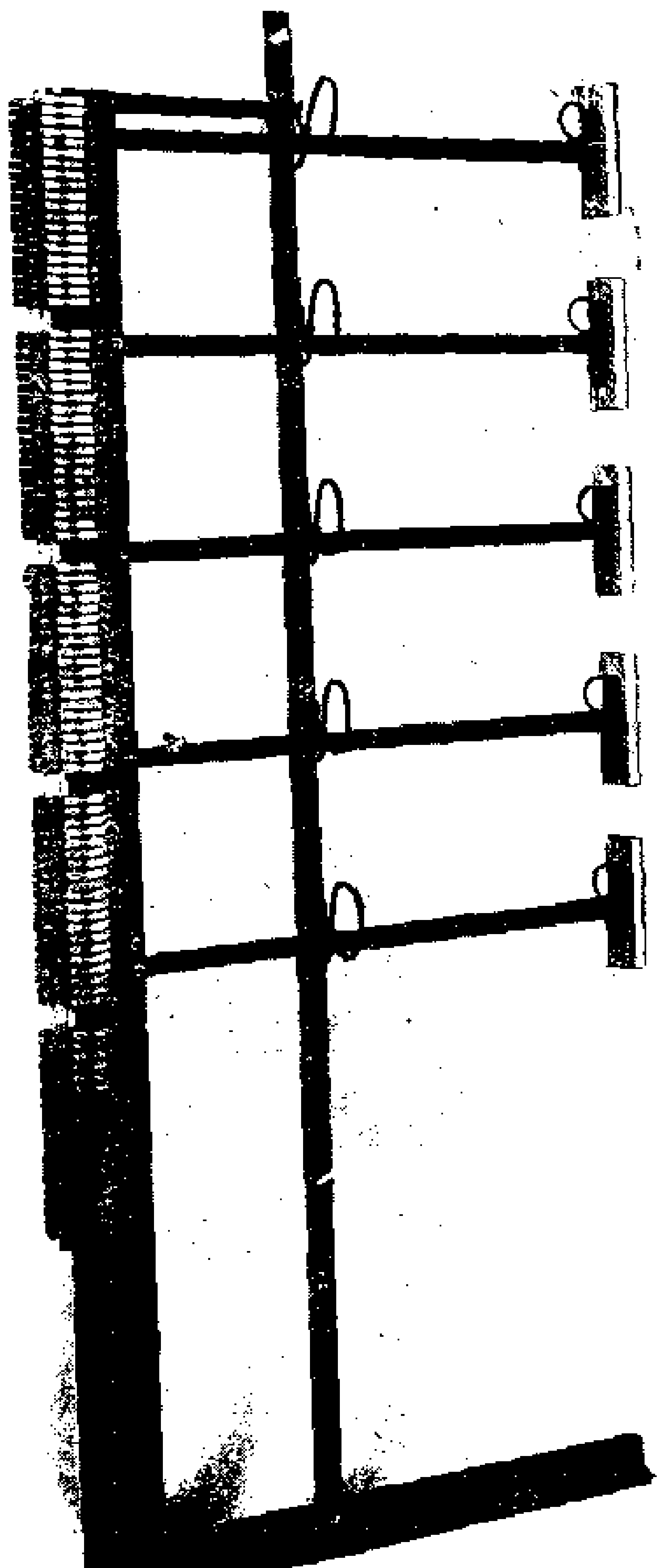


Fig. 10. – Single Bay of Distributing Frame.

flats, while the protectors are supported by a strip of 4 inch by one half inch flat set vertically, as shown on the left hand. Theoretically, boards of different sizes could be proportioned of different sized shapes, but practically the saving in iron would not pay the expense of a new design,

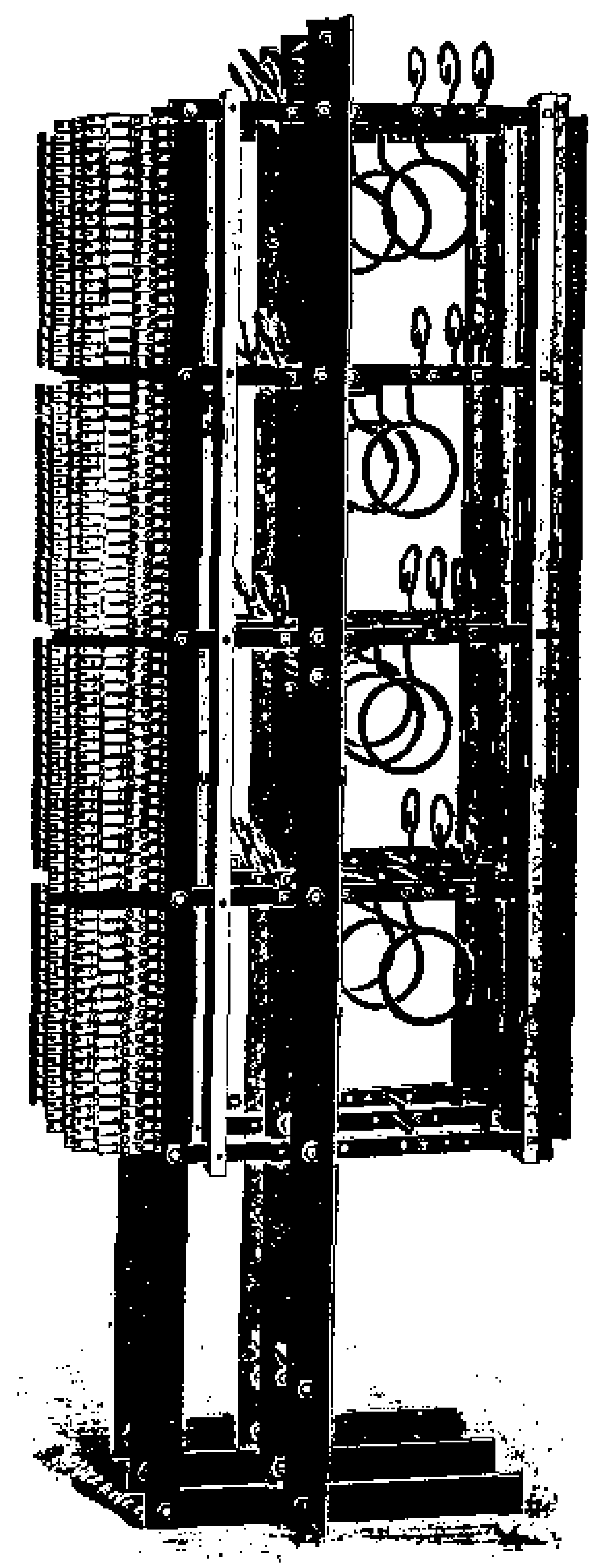


Fig. 11.—Distributing Board.

and the cost of stocking a great variety of shapes. For a 5000-line board the base would be about 33 inches long. The distance from the face of the arrester strip to the center of the vertical bar is 9 inches, from the center of the vertical to the face of horizontal runs is 20 inches, with a clear space of 9 inches between shelves. The horizontal spacing of arrester bars is 8 inches, the spacing of horizontal runs, 9 inches. As the board is formed of single bays like Fig. 10, any capacity may be secured by

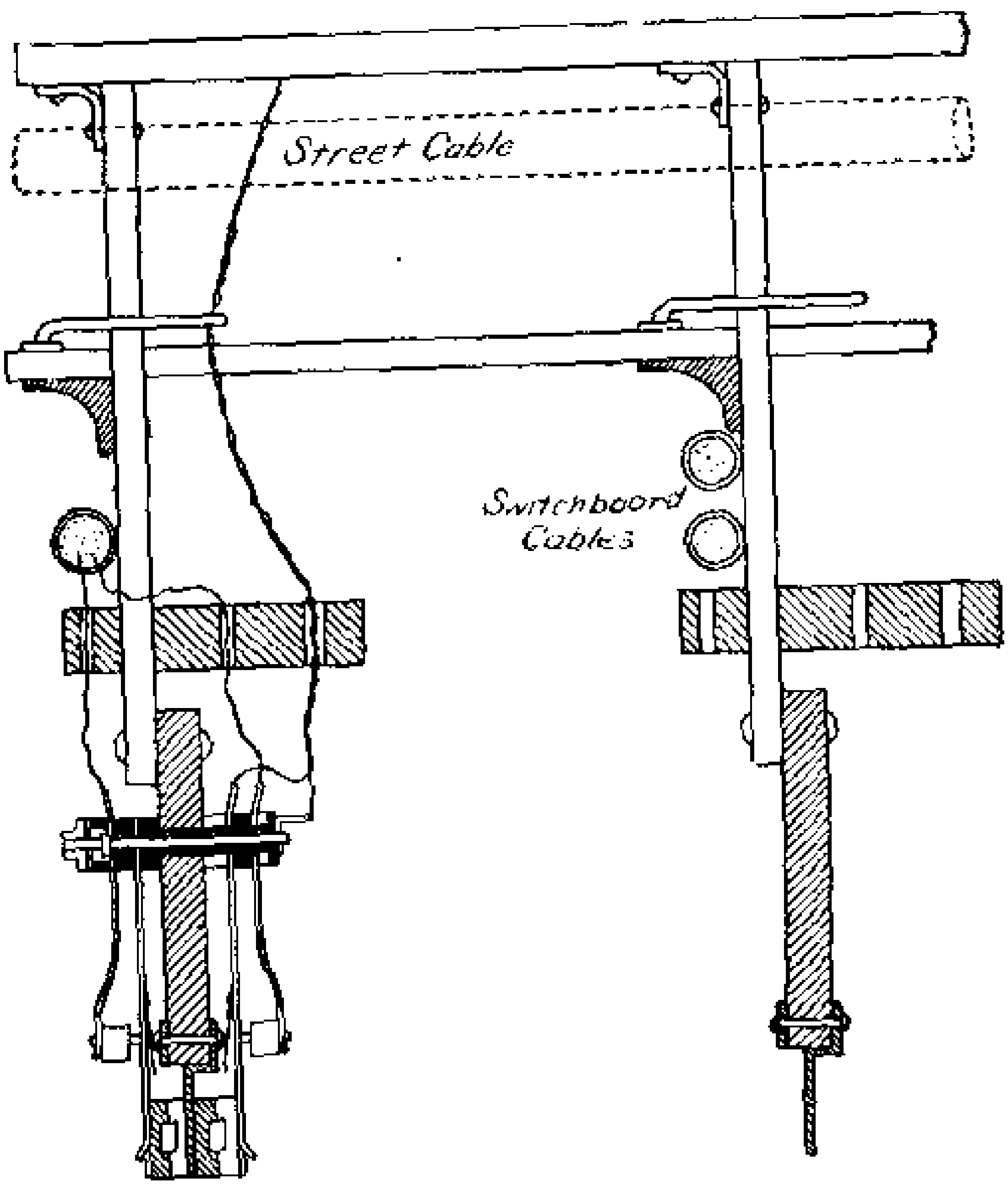


Fig. 12.—Section through Shelf of Distributing Board. 20

changing the number of bays. A complete board is shown in Fig. 11, giving a side view. Fig. 12 is a section through a shelf of such a board. The street cable enters along the horizontal run and is attached to clips, shown in elevation in Fig. 13. The switchboard cables extend vertically along each upright and are fanned out into one side of the protectors. From the other side, the jumpers

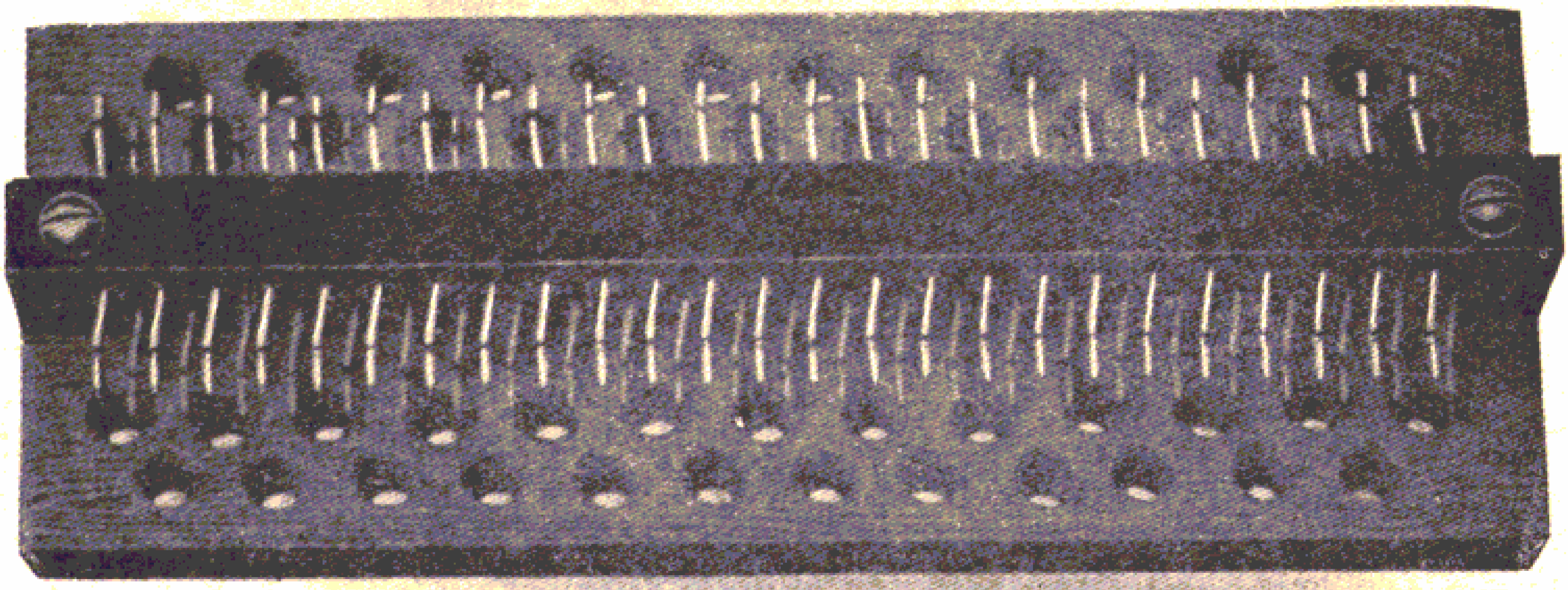


Fig. 13.—Street Cable Clips Distributing Board.

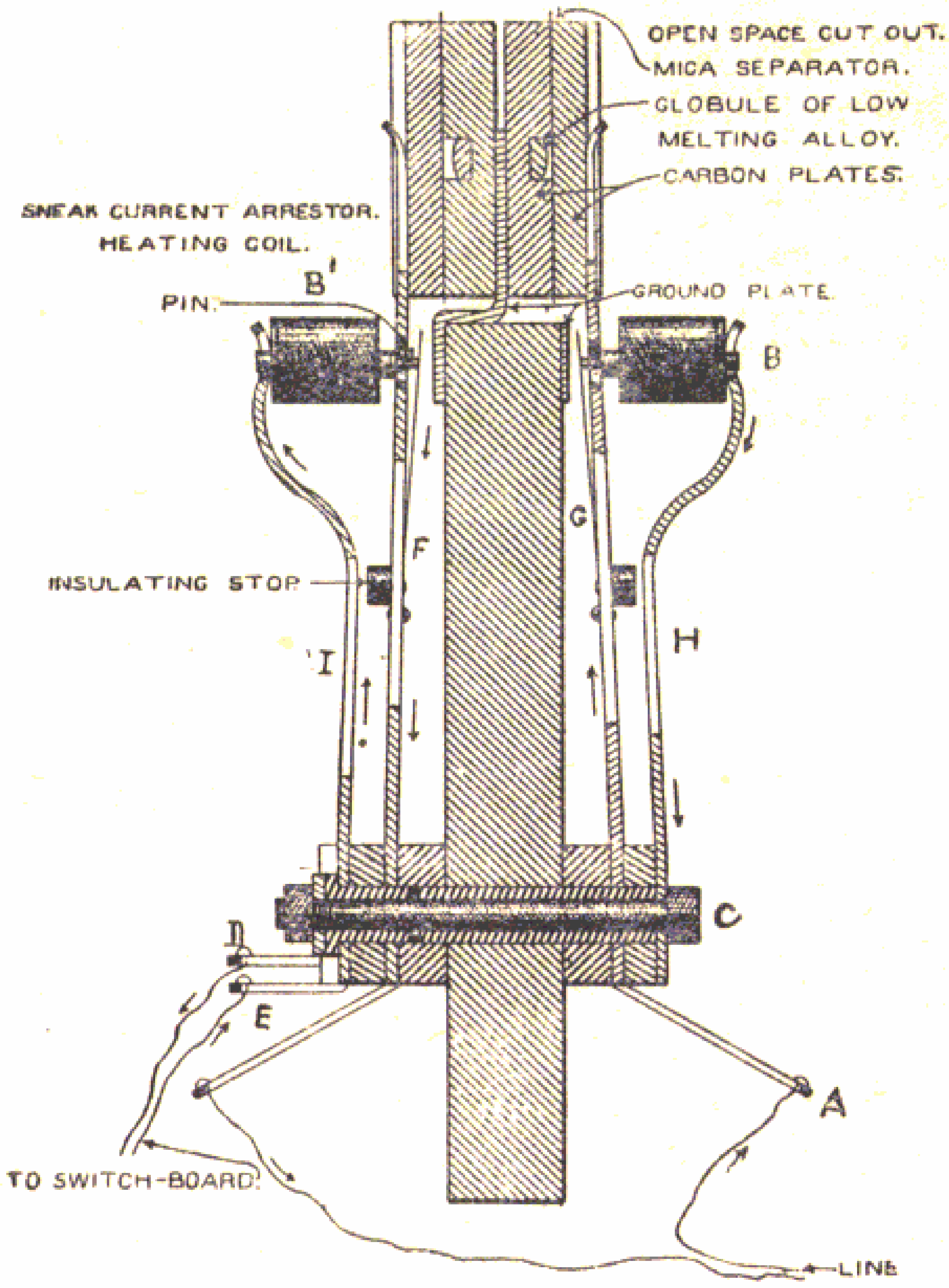


Fig. 14.—American Bell Distributing Board Protector.

run to the cable conductors. From this arrangement the cable side is usually called the horizontal side and the switchboard side the vertical run.

The method of calculating a distributing board is as follows: Assume a 4000-line board required: on account of dust it is inexpedient to set arresters nearer than a foot from the floor; without a step ladder a man cannot work on an arrester over 6 feet from the floor. Hence the available vertical space is 5 feet. If arresters are set one half inch centers there will be 120 pairs on a vertical; the number of verticals will be $\frac{4000}{120}$, say 34 strips, to which must be added an allowance for private lines, trunk lines call wires, etc., requiring from 40 to 45 strips for the entire frame. With verticals at 8 inch centers, the frame would be from 27 feet to 30 feet in length. As the frame is 6 feet high there will be room for eight horizontal strips on 9 inch centers each say 30 feet long or 240 feet of run. As there are no arresters less space is required, three eighths inch centers being ample; thus the horizontal runs give space for 7600 pairs. Usually the cable wire is about 30 per cent in excess of the switchboard, so space for say 5500 lines must be equipped, which will need about 6 runs placed in the center of the board. The clips for the horizontal or street cable side are simple. One form has been shown in Fig. 13. A base block of maple is provided long enough to carry twenty pairs. On this a strip of hard rubber is fastened, and the terminals proper, consisting of pins or narrow strips of metal with a slot or groove in each end, are driven through the rubber. To the ends of the metal connector thus provided, the cable wire and corresponding jumper is attached, by thrusting the wire into the slot and touching it with a hot soldering iron.

The original form of the distributing-board protector, devised by the American Bell, is shown in Fig. 14. One side of the line enters by spring A, traverses this spring to the heat coil B, thence through the heat coil in the

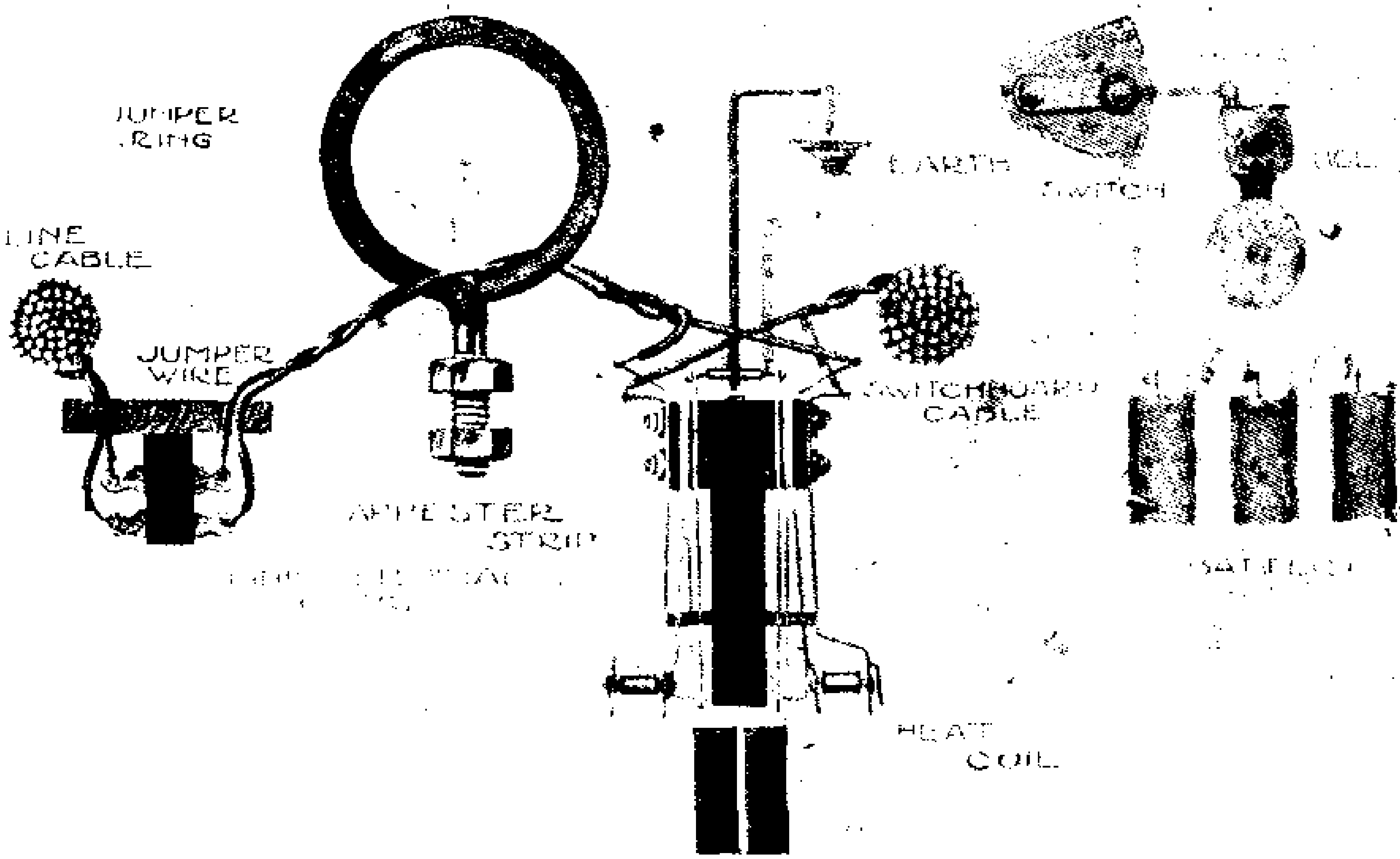


Fig. 15.—Circuit of Distributing Board.

direction of the arrows to spring H and bolt C, through the bolt to terminal D and thence to the switchboard. The return wire enters the switchboard terminal E, passes in the direction of the arrow to heat coil B', thence to line spring F. It will be seen that the springs F and G bear upon carbon plates that form an open space cut-out. Each heat coil contains a small pin which bears upon a thin spring that is attached underneath the main springs *F* and *G*. In case of an abnormal current the solder which holds this pin is melted by the heat developed inside the coil. The springs *H* and *I* then force the pin inwards, and ground it upon the iron-work.

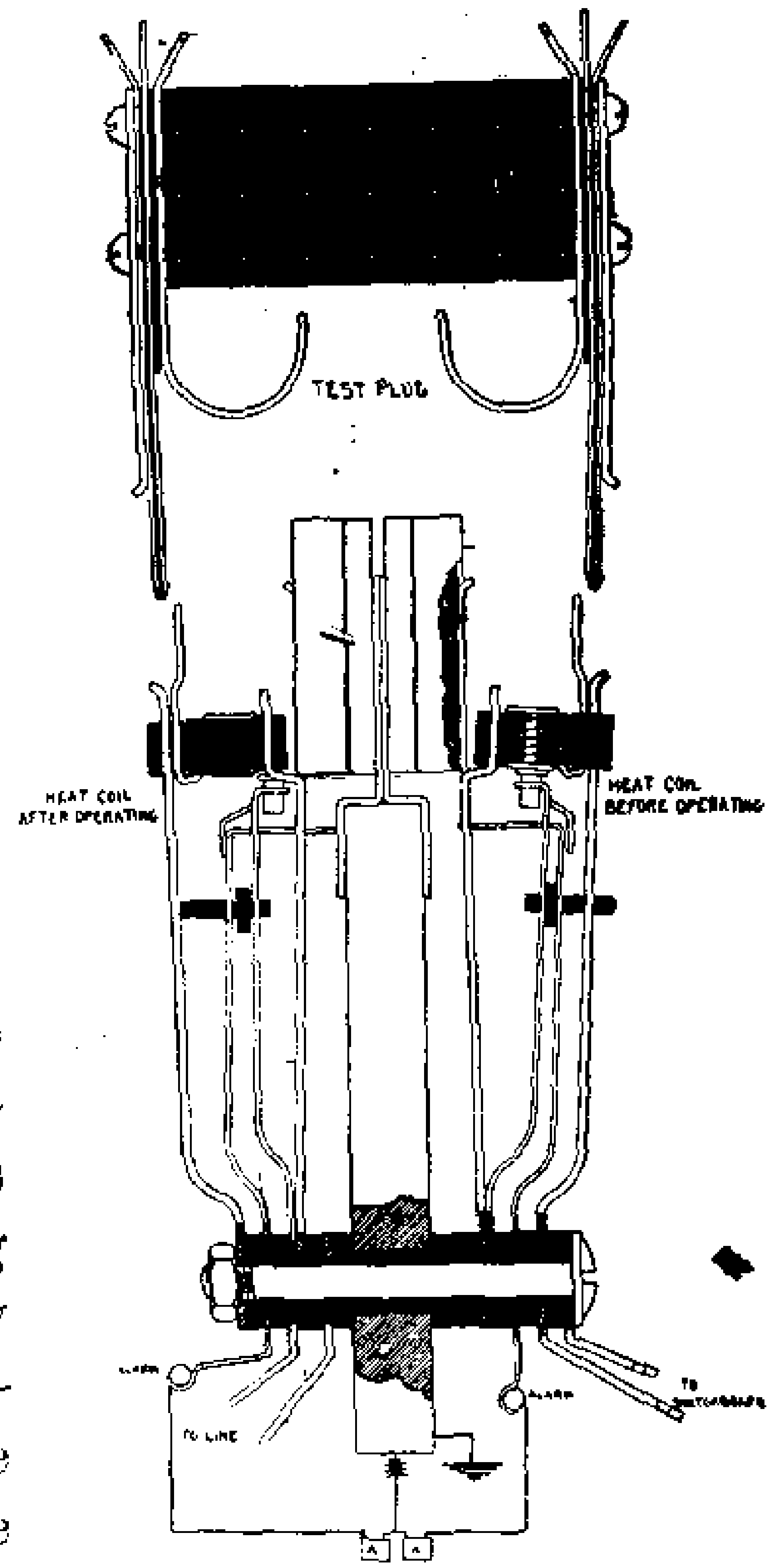


Fig. 16.—One Form of Cooke Protector.

For common battery installations it is necessary to ground the outside line, and to open the switchboard side, or otherwise the grounding of the common battery may produce disastrous results, and in order to avoid prolonged injury to the service it is desirable that an alarm should be given whenever a protective device operates. This is accomplished by placing an alarm bell and battery in circuit with all protective devices and the ground. When any one fails the bell rings. The complete circuit of the distributing-board is shown in Fig. 15. Other designs differ chiefly in the arrangement of the heat coil and the ease with which the subscriber's line may be tested. The Sterling heat coil consists of an insulating case that carries two slotted heads. Inside the case there is a coil of resistance wire, which surrounds a metallic tube. The head has a pin which extends inside of this tube and is soldered there by fusible metal. When the heat coil operates, the head is pulled away from the rest of the heat coil. In the Rolfe protector, the heat coil is replaced by the automatic self-repairing cartridge, described in Vol. V, p. 384. In the Cooke protector, Fig. 16, the heat coil is inserted in a small carbon block placed between the line springs. In

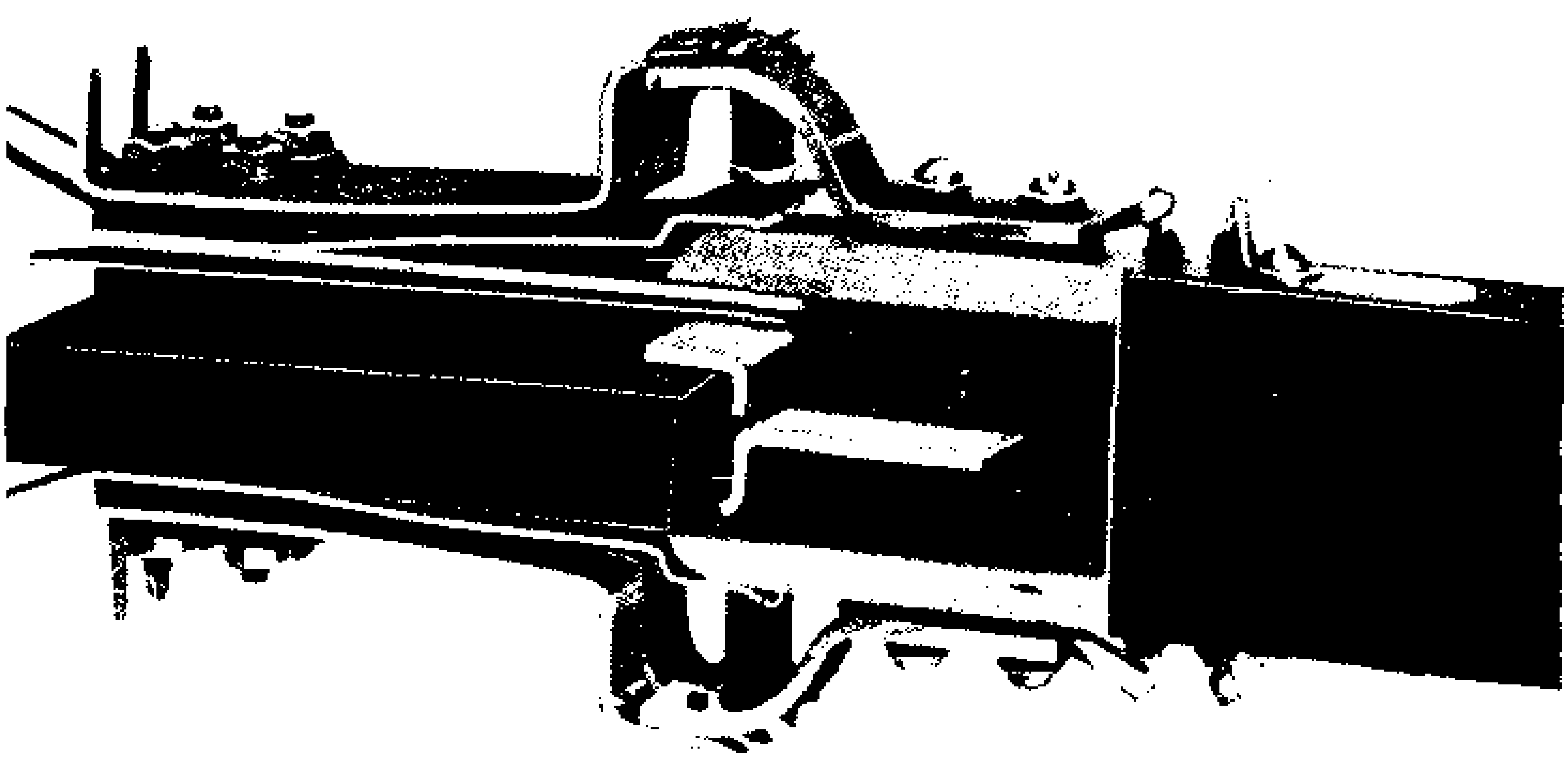


Fig. 17 --Kellogg Test Plug.

the center of this block there is a metal stud which carries a resistance coil and to which a copper rivet is soldered. The carbon and the contained heat coil are warmed by the passage of an abnormal current and this unsolders the metal pin. Both the Rolfe and the Cooke protectors are improvements, as they render repairs easy. In the older forms of heat coils this was a difficult matter, requiring an expert mechanic and special tools. All modern protectors afford great facility in making tests at the distributing board. In each case a peculiarly formed test block is supplied which may be quickly inserted between the line springs, and when in place extends each side of the subscriber's line through a flexible cord to any form of test apparatus that the wire chief may desire to employ. Fig. 17 shows the Kellogg protector with the test plug in place.

The distributing boards so far described are usually called *main distributing boards* because they are used

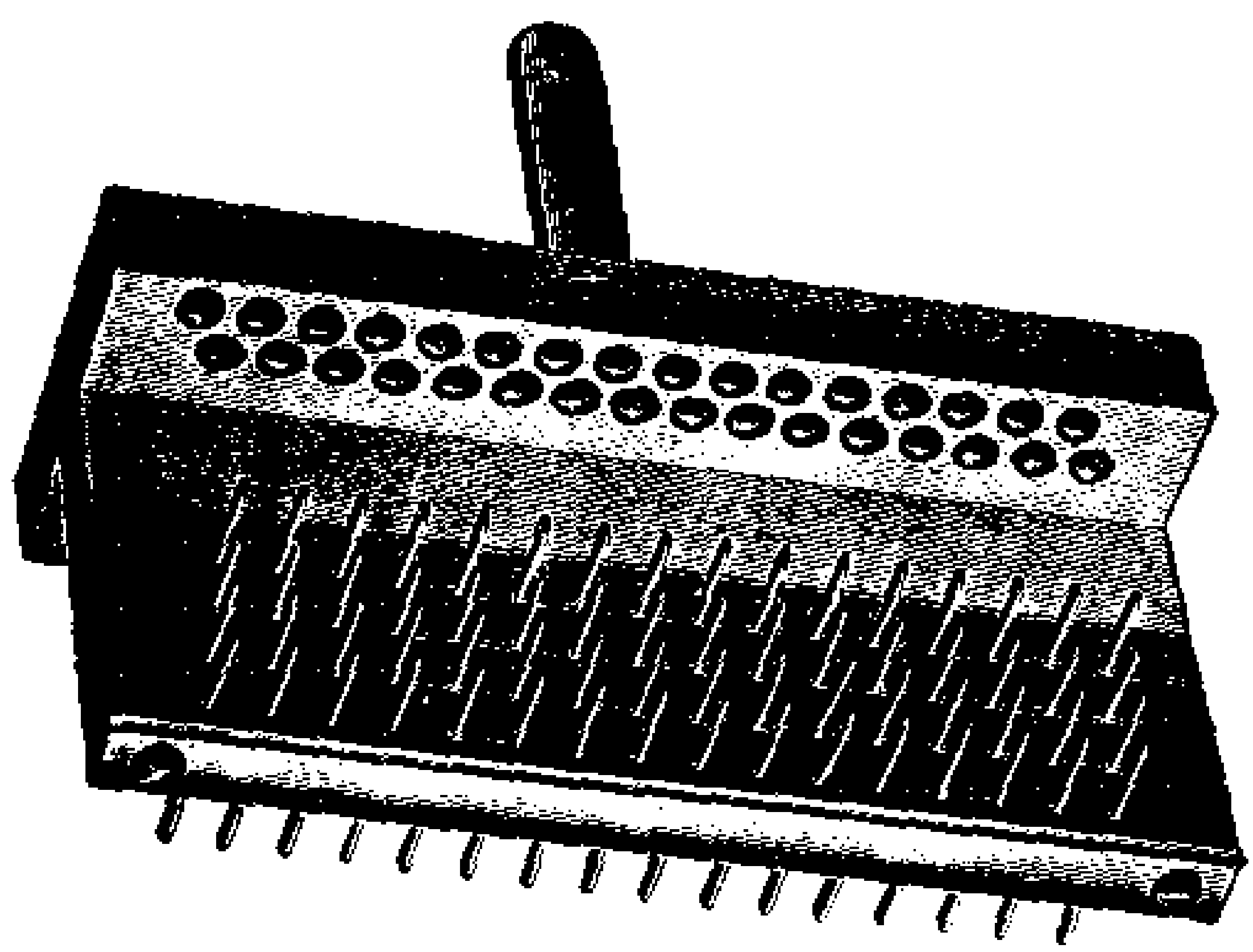


Fig. 18.—Terminal Block with Four Banks of Clips.

to enable a rearrangement between *all* the cable plant and *all* the switchboard. But in the case of multiple switchboards, any set of multiple jacks could be associated with any line signal and answering jack, and cases might arise where it would become advisable to quickly change the mutual relations of the multiple and answering jack. Hence it is customary to carry the switchboard cables from the protected side of the main distributing board to the horizontal side of the second distributing board, called the *intermediate distributing board.* The answering jacks are connected to cables which run through the horizontal side of this latter board, while the multiple jacks are carried to the vertical side. Then by means of jumpers any multiple jack can be connected to any answering jack. In many of the modern switchboards more than two wires are needed for each circuit, hence the distributing-board terminal becomes correspondingly complex. Fig. 18 indicates a method of building terminals of any desired capacity.

One of the important, oftentimes least understood, and seldom employed functions of the distributing board, is the opportunity that it offers to easily rearrange and adjust the load of the various operators. Suppose a new office to be opened and a hundred lines placed before each operator. There is only means of making the roughest kind of a guess as to the amount of traffic each line will originate.

Operator "A" may get 2000 messages a day and operator "B" 1000, "A" will be overloaded or "B" underloaded; nothing is more destructive of good service. After a short experience subscribers can be classified as to the quantity of business they originate, and then by the change of a few jumpers, the lines reapportioned among the operators in such a manner as to give each approximately 1500 messages per day, and this without any change either in apparatus or numbering; in fact no one but the wire chief and the traffic manager need be aware that a change has occurred. Unfortunately, adjustment of the load line is a factor in operating to which but scant attention is paid, for astonishing as it may seem, some large boards are installed without an intermediate board.

CHAPTER III.

CIRCUITS, SWITCHBOARDS, AND APPARATUS FOR SMALL EXCHANGES.

THE object of a telephone switchboard is to link subscribers together in talking relations, and the concatination of cables and apparatus with which this is performed is called a circuit. To depict every circuit that has appeared, flourished for a time, and vanished, would be an endless task. But all circuits may be sorted into certain general classes, and the generic features of each division exhibited sufficiently to familiarize the reader with the general principles upon which they are based, and thus enable him to quickly appreciate the workings of its various congeners.

Circuit classification is of necessity partly functional, depending upon the nature of the work to be performed, and partly manufactural, depending upon the kind of apparatus and method selected to do that work; for each of the prominent manufacturers, in the development of his product, has followed lines more or less peculiar to himself and has hewed out a certain more or less definite path in an endeavor to specialize and differentiate from his various competitors. Many viewpoints could be taken in preparing a circuit classification, but for the present purpose the following arrangement, shown in Fig. 19, has been selected as lending itself to a presentation of the salient features of the various groups.

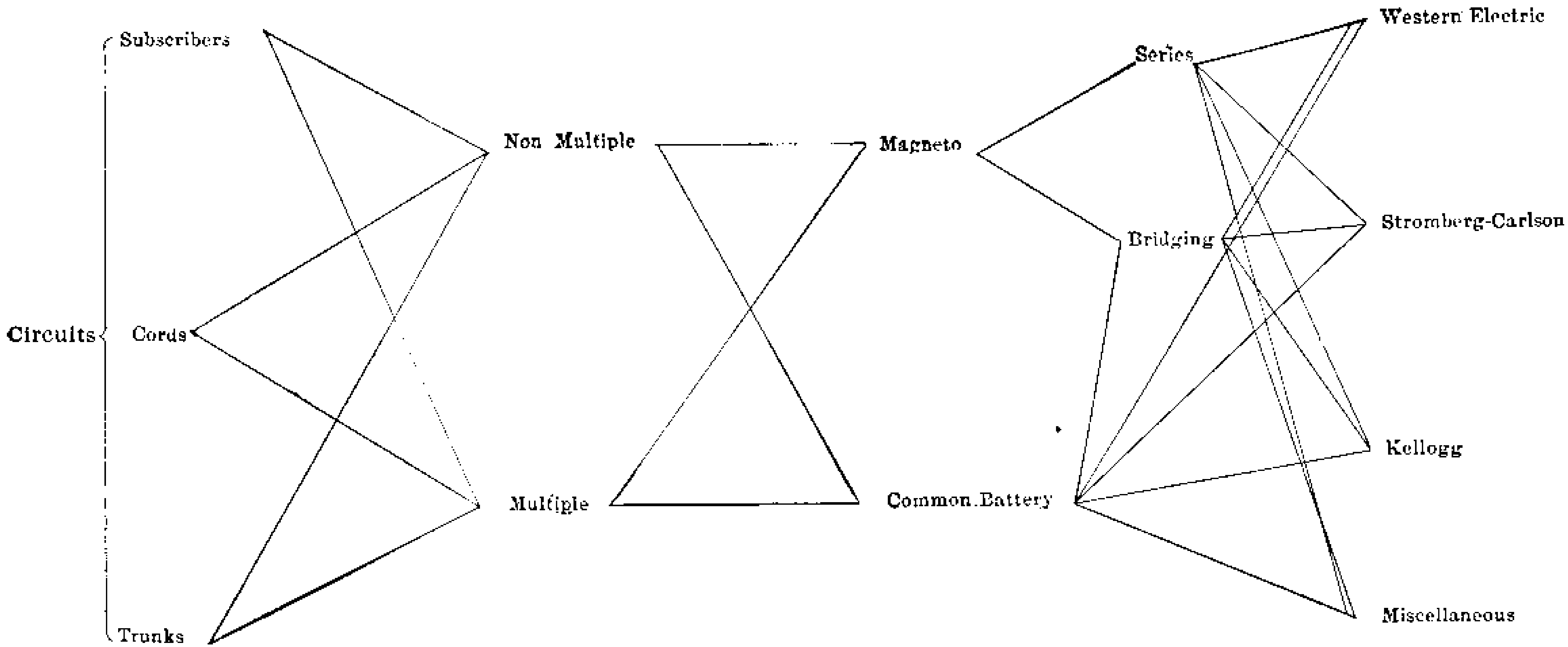


Fig. 19.—Circuit Classification.

The subscriber's circuit is that which connects the substation with the switchboard, and must in the switchboard contain means whereby the subscriber can signal the operator. The cord circuit enables the operator to connect together the lines of any pair of subscribers which appear within her reach. This circuit must contain means whereby the operator can take the calling subscriber's order, can ascertain whether the desired line is disengaged, can signal the called subscriber, and at the end of the conversation receive notification that the parties desire to be disconnected.

The trunk circuit enables an operator to connect any subscriber whose line appears within her reach, with some subscriber that does not so appear, but is within the range of some other operator. To all intents the trunk circuit is merely a means whereby the cord circuit of one operator can from time to time be temporarily extended to a distant point, because its essential requirements are the same as those of the cord; but as the trunk circuit enables two operators to coöperate in connecting a pair of subscribers, its apparatus must be so modified as to enable both to work in unison.

In the following discussion of switchboards and their circuits, little mention is made of grounded lines, partly because the objections to the grounded line are so numerous, so forcible, and so well recognized, that it has largely disappeared from exchanges of magnitude, its use being restricted to rural districts that are relatively unimportant, and partly because it is now customary, even in the smaller switchboards, to design the apparatus and wiring to be completely metallic, at least as far as the distributing board, then where grounded lines are used, a ground is placed upon one terminal at this point. This practice is growing more and more into vogue, because circumstances are constantly arising where it is desirable to change a previously grounded line into a metallic one. If the switchboard is wired metallic, the change is an easy one, while the additional first cost of making the switchboard metallic is small. Hence from the viewpoint of the switchboard, it may be assumed with reasonable accuracy that grounded lines play too insignificant a role to require detailed consideration.

These broad fundamental principles pave the way for more detailed analysis, and in the various following illustrations it must be remembered that each is merely typical of a large class, the various members of which vary more or less in detail, though the general fundamental arrangement of every class is the same as that of the example selected. For the sake of simplicity, it is convenient to commence with what may be termed switchboards for small exchanges, namely, those in which one or two operators are able to handle all the business.

The first telephone exchange is said to have been started in Boston in 1877. It is reported that some burglar-alarm wires were used for lines that were equipped with vibrating bells and signals. An ingenious attendant hung a pith ball outside each bell and when the subscriber rang, the vibration of the gong caused the ball to swing, thus denoting the one which had signaled; then the operator walked to the calling line, wrote upon a piece of paper the message which the subscriber wished to transmit, and proceeding to the line of the desired party, delivered the message "viva voce." The next obvious step was the provision of facilities whereby any pair of subscribers could be connected by a flexible conductor and could talk together so long as they might see fit. Hence a clearing-out signal in the cord was required. Such a circuit contains all the elements that are now employed in small exchanges. There has been a vast amount of labor spent upon refining and perfecting the details of apparatus, and now even the smallest of switchboards are equipped with apparatus which is so carefully and skilfully designed

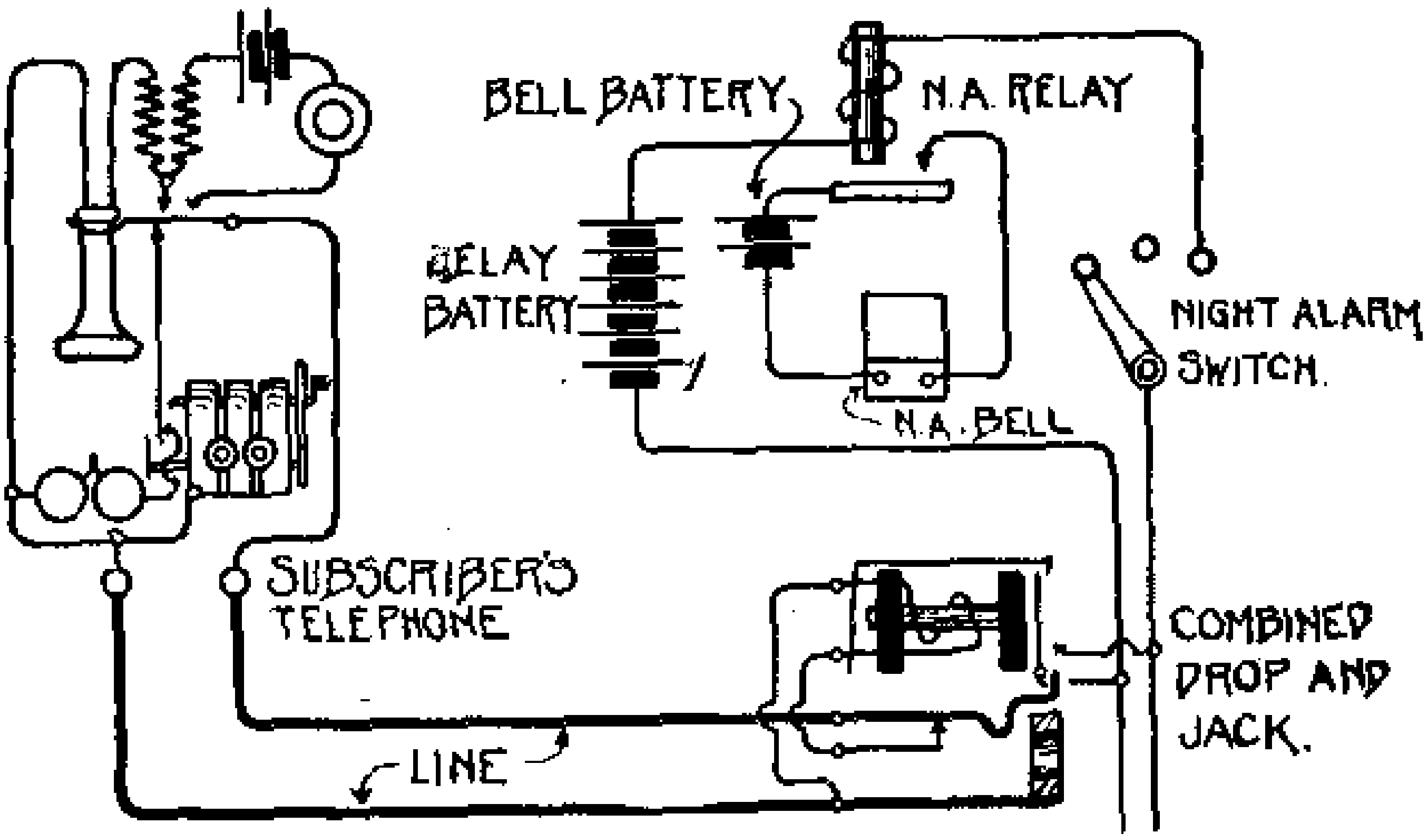


Fig. 20.—Simple Subscriber's Circuit.

and manufactured that it has become almost self-maintaining.

A common and successful form of subscriber's circuit is shown in Fig. 20. The substation has a local battery transmitter, induction coil, receiver, hook switch, magneto bell, and ringing generator grouped in the familiar manner. From the terminals the lines proceed to the office and terminate in a switching contrivance known as a jack, shown in detail in Fig. 21. Jacks of this description consist of a metal base upon which two flexible springs insulated therefrom are supported. One terminal of the line is attached as in Fig. 20, to the base, while the other is carried to one of the springs. From the base a conductor runs to the annunciator or signal, while the other terminal of the signal is carried to the second spring in the jack. The relation of the springs is such that when a plug of proper design is pushed into the hole in the base, the line spring is lifted away from the spring to which the annun-

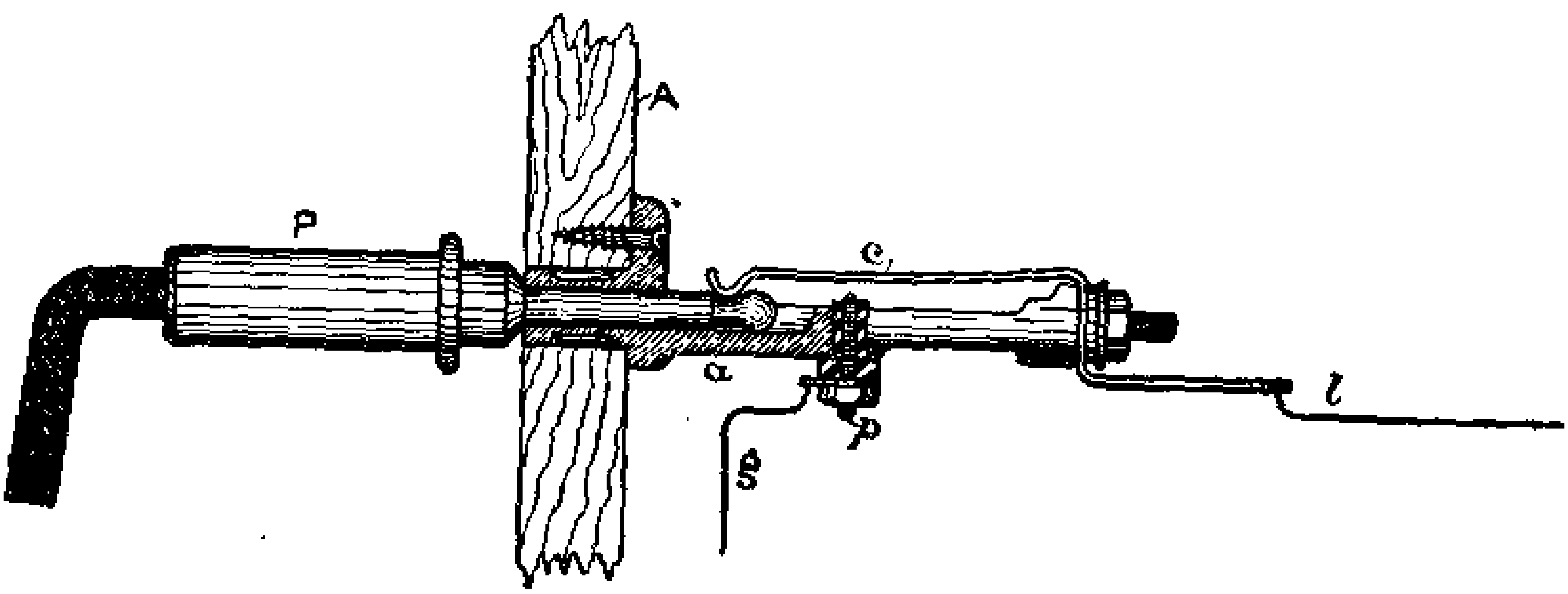


Fig. 21.—Jack.

ciator is attached, thus opening the circuit of the annunciator. The calling signal consists of an electro magnet, as shown in Fig. 22. Usually the armature is swung upon trunions attached to the rear. From the armature a lever extends to the front, having a catch at its extremity that latches a shutter. When the electro magnet is excited the armature is attracted, and raising the lever allows the shutter to fall, disclosing a disk upon which the number of the calling subscriber is painted. In small exchanges there is so little business during the night that it is inexpedient to keep an attendant at the switchboard, but notification must be given whenever a call does arrive, so it is customary to provide what is termed a night bell. This is diagrammatically illustrated in Fig. 20, whence it appears that when the shutter of the drop falls it touches a contact connected to a circuit containing a local battery, a vibrating bell, and a switch. When the switch is closed the falling shutter sounds an alarm. During the day the switch may be opened and the bell thrown out of commission.

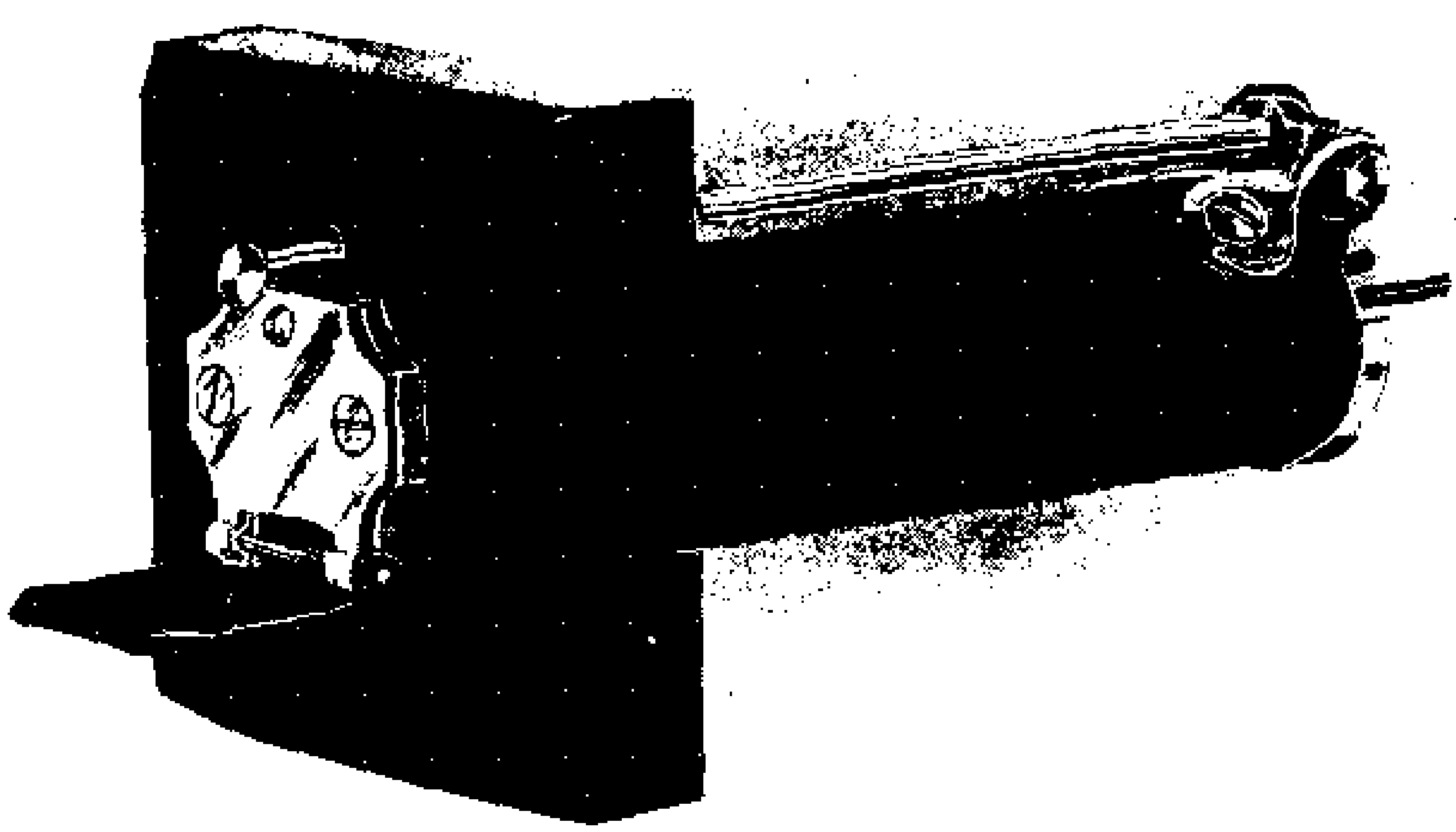


Fig. 22.—Drop.

Depending on the service, drops are wound for from 50 to 1000 ohms.

The falling of the drop shutter notifies the operator that a calling subscriber desires to be connected with some one else. For this purpose the cord circuit is used, *i.e.*, a flexible conductor so arranged that it may be temporarily attached to any pair of jacks, and provided with apparatus whereby the operator may temporarily connect herself to the calling subscriber's line to receive his order, and may signal the one to be called. A typical cord circuit is diagrammatically shown in Fig. 23. There is a long, flexible conductor, terminating in two metallic plugs, which fit the jacks. Three switches are provided, shown at *A*, *B*, and *C*. The switches at *A* and *C* enable the operator to connect a source of signaling current to the jack of either subscriber. Switch *B* enables the operator to connect her local circuit with the cord circuit. The local circuit consists of a transmitter *T*, local battery *S*, induction coil *I C*, and receiver *R*. Lastly the cord circuit must be provided with a signal to notify the operator when the subscribers have completed their conversation. This is a clearing-out

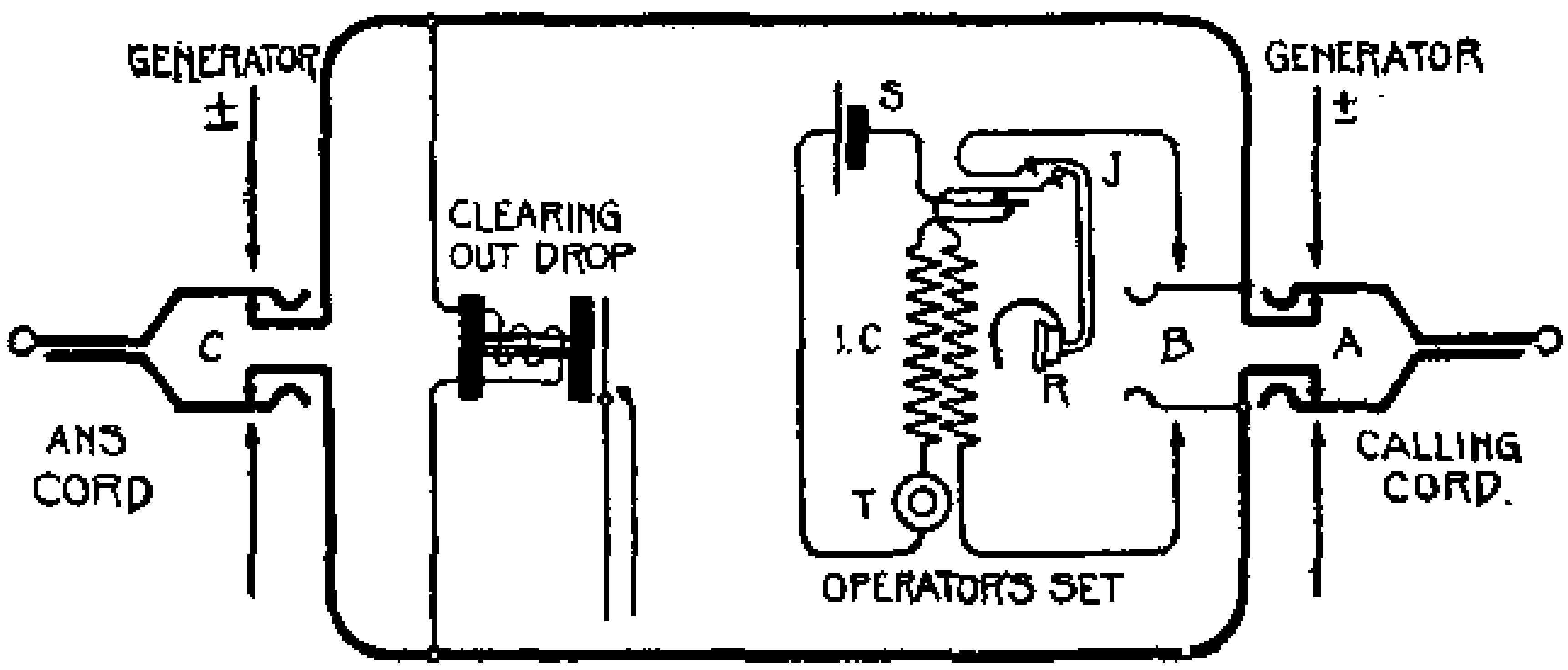


Fig. 23.—Cord Circuit.

drop, similar in general construction to the calling signal, except that it is usually bridged across the line and has resistance of from 500 to 2000 ohms, thus its presence does not appreciably shunt the voice currents, and yet it is sufficiently sensitive to enable subscribers to ring off by turning the handles of their magnetos.

The plug is an important piece of apparatus, a common form is shown in section in Fig. 24. The plug consists of a metallic spindle having a more or less spherical head, shaped to fit the springs of the jack into which it is intended to work. This spindle is inclosed in an insulating case of rubber, and thrust inside of a metal shell that forms a convenient handle. The spindle is connected with one of the conductors in the cord, while the shell is joined to the other, as is shown in the illustrations; hence when the plug is placed in a jack, one of the cord conductors is

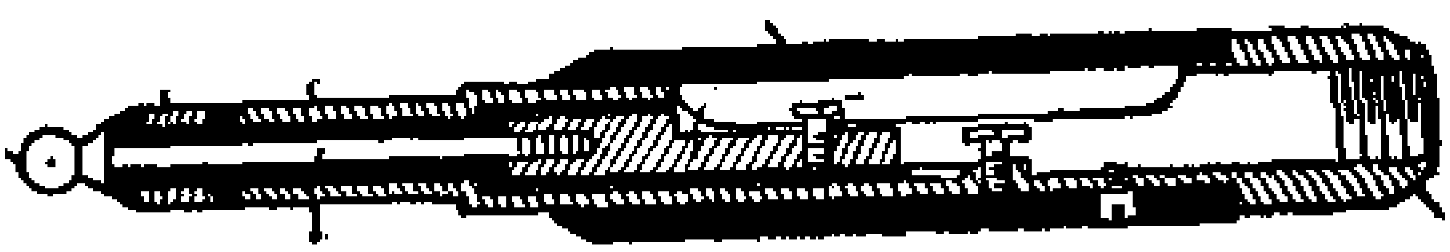


Fig. 24.—Plug.

connected to the jack spring, and the other to the jack base.

At first thought the switchboard cord seems to be a simple bit of apparatus, but a completely satisfactory cord

Fig. 25.—Cord.

has never yet been devised. Cords are in constant use, are pulled about by the operator from one jack to the other; they are carelessly handled and are constantly bent

Fig. 26.—Connection of Cord and Plug.

and twisted in the most severe manner. The operator's hands are more or less damp, and difficulty is experienced from the short-circuiting of the conductors. A typical form of cord is shown in Fig. 25. The center is a strand of linen lock-stitch twine, mixed with three fine tinsel wire strands, then comes the true inner conductor, made of spiral steel wire.

This is insulated by a braiding of silk, then a linen braid, then a loose tinsel braid upon which the outer conductor of round spiral steel is placed, covered first by a cotton, and then by a linen braid. At each end, the cord is reinforced for about fourteen or fifteen inches by an

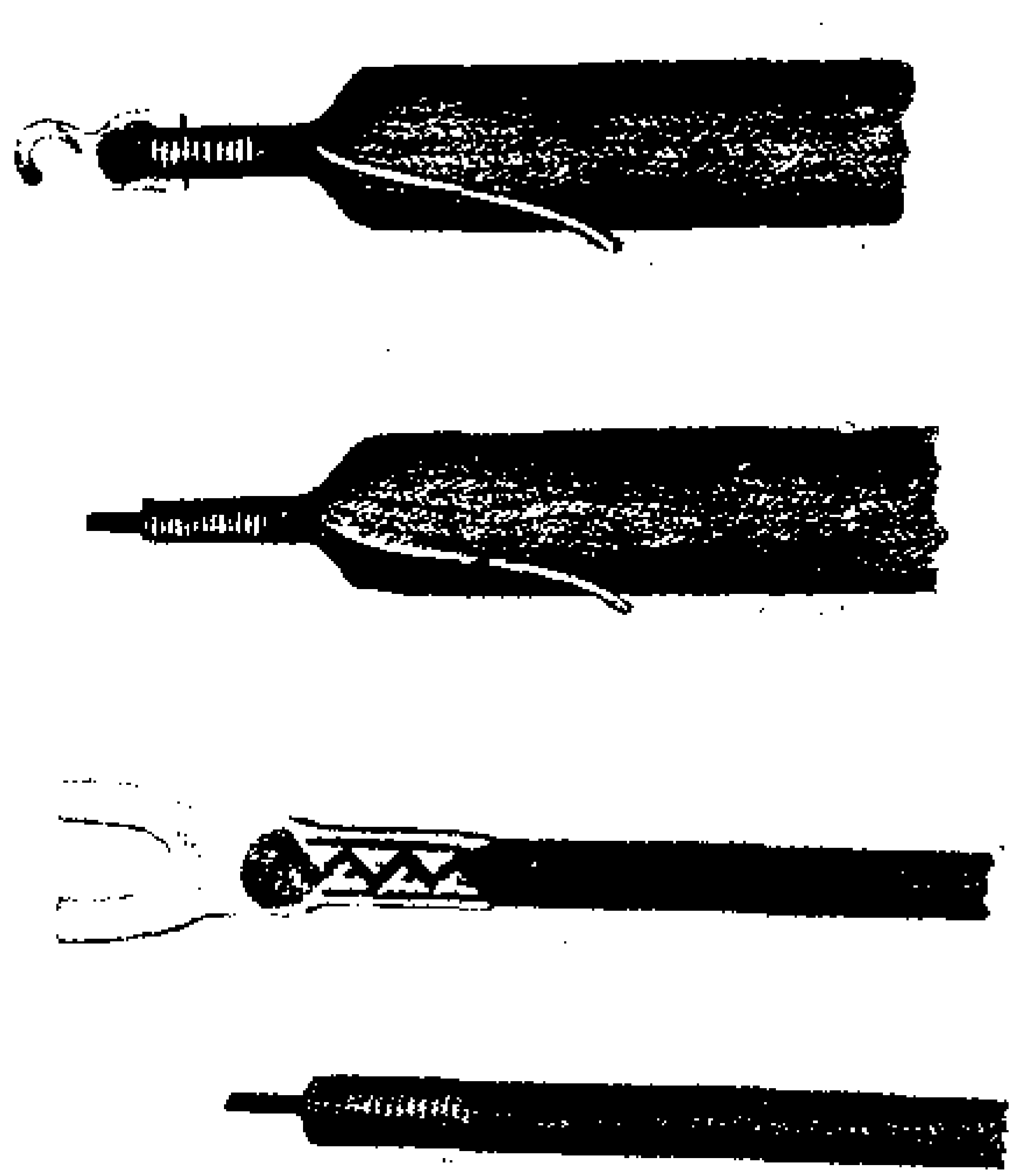


Fig. 27. — Cord Terminals.

additional braid of linen. The tinsel is used to decrease the resistance of the steel wire used for the conductors. Some manufacturers employ a bronze wire in place of the steel, but the most recent experience indicates that the latter is preferable.

To make a good electrical connection between the conductors in the cord and the terminals in the plug, is a difficult problem, on account of the small available space. Fig. 24 shows that the handle of the plug is hollowed out so that the cord may be inserted therein. Two screws are provided, one tapped into the plug handle, the other in the spindle. The handle of the plug is furnished with a screw thread into which the braid of the cord may be forced, and then the ends of the cord conductor are tucked under the respective screws and clamped into place, as is shown in Fig. 26.

The other end of the cord is whipped with braided twine in a substantial manner, allowing the central strand of linen twine to project outside of the whipping. Then punchings in the form of hooks or clips are soldered to the respective conductors and wrapped with linen twine to secure them firmly to the braiding, as is shown in Fig. 27. Inside of the framework, which forms the switchboard, a wooden bar is provided, termed a "rack" or a "running board." Upon this bar U-shaped punchings of metal are screwed. To one end of these punchings the cord terminals are secured, either by means of a screw or by a touch of solder, while to the other end the proper wires from the switchboard cabling are attached.

The switchboard framework is usually constructed with a broad shelf in which a number of holes are bored, slightly larger than the cord and slightly smaller than the handle of the plug. Underneath this shelf, the framework provides a receptacle of sufficient capacity to hold the cords, and thus whenever a cord is out of service it naturally drops of its own weight into such a position as to cause the plugs to rest uprightly, their bases standing upon the holes through which the cords run. To assist the cord in properly falling into place and to hold the plug upright, it is customary to provide a pulley weight which consists of a roller running upon the cord and loaded with a lead weight.

The diagram of the cord circuit, Fig. 23, shows the

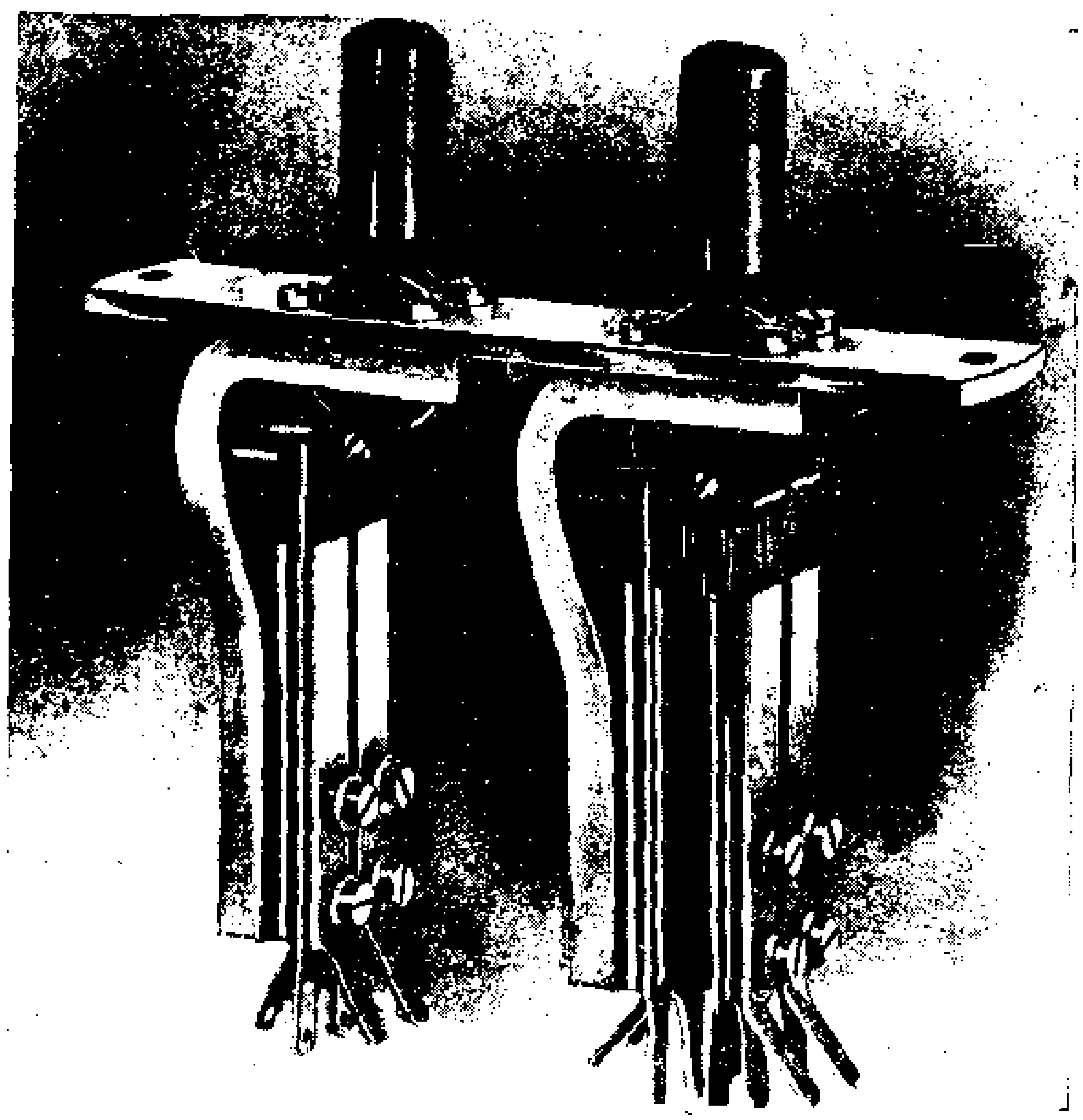


Fig. 28.—Ringing and Listening Key.

switching appliances which enable the operator to connect her telephone set and to signal the called subscriber. Such appliances are usually termed "keys," and typical designs are illustrated in Figs. 28, 29, and 30. Fig. 28 shows separate ringing and listening keys. There is a substantial escutcheon plate which may be affixed to the surface of the switchboard shelf. To this two brass L-shaped plates are riveted, one for the listening key and the other for the ringing key. The L-shaped projections carry sets of insulated flexible springs having terminals to which the cabling may be soldered. The terminals should be supplied with platinum points to secure good contacts. To the escutcheon plate a cam lever, usually provided with a rubber roller which actuates the springs, is attached. When the cam lever is moved, the roller impinges upon the end spring and breaking the contact which it normally completes makes another contact upon the other spring. As soon as the cam lever is released, the tension of the spring returns the lever to its normal position and closes the original circuit. In Fig. 28 the listening key is shown upon the left hand. The heavy wires of Fig. 23 are connected to the central springs, while the light lines indicating the circuit of the operator's telephone set, are connected to the other springs. The ringing key is arranged in a similar manner, excepting that the terminals of the ringing generator are carried to the springs instead of to the leads of the operator's set. When an operator wishes to take an order, she presses the handle of the listening key and is placed in talking relations with the calling subscriber. When she wishes to signal, she releases the handle of the listening key, her telephone set is automatically cut out, and then pressing the handle of the ringing key, she cuts off the calling subscriber and places ringing current upon the line to be called.

Fig. 29 shows a combined ringing and listening key. In this device the cam lever has motion in two directions instead of one. When the handle is pressed towards the right, the roller rides against a long spring in such a manner as to separate its normal contacts and causes it to complete another circuit with the extreme left-hand spring. This is the listening position, and the key will remain connecting the subscriber to the operator's telephone set until it is forcibly replaced to its normal position. If the handle be pushed toward the left, another circuit with the right-hand spring, to which the ringing generator is attached, is made. This spring is so arranged that the key will not remain set, and ringing current will only be applied so long as the operator holds the key in the ringing position. Fig. 30 shows two sets of keys, the lower one being a device for party-line ringing, while the upper one is an order-wire key. The left-hand portion of the lower part of the illustration will be readily recognized as similar to Fig. 29. In addition there are four other sets of keys controlled by push buttons. When the operator pushes the cam-lever handle to the right, she connects her telephone set as is indicated in Fig. 29; when she pushes the key in the other direction, the cord circuit may be connected through either one of the five ringing buttons to ringing current. Each of the buttons is arranged to transmit a particular kind of current. To signal, the

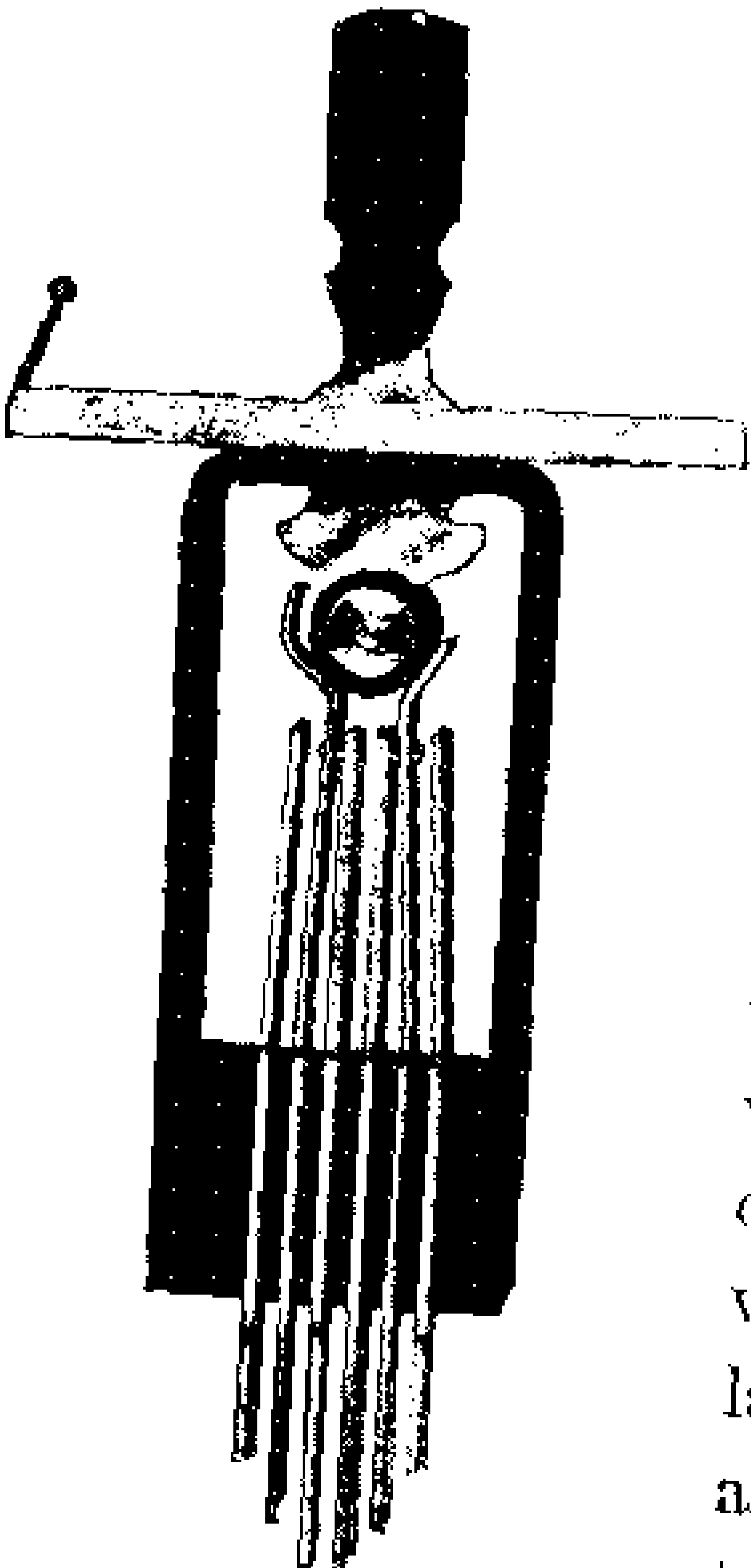


Fig. 29.—Combined Ringing and Listening Key

operator sets the master key at the left hand, and then presses the appropriate ringing button. The order-wire keys shown at the top of the illustration are simple sets

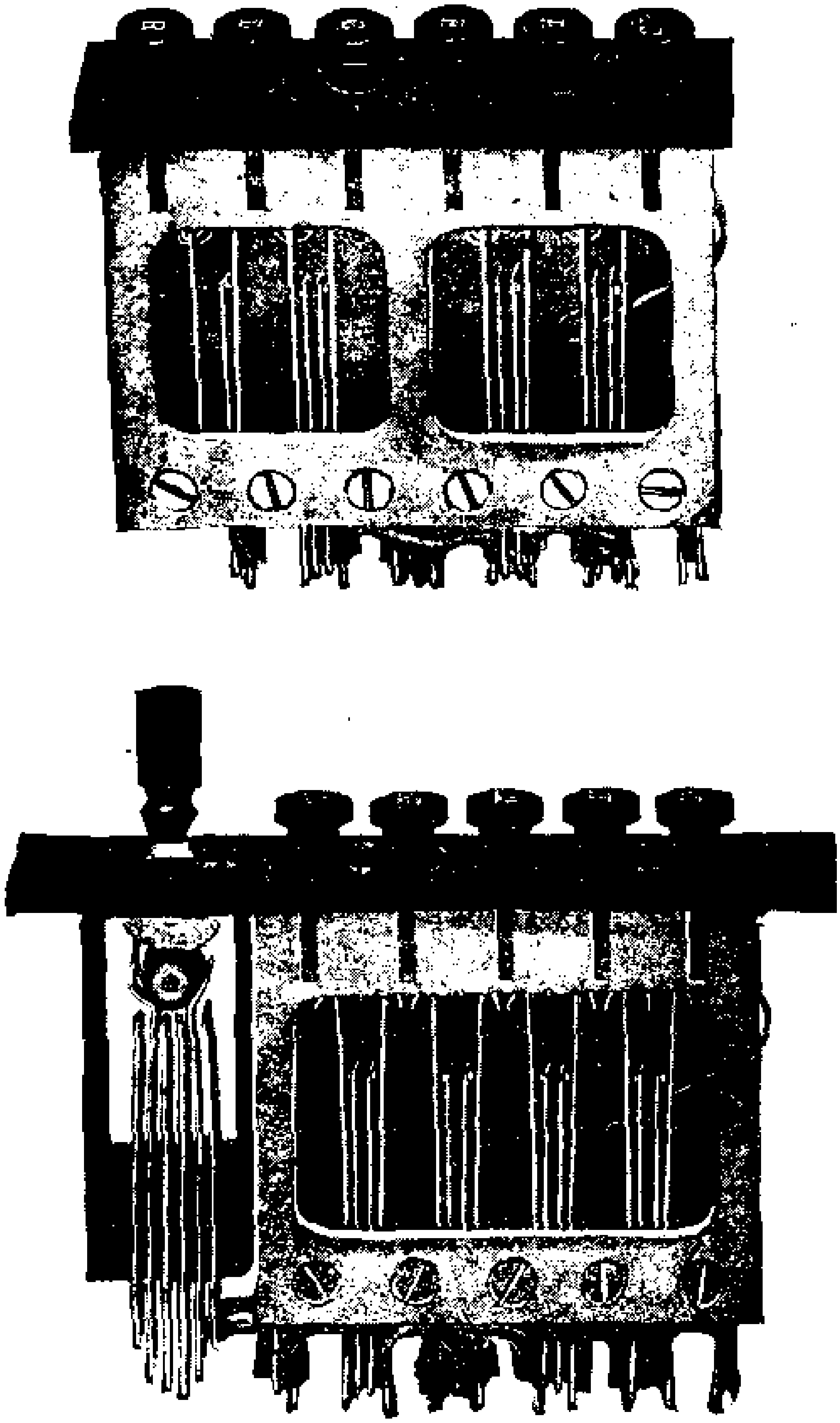


Fig. 30.—Party Line and Order Wire Keys.

of springs, each controlled by a push button whereby the operator may connect her telephone set with such circuits as are used for the transmission of exchange business.

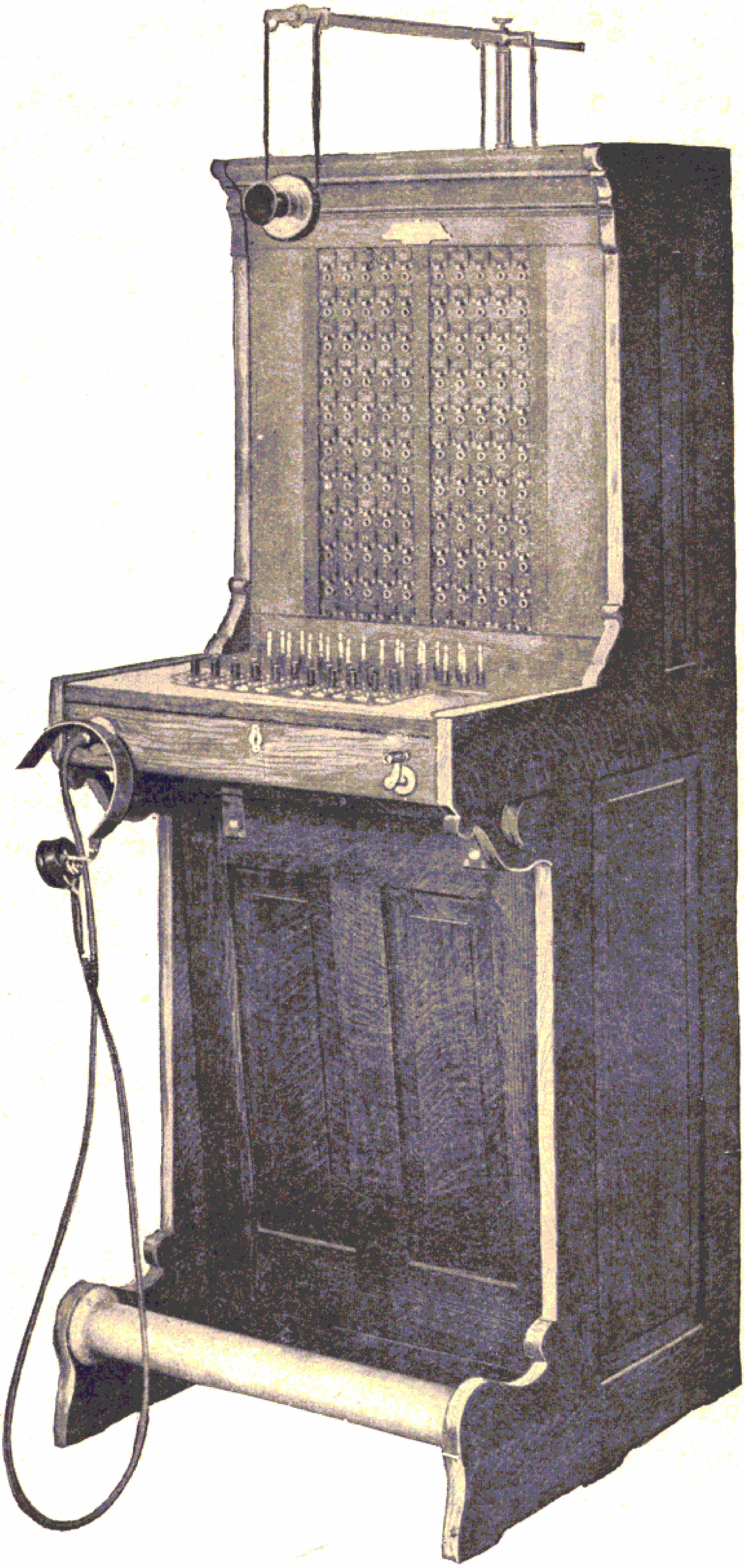


Fig. 31.—Front View of Small Switchboard.

The switchboard consists of the assemblage of the above apparatus in a manner to render it conveniently workable. The board usually consists of a framework of hard wood, solidly built, and resembling in general the illustrations of Figs. 31 and 32, which are respectively front and rear views of a small board. The essential features consist in an upright panel which is arranged to support the jacks and calling signals. Upon the top of this panel an adjustable arm is arranged, to which the operator's transmitter is fastened by flexible cords. Directly beneath the panel is a shelf, upon which the plugs are placed in pairs, the ringing and listening keys being in front. The cord shelf is arranged at a convenient height to enable the operator to sit easily at the switchboard, and reach all jacks and signals and manipulate the cords and keys. The base is usually finished with a rod or rail that forms a foot-rest for the operator. From Fig. 32, the general arrangement of the apparatus may be seen. The back of the board is fitted with doors as nearly dust proof as possible. The drops and jacks set on strips are secured to the woodwork, filling the panel. The switchboard cabling extends from forms attached to the drops and jacks to the side of the board, thence runs downward and into the cables seen in the foreground. Under the panel the running board or connecting rack is seen, to which the cord terminals are secured and from which the cords hang, held in position by the cord weights. On the left, the ringing generator is secured to the side of the switchboard, and directly beneath it is a shelf upon which the night bell, the operator's induction coil, and other miscellaneous apparatus is placed. Fig. 33 is a skeleton diagram showing the com-

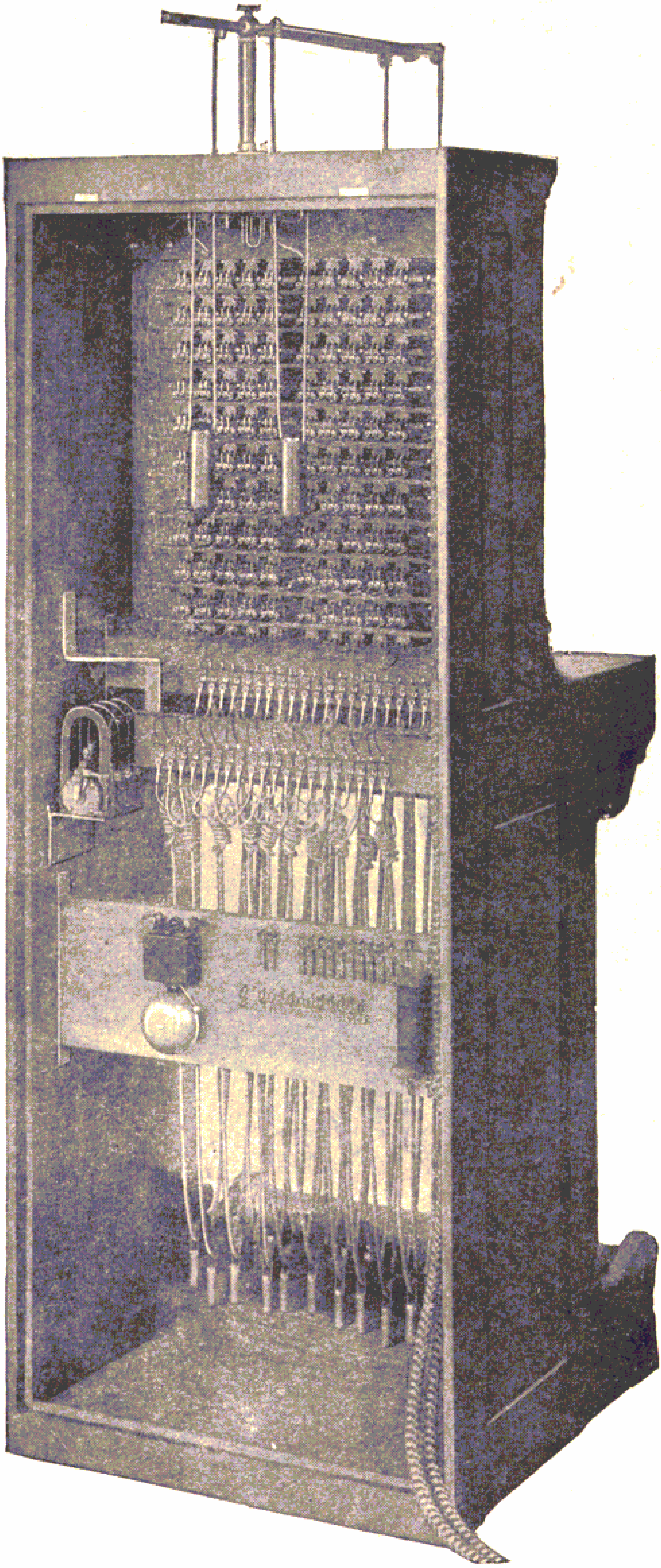


Fig. 32.—Rear View of Small Switchboard.

plete circuits of a small switchboard of about one hundred lines. Only one subscriber's line is shown and one cord circuit, but the wiring may be multiplied to any desired extent.

The board should be constructed of the soundest, strongest, and most carefully seasoned wood. All joints should be mortised and tenoned and should be secured by knee-irons and braces. To make the operator's work efficient all apparatus must be placed easily within reach. All sorts and forms of cord shelves have been tried, but modern practice now believes the horizontal key shelf is the most convenient.

Switchboard apparatus should be so arranged as to be permanent and substantial, and so planned that when cases of trouble do arise they may be easily and readily dealt with. Jacks illustrated in Fig. 21, are usually mounted by drilling a hole in a substantial strip of wood into which the jack is inserted and firmly fastened by the threaded cap. In case the jack fails, it is easy to unscrew the escutcheon and remove it. The drops are more likely to get out of order; as they occupy considerably more room, it is difficult to so mount them as to render repair easy. The arrangement commonly adopted is that of Fig. 36. An iron strip is provided of suitable length to extend across the panel, and to such strips the drops are bolted. Then the strip is fastened in its place by wood screws. In order to prevent cross talk all the drops should be iron-clad, that is, the winding is inclosed in a solid iron tube. The winding will depend entirely upon the nature of the circuit, for the drops may be bridged across the line, in which case they must be wound for a high resistance, 500

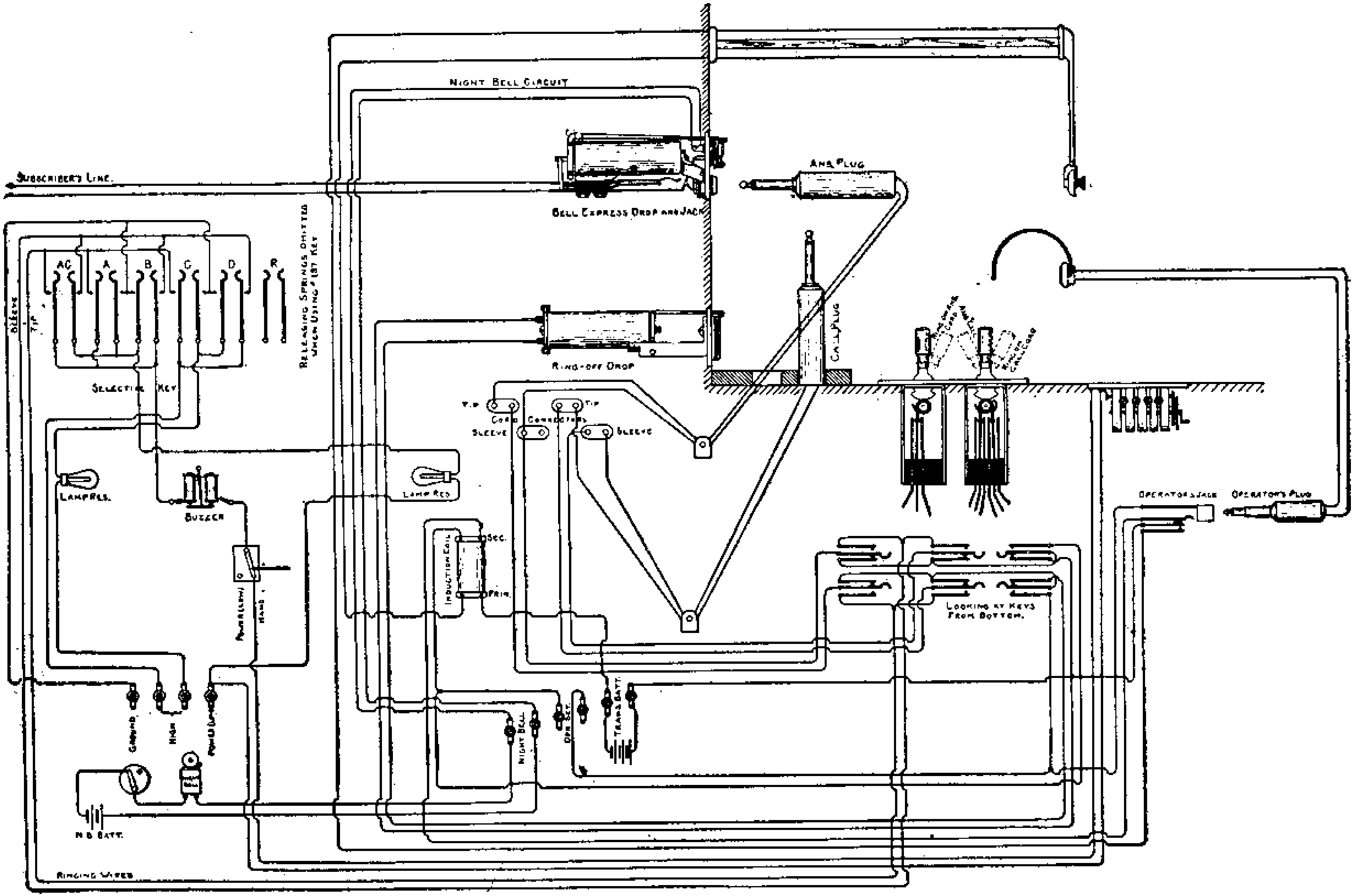


Fig. 33.—Complete Circuit of a Small Board.

to 2000 ohms, in order that they may not shunt the telephonic talking currents. Lower resistance drops may be used (50 to 100 ohms) when they are connected in series with the line and are automatically removed by the insertion of the plug. The armature trunions must be machined exactly in line, the armature carefully centered, the screws provided with lock nuts, the levers stiff and yet light, and the catches so arranged that they shall retain the shutter in position against all ordinary jars and yet be easily released when actuated by the ringing current.

Consider the work which the operator must perform to complete a connection:

1. Subscriber's drop shutter falls.
2. Operator lifts answering plug and inserts it in jack.
3. Operator presses listening key and takes subscriber's order.
4. Operator lifts connecting plug and inserts it in jack of calling subscriber.
5. Operator presses ringing key and signals called subscriber.
6. Operator restores shutter of calling subscriber's jack.
7. At termination of conversation, clearing-out drop falls.
8. Operator removes calling subscriber's plug.
9. Operator removes called subscriber's plug.
10. Operator restores shutter of clearing-out drop.

This list shows that the operator must make eight different motions, of which two, or 25 per cent, are required to restore the shutters of the signaling annunciators; much time and ingenuity has been expended in devising appli-

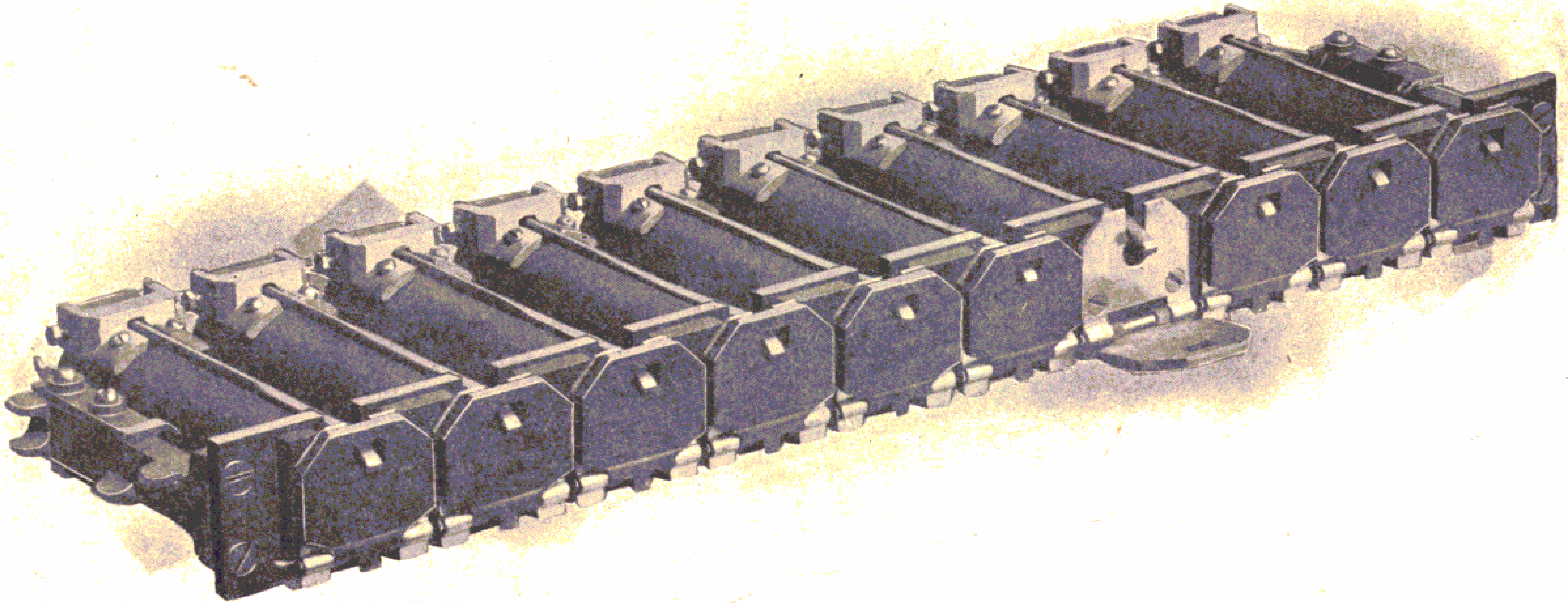


Fig. 36.—A Strip of Drops.

ances whereby this should be rendered automatic. Fig. 37 shows an arrangement in which both the drop and jack are mounted upon a single plate, so arranged as to form a unit. The subscriber's number is displayed upon the front of the shutter and disappears as soon as it falls. The jack is placed directly beneath, but the relation of the drop and jack may be more readily studied from Fig. 38, which shows three sectional views. The long spring *E* is arranged to protrude through the front of the plate *C*, having an upturned end *D* upon which rests the shutter after it has fallen. When the plug is inserted, the tip raises the spring *D* and automatically restores the shutter. Fig. 39 is a rear view that still further exemplifies construction. So long as the plug is in the jack, the shutter is locked and no false signals can be given. An extension of this principle can be applied to the clearing-out drop in such a manner that the return of the pair of cords to its normal position will restore the shutter.

This switchboard design is applicable to small exchanges of from 50 to 400 subscribers, where there is sufficient business to require the attention of from one to three operators. At present there is an enormous development of telephony throughout the rural districts of the country, where but few lines converge to a single point, in such a case a smaller and simpler switchboard suffices. Several types have been proposed, illustrated in Figs. 40 to 43 inclusive. Fig. 40 shows a board which is merely a development of the cabinet wall set. The magneto generator and battery are contained in the cabinet that forms the base; upon the upper part of the back board a dozen drops and jacks are mounted, to which the various sub-

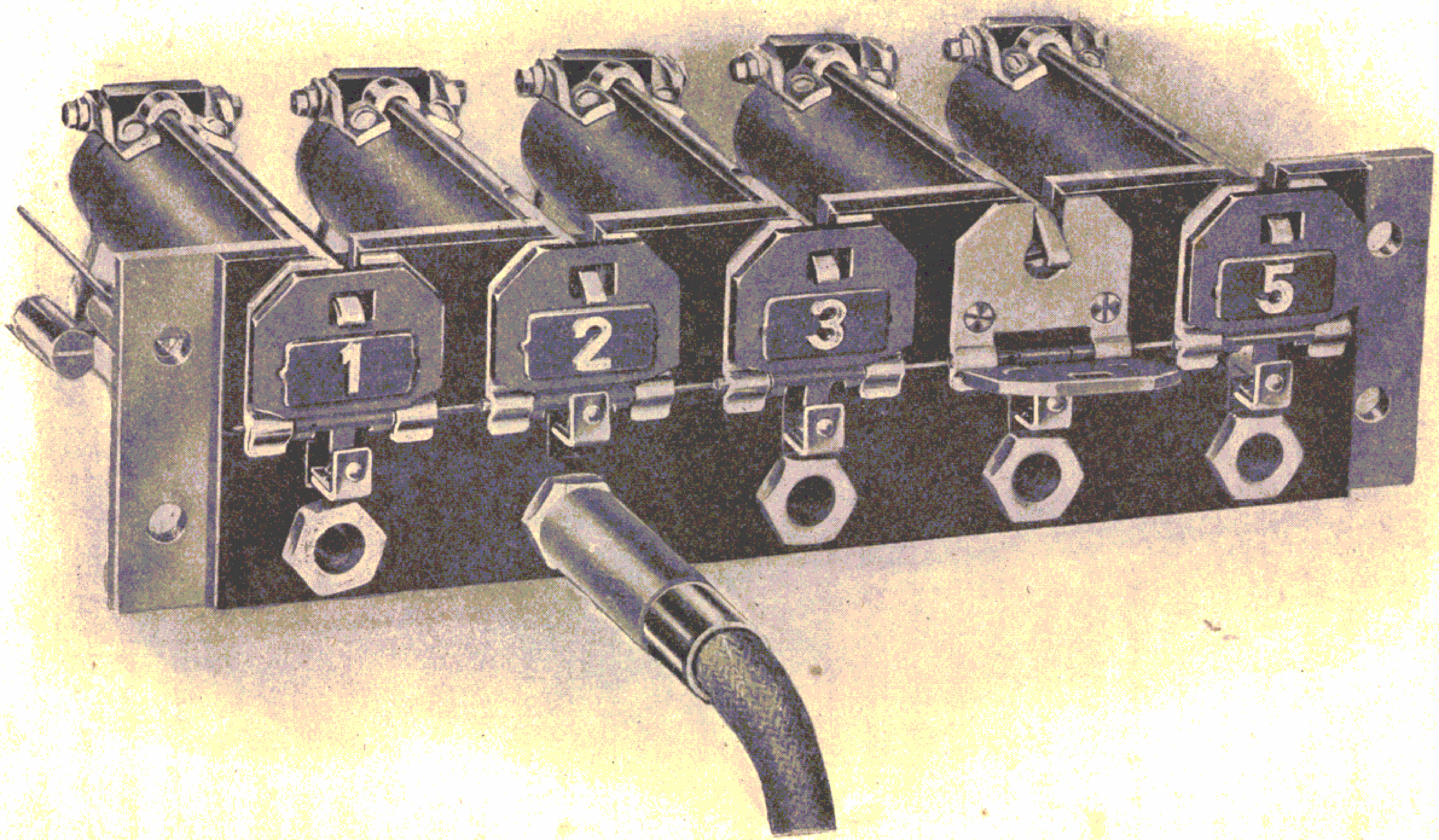


Fig. 37.—Bank of Combined Drops and Jacks.

scribers' lines converge and across which the signal bell is bridged. Boards of this kind are frequently found in the country store. The signal bell notifies the owner that a party is calling; he answers in the ordinary manner, and calls the subscribers by means of the single pair of cords standing on the shelf beneath the transmitter. Of course only two subscribers can hold conversation simultaneously, because only one pair of cords is supplied. In Fig. 41 this type of switchboard is further elaborated, several pairs of cords and plugs being supplied, so that more than two subscribers can converse simultaneously. In Figs. 42 and 43 a different form of calling apparatus is shown. A separate bell, jack, and cord is supplied for each subscriber, so the operation of completing a connection simply requires the operator to throw a key, take the subscriber's order, and insert the plug (always attached to the calling subscriber's line) into the jack of the one to be called. A few turns of the magneto generator rings the called subscriber. This form of signaling apparatus has become so popular as to deserve further the illustration of Fig. 44. Fig. 44 shows an enlarged view of the combined ringer and jack. The jack, which is built in much the same fashion as that shown in Fig. 38, is mounted directly below the ringer and secured to the same plate which sustains the gongs and magnets. The rod carrying the clapper extends through the ball. It carries a catch similar to that which holds the drop shutter, and the rod projects through a hinged shutter in such a manner that so long as the rod is quiet, the shutter is held in its normal vertical position. As soon as the subscriber rings, the vibration of the rod not only sounds the gong, but releases the shutter, and allowing it to fall indicates the line which has signaled. The insertion of the plug restores the shutter in the manner

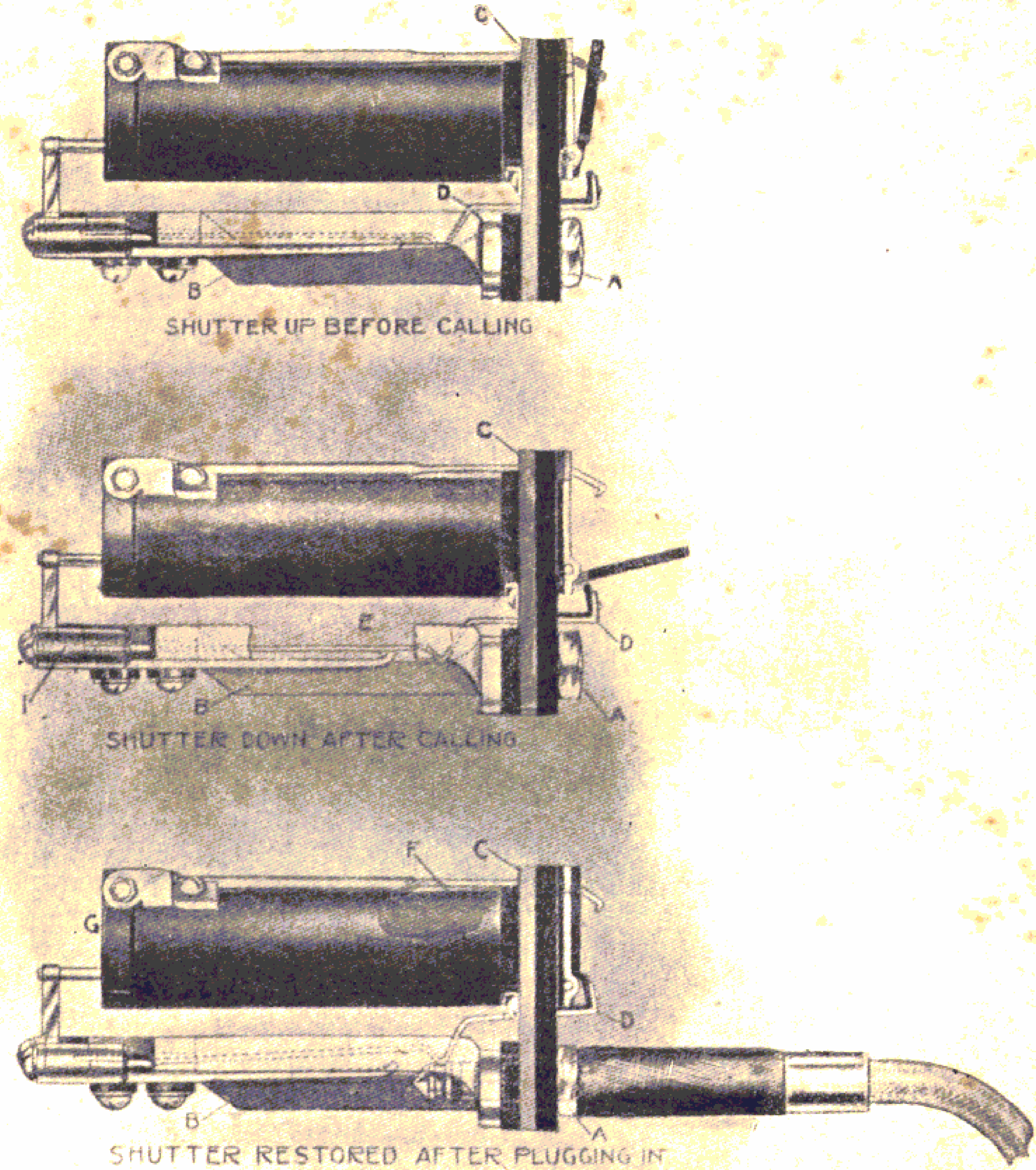


Fig. 38.—Sections of Mechanically Restoring Drop.

already described for the automatic drop, and when the shutter is replaced it locks the clapper.

So far no mention has been made of that most important piece of apparatus — the repeating coil. The repeating coil, at least in small switchboards, is chiefly used to render telephonic connections between dissimilar lines less noisy. A repeating coil is a transformer; it consists of an iron core upon which two coils of wire are wound, which are electrically entirely distinct, but magnetically connected. Electrical impulse traversing one coil will

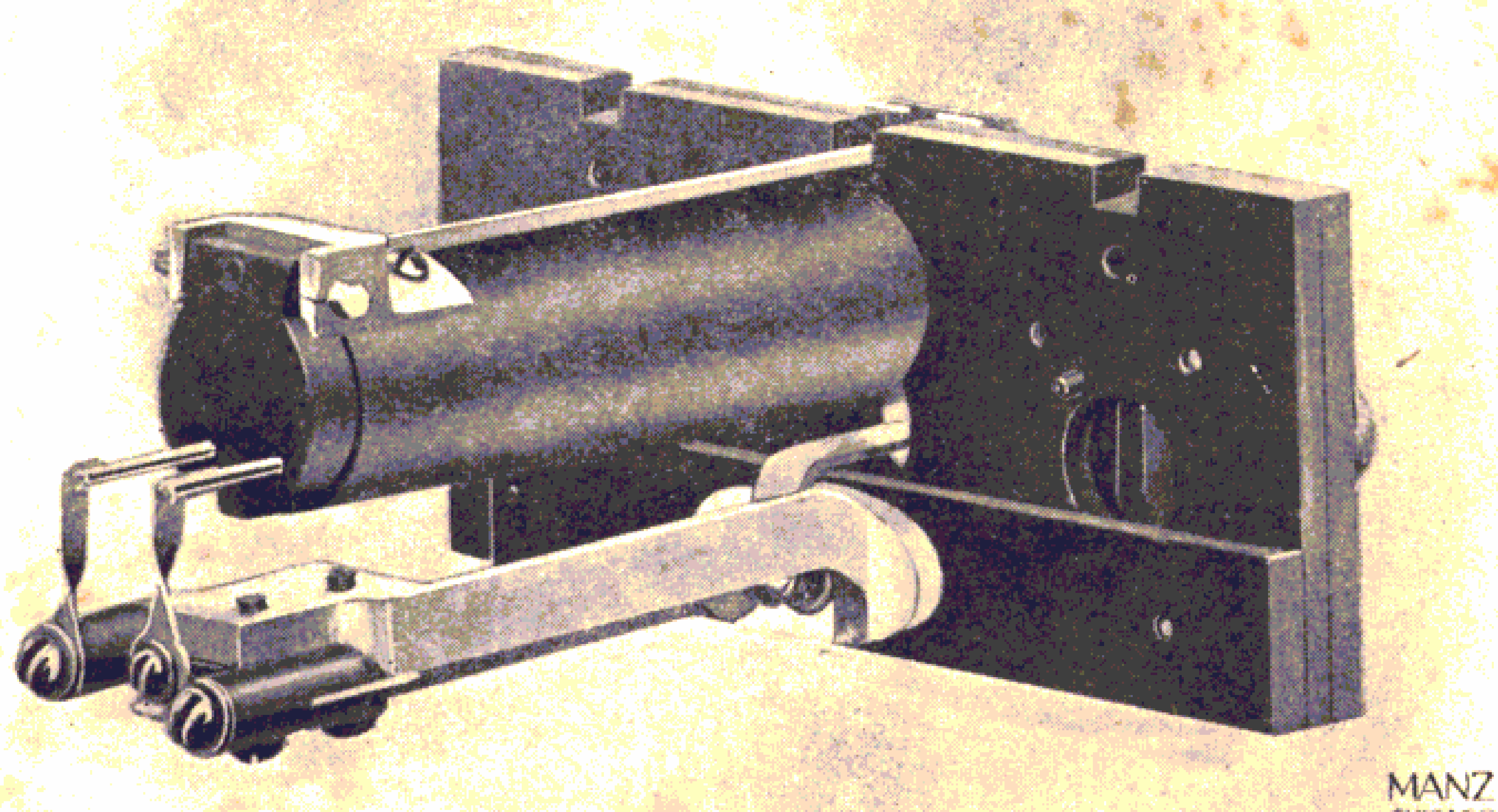


Fig. 39.—Rear View Automatic Drop and Jack.

change the electro-magnetic relations of the other, and consequently will produce similar impulses in the second. Fig. 45 gives a common form of repeating coil, while Fig. 46 is a section showing the method of winding. From the properties of the transformer it follows that if such a coil be inserted in a telephone line, it will cut the line

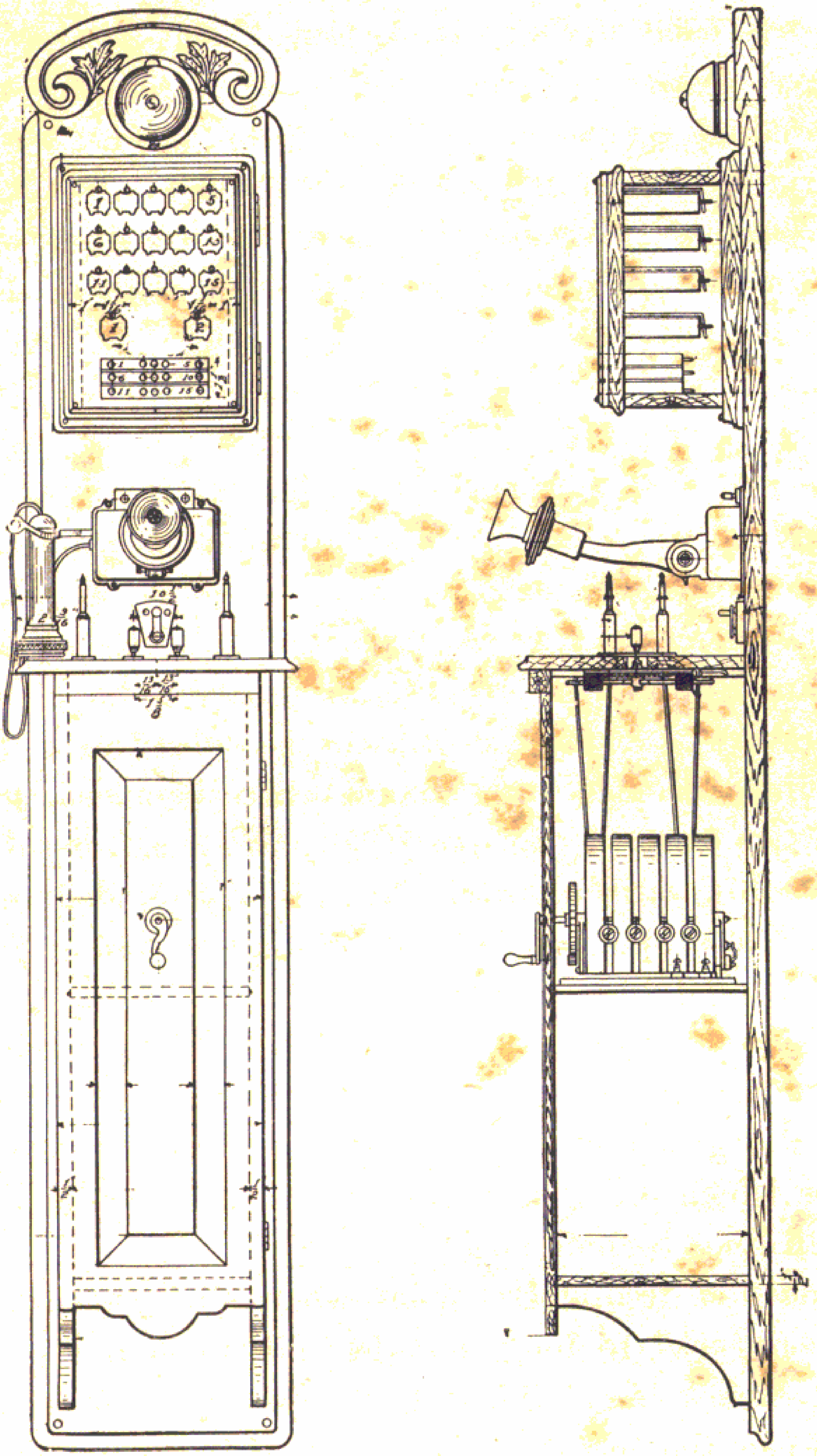


 Fig. 40.—Rural Switchboard, Design No. 1.

into two parts, each of which is electrically separated from the other, yet electrical waves set up in one circuit of the line will produce corresponding ones in the other. From this property a coil of this kind takes its name of "repeating coil," because it is able to repeat impulses from one circuit of the line into the other. Fig. 47 is a set of diagrams demonstrating the use of the repeating coil. At *A* two telephone stations, *X* and *Y*, are connected by a single wire with an earth return. Paralleling the single wire another line, such as an electric light lead, is represented, that is likely to render the grounded line noisy, because as one side of the telephone circuit is of wire and the other is formed by the earth, the resistance and capacity of the two parts are different and the line is unbalanced. If for the earth return a metallic conductor be substituted, the telephone line becomes much more nearly balanced, and then if the two sides be transposed, as at *B*, it can usually be made to talk satisfactorily. Now, if a grounded line be connected to a balanced metallic line (as shown at *C*), the single wire of the grounded portion will be likely to be noisy, and when joined to a metallic line the disturbing impulses perturb the entire circuit. Furthermore, the connection of the grounded line to the metallic line destroys the balance which previously existed on the metallic circuit, so both lines become noisy.

This condition frequently arises when short-grounded lines are connected to long metallic toll lines and conversation becomes impossible. If a repeating coil is inserted between the metallic line and the grounded one, the metallic line is likely to be much less noisy, because the coil electrically separates the two and prevents any

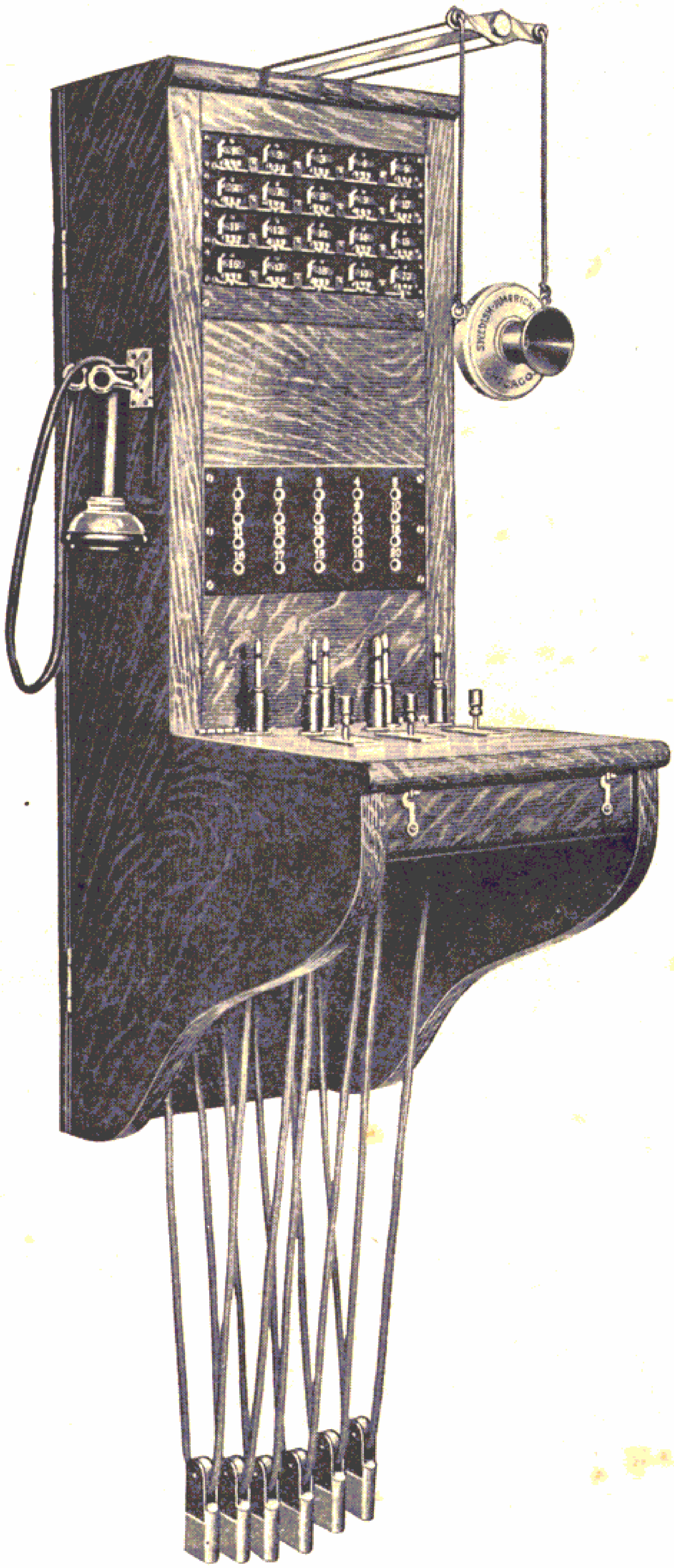


Fig. 41.—Rural Switchboard, Design No. 2.

actual flow of disturbing currents into the metallic line circuit, while by its transformer properties the coil re-

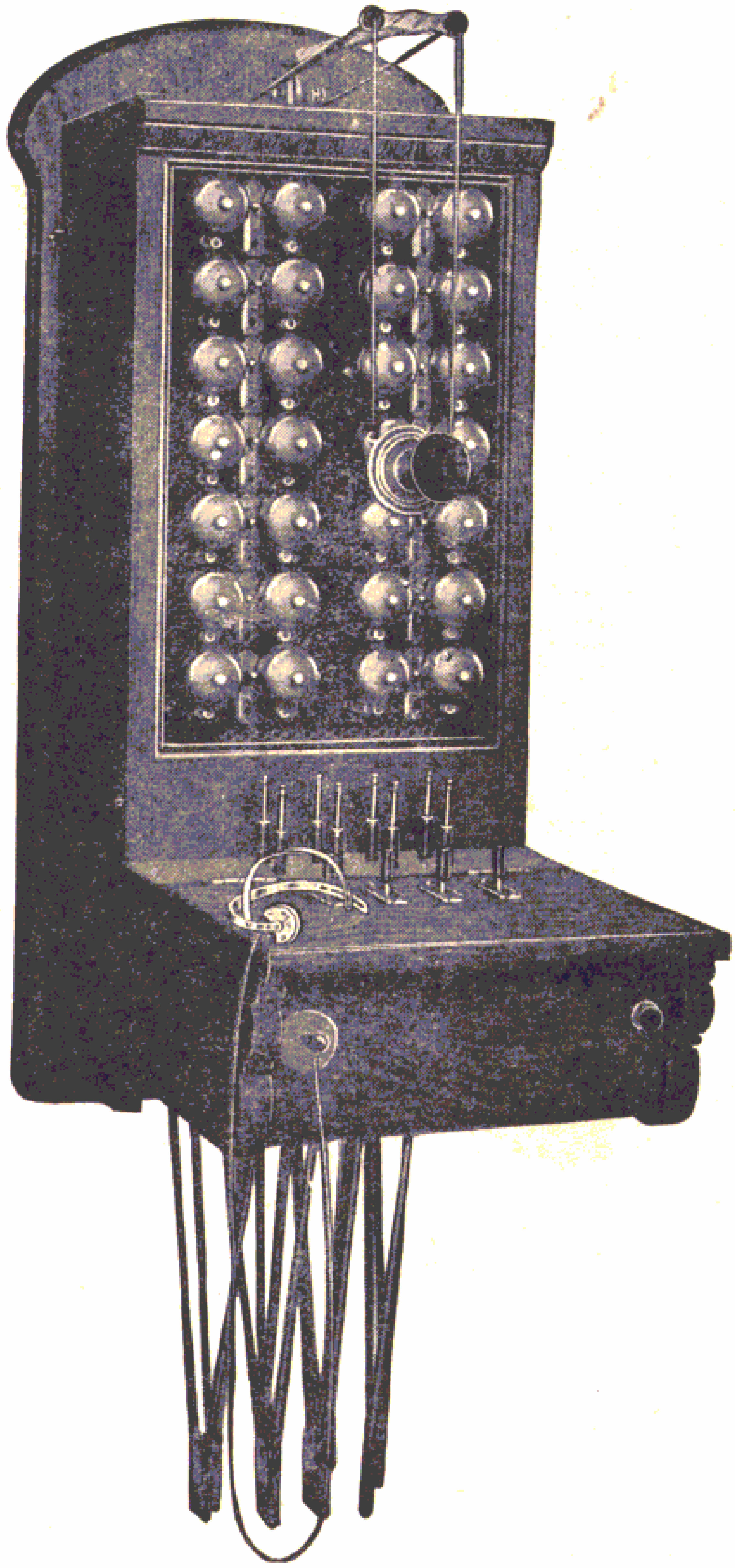


Fig. 42.—Rural Switchboard, Design No. 3.

peats between the metallic and grounded lines the fluctuating voice currents which originate in either. One method of inserting the repeating coil is shown at *D.* Here the coil is placed in the grounded line before it

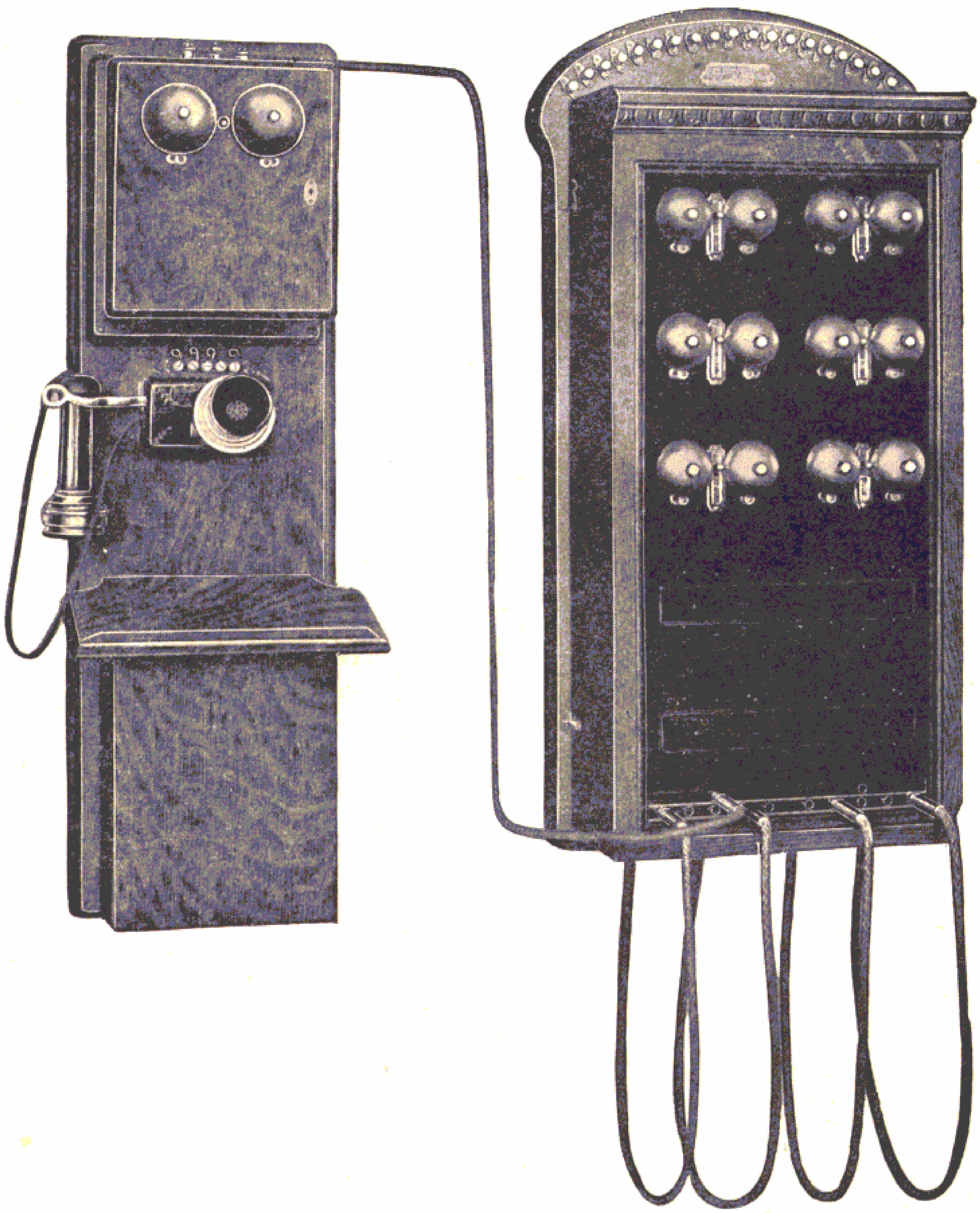


Fig. 43.—Rural Switchboard, Design No. 4.

reaches the jack in the switchboard. To this there is no objection excepting that a coil is required for every line, increasing the expense of installation. At *E* the coil is placed in the cord circuit and only as many coils need to be supplied as there are cords. When only a few of the lines are grounded or operated by common return, it is advisable to place coils in each one rather than to bother with inserting them in the cord circuit. Where there are many grounded lines it is cheaper to place the

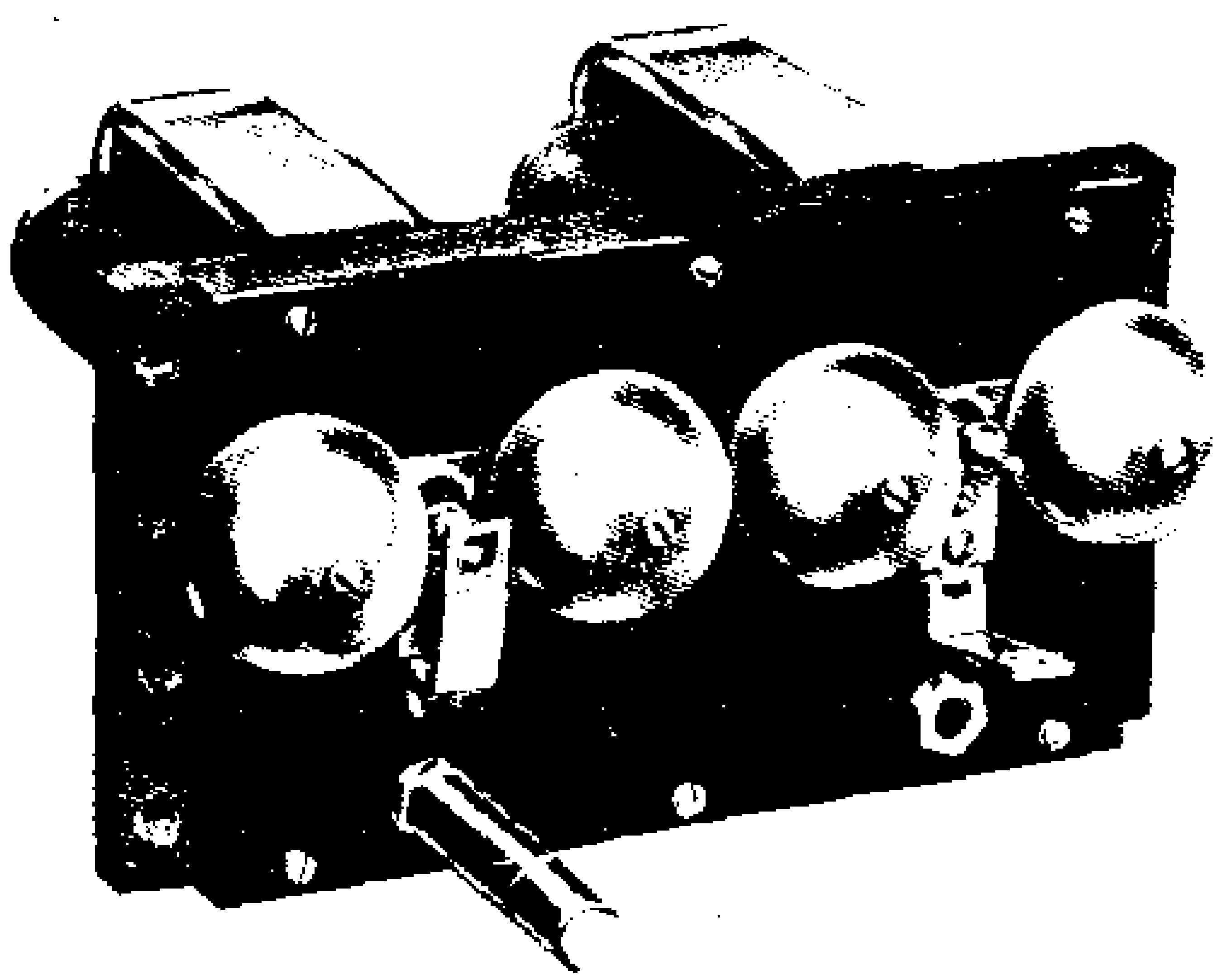


Fig. 44.—Combined Signal and Jack.

coil in the cord circuits. Coils in the cord circuits must efficiently transmit both talking and ringing impulses. Ringing current is of low frequency and of considerable strength, while talking currents are of high frequency and weak. A coil which will transmit ringing current efficiently, requires a large volume of iron and copper, the best design for this purpose resembling a small electric-light transformer. For talking currents the coil may be made very much smaller and cheaper. So there are two methods of inserting the coil in the cord circuit, shown in Fig. 48. At *A* the coil is inserted permanently between the clearing-out drop and the con-

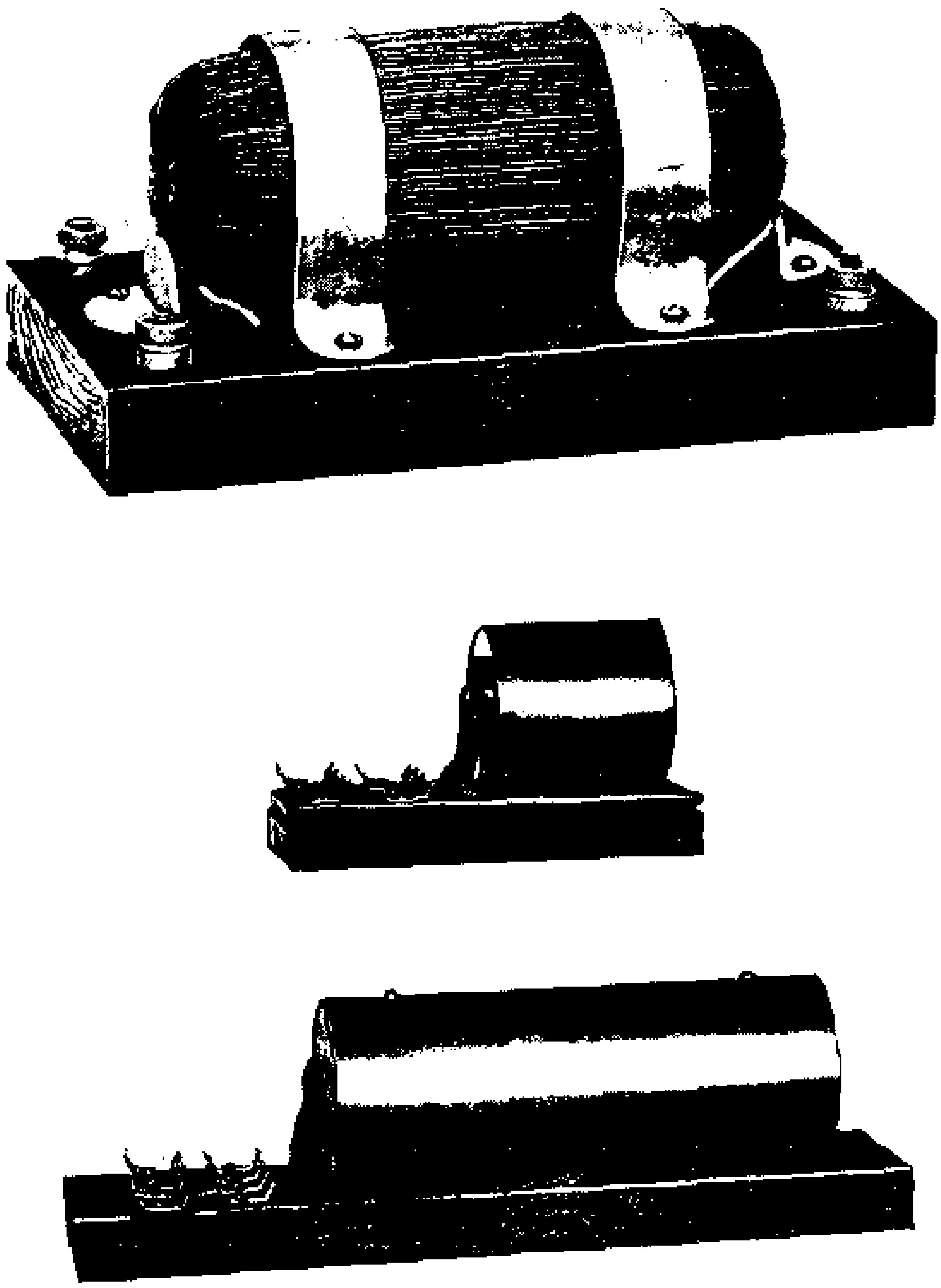


Fig. 45.—Repeating Coils.

necting plug. By so locating the coil the operator can ring the called subscriber, but it is difficult to ring the calling subscriber, which sometimes may be desirable; then it is necessary for the operator to substitute another plug, call the subscriber, and after he has reached the telephone, insert the plug carrying the repeating coil. At *B* the repeating coil by means of an additional key *D*, may be cut in or out of the cord circuit at the pleasure of the operator, who usually, by listening in, determines

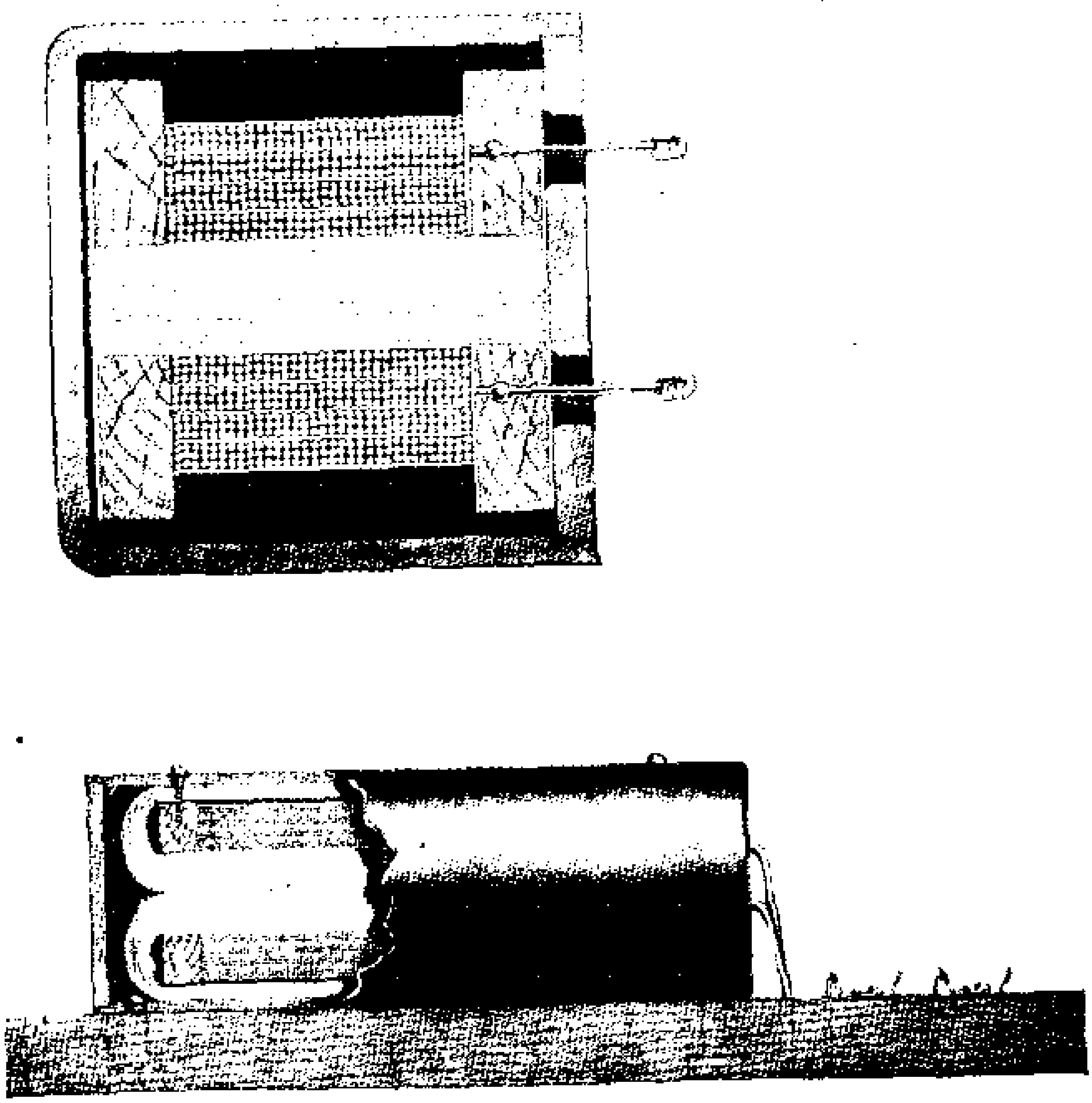


Fig. 46.—Section of Repeating Coil.

whether or not the line is quiet, and cuts the coil in whenever it is necessary.

The apparatus and methods of assemblage described above apply to the construction of magneto switchboards. While lamp signals and common battery systems have been chiefly developed in large exchanges, there is a growing tendency to use them for small offices on account of the cheaper and better service which is secured. The incan-

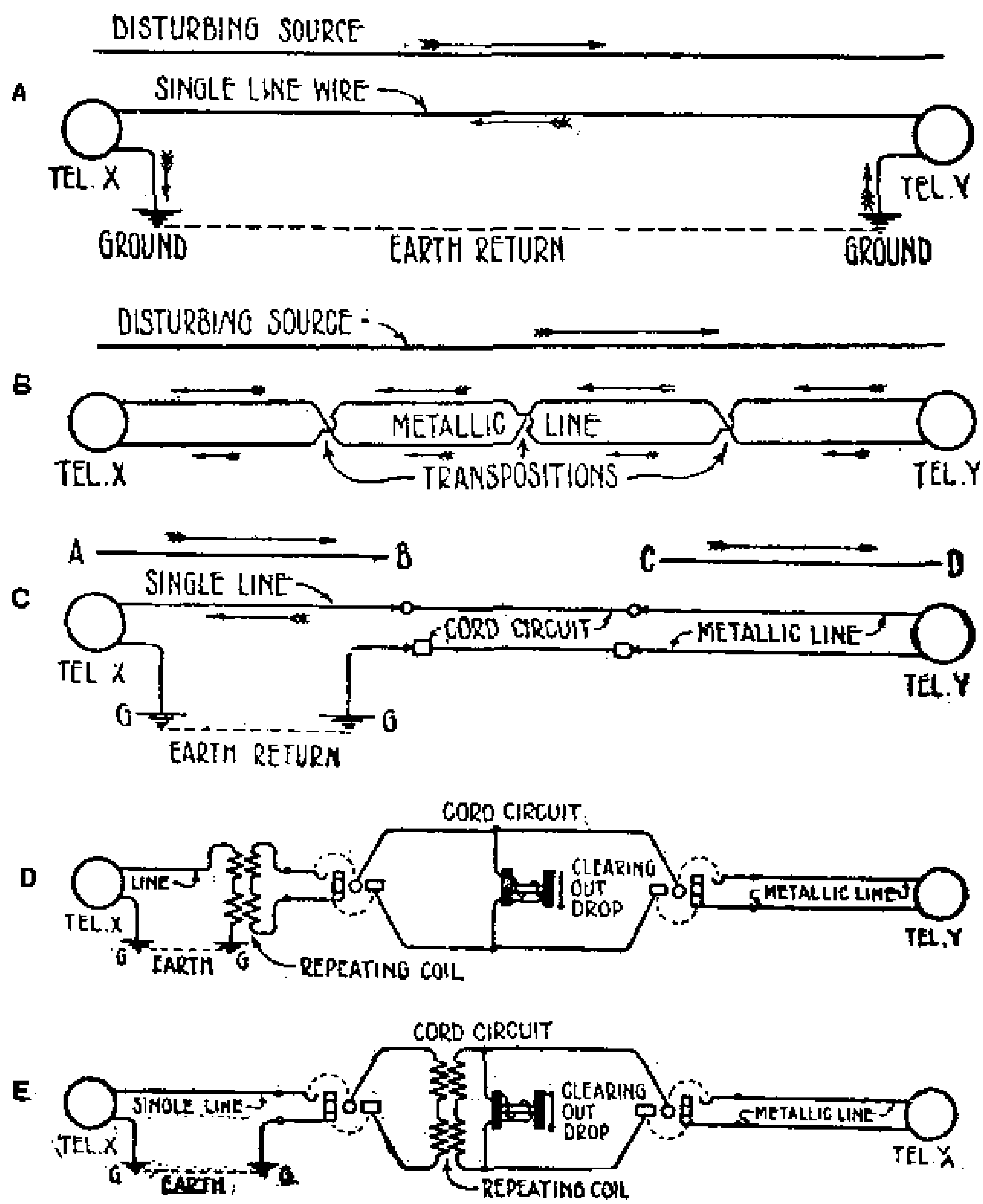


Fig. 47.—Diagrams of the Action of a Repeating Coil.

descent lamp possesses many advantages as a signal over all others yet invented. It is far more conspicuous, can be placed in a smaller space, and is entirely self operative. Lamp signals are worked in a local circuit by means of a relay, that is, the subscriber in calling or clearing out performs some act which closes or opens his line circuit, and thus energizes or deënergizes a relay at the office, whose function is to open or close a local battery circuit and illumine or extinguish the signal lamp. Hence the relay is the foundation of the lamp signal system, and in no other direction has telephonic apparatus been so highly developed and specialized. Figs.

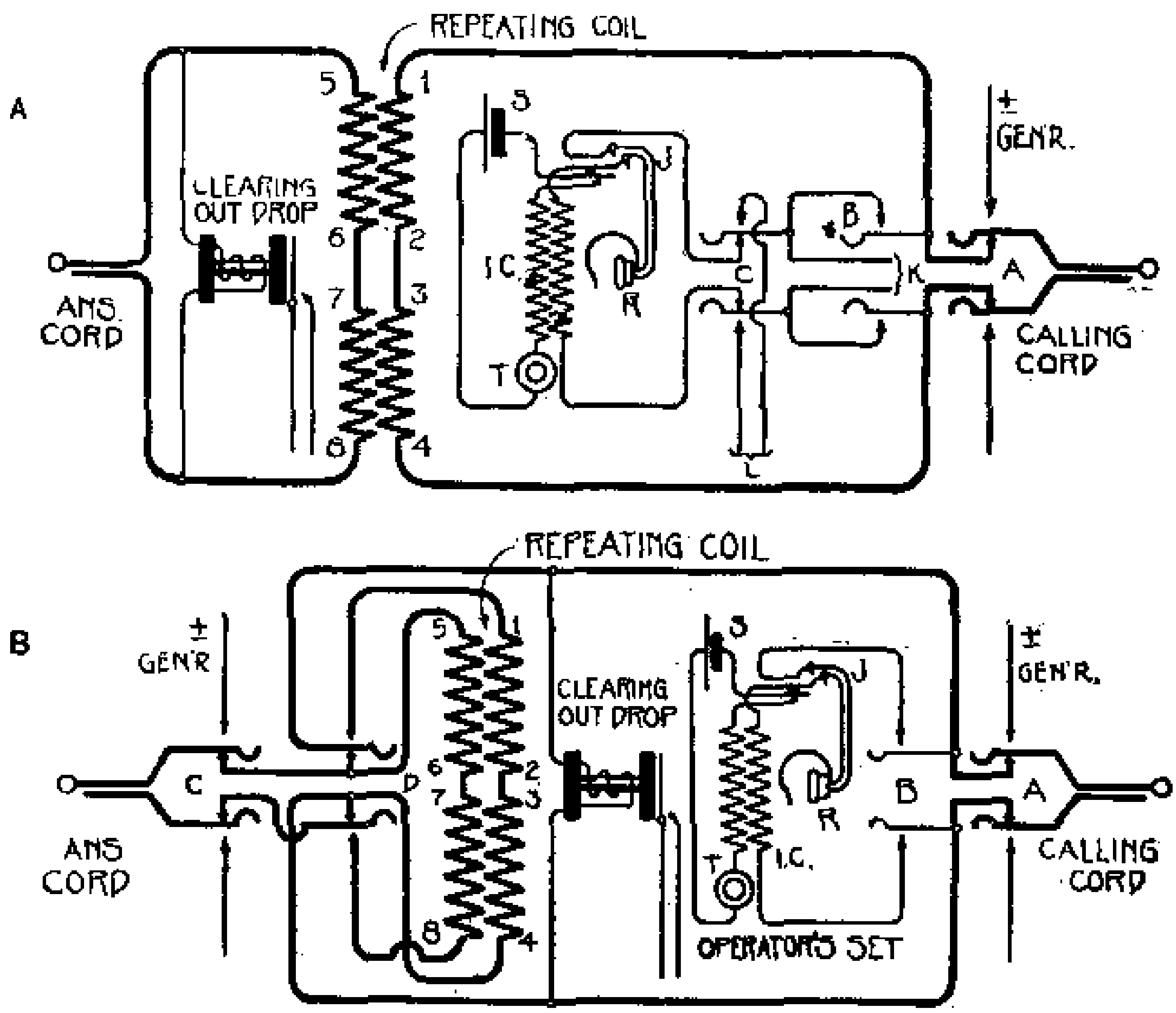


Fig. 48.—Repeating Coil Circuits.

49 and 50 are typical examples. The essential features are an electro magnet, a delicately poised armature, capable of very accurate adjustment, carrying a platinum contact to open and close the local circuit, the whole being surrounded by a case, absolutely dust proof, through which the leading-in wires protrude. There are hundreds

of relay designs, but so long as the fundamental characteristics are secured, and the best material and workmanship employed, there is little to choose. Given a

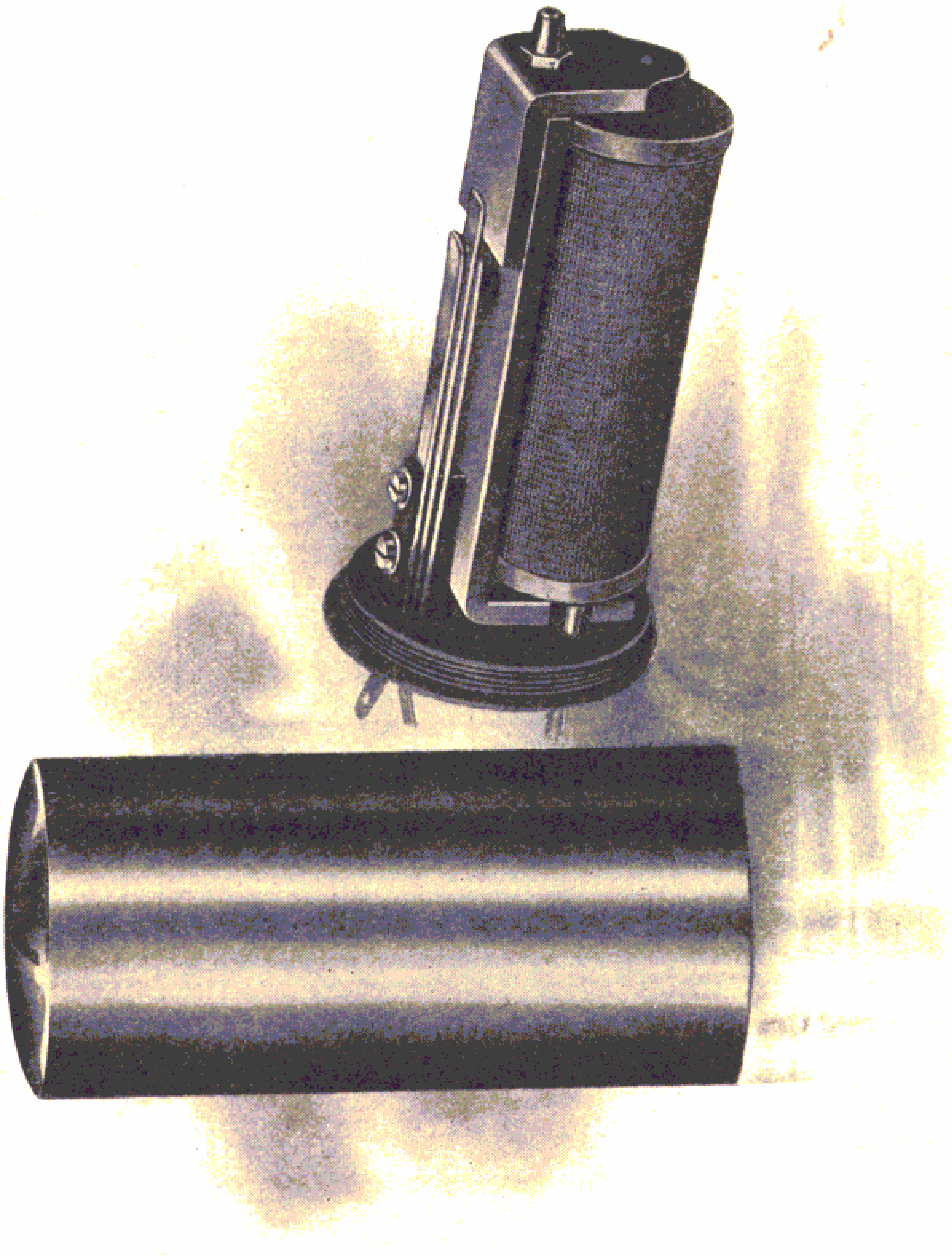


Fig. 49.—Encased Relay.

good relay, the ingenious telephonist can literally make a circuit do anything he wishes.

The switchboard lamp is of the incandescent type, a typical form being represented in Fig. 51. It consists of a glass tube a little less than a quarter of an inch in diameter, and an inch or an inch and a quarter long, in which the carbon filament is sealed. The rear end of the lamp is clasped by a pair of thin brass strips that are riveted to a wedge-shaped hard wood plug that constitutes the lamp base. The filament terminals are con-

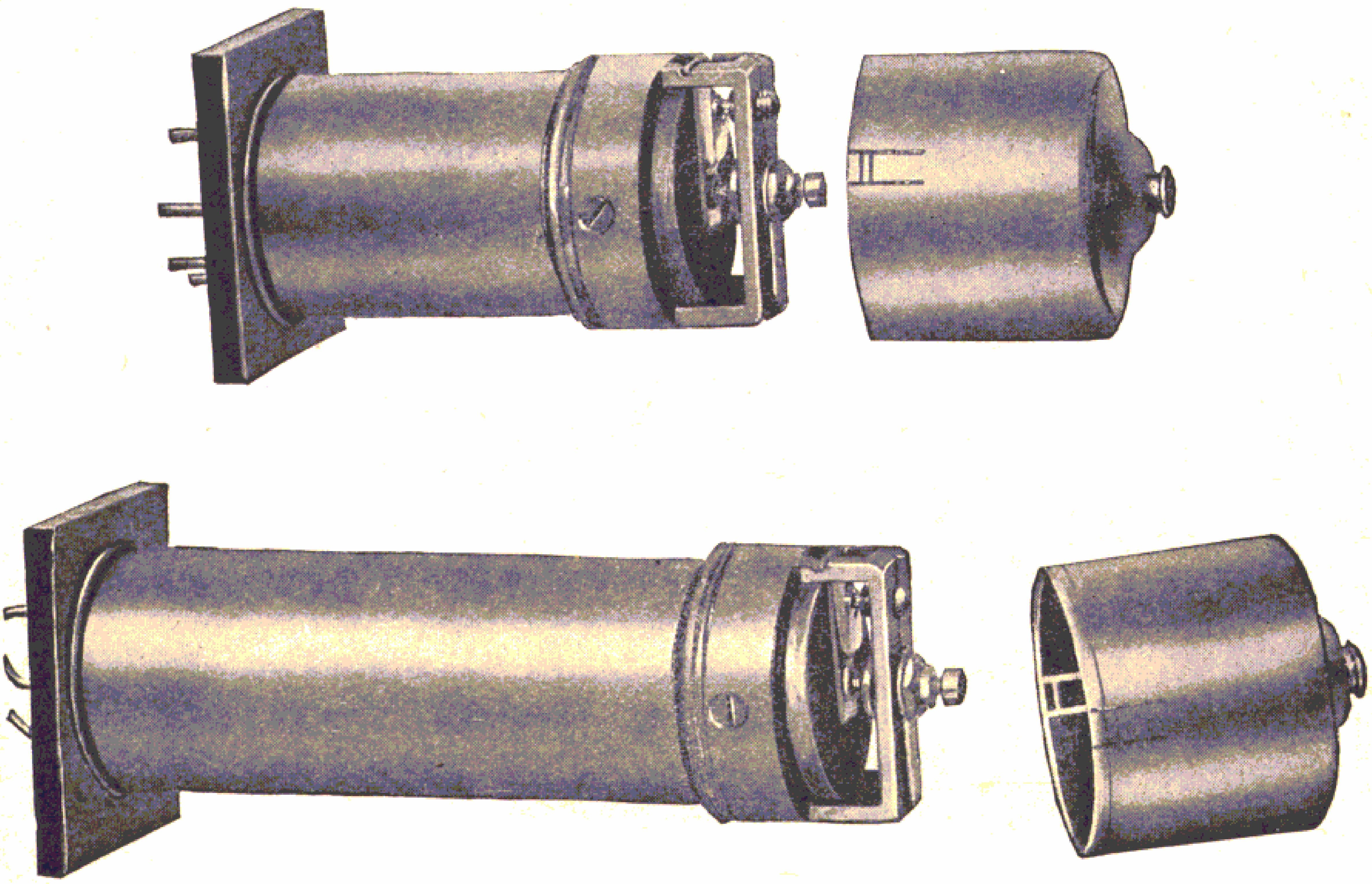


Fig. 50.—Cap Covered Relay.

nected by platinum wire to the brass strips, which thus become contacts. Present practice tends to the use of lamps rated at one-fourth to one-half candle power, using from one-tenth to two-tenths amperes, on circuits of ten or twenty volts. Lamp makers will supply lamps of almost any desired candle power, current consumption, or voltage, so while circuits using lower voltage lamps, two, four, and eight,—and higher ones, even up to forty,—are common, they do not form the prevailing practice.

In the switchboard, lamps are held in a *lamp jack*. There is a strip of insulating material, usually hard rubber, into

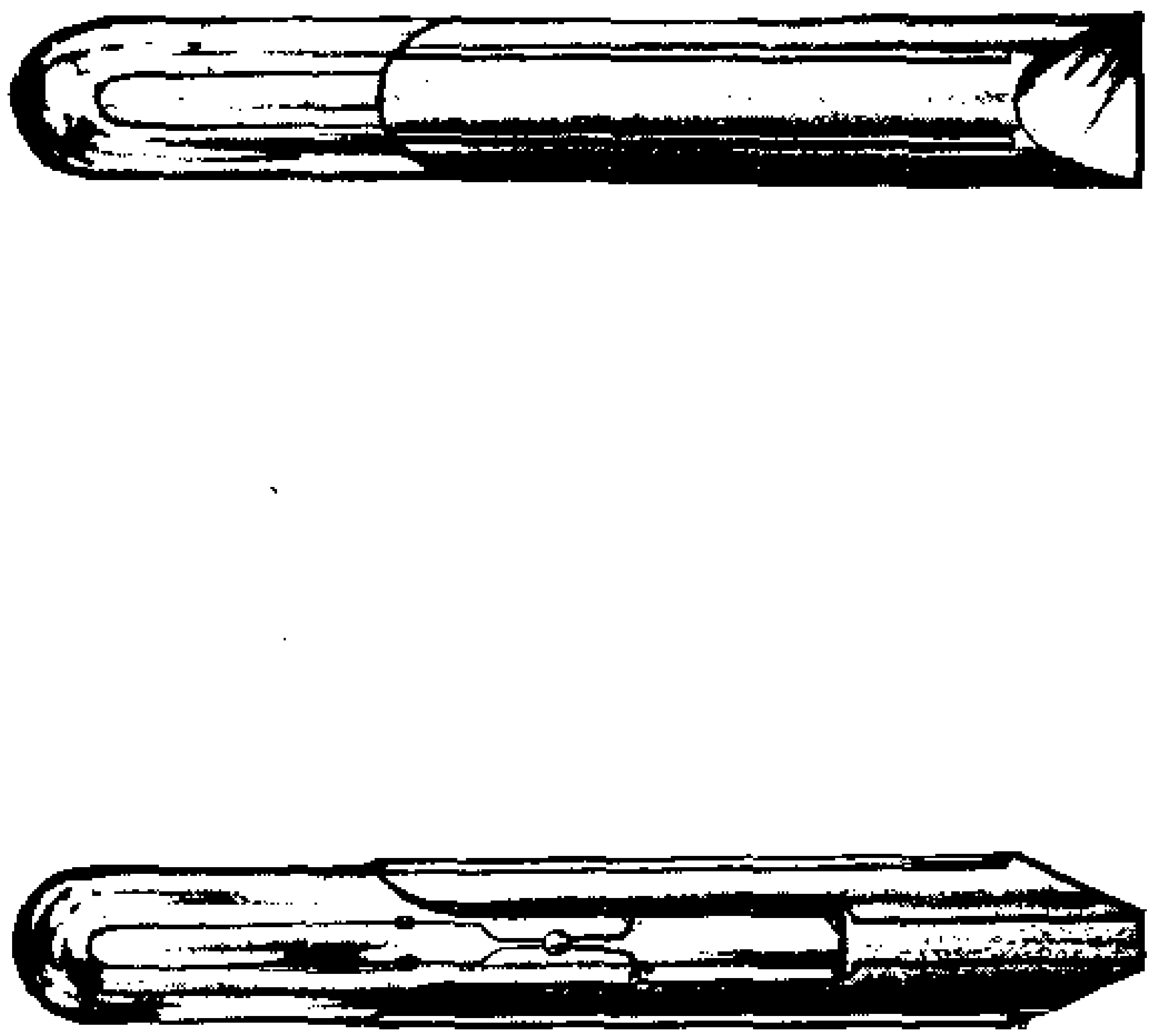


Fig. 51.—The Switchboard Lamp.

which holes are drilled to receive the lamps. In the rear of the strip the rubber is slotted away, and a pair of springs so arranged as to clasp the lamp terminals when it is inserted in the hole. After the lamp is in place a brass cap bearing a designating mark, as in Fig. 52, closes the opening. Fig. 53 shows a bank of lamp jacks, the spring terminals, to which the battery wires are attached, being seen at the right. As a clearing-out signal the lamp is particularly useful, because it can be placed in the cord-shelf directly under the operator's eye, and in front of the cord. For this location a single lamp jack is desirable, which may be secured in a hole drilled in the shelf. A cord shelf jack is shown in Fig. 54.

The keys illustrated in Fig. 55 are widely known as the horizontal type, and have come to be extensively used. Here the two sets of springs are placed horizontally instead of vertically and for this reason, a more substantial design and the possibility of employing a greater number of springs secured.

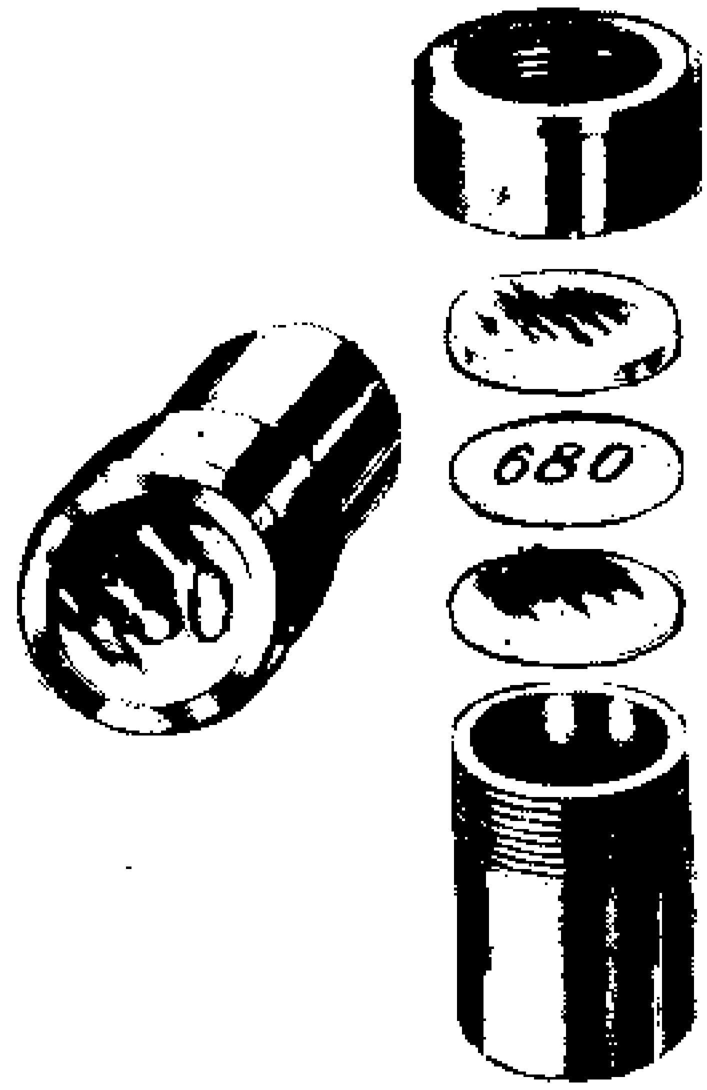


Fig. 52.—Lamp Cap.

A typical circuit for a common battery lamp signal switchboard of three panels is shown in Fig. 56. The substations are equipped with the usual apparatus (see Vol. 5, p. 272); the sides of the line end in the jack in the switchboard. So long as the receiver is on the hook, no current can pass from the office battery, because the condenser at the substation opens the line. This condenser does not prevent the passage of alternating currents, so the operator can ring. When the receiver is lifted there is a current from battery through the relay, the receiver and the transmitter at the substation, the contacts of the jack, thence to the other side of the battery via ground, or a conductor common to the entire switchboard. The relay attracts

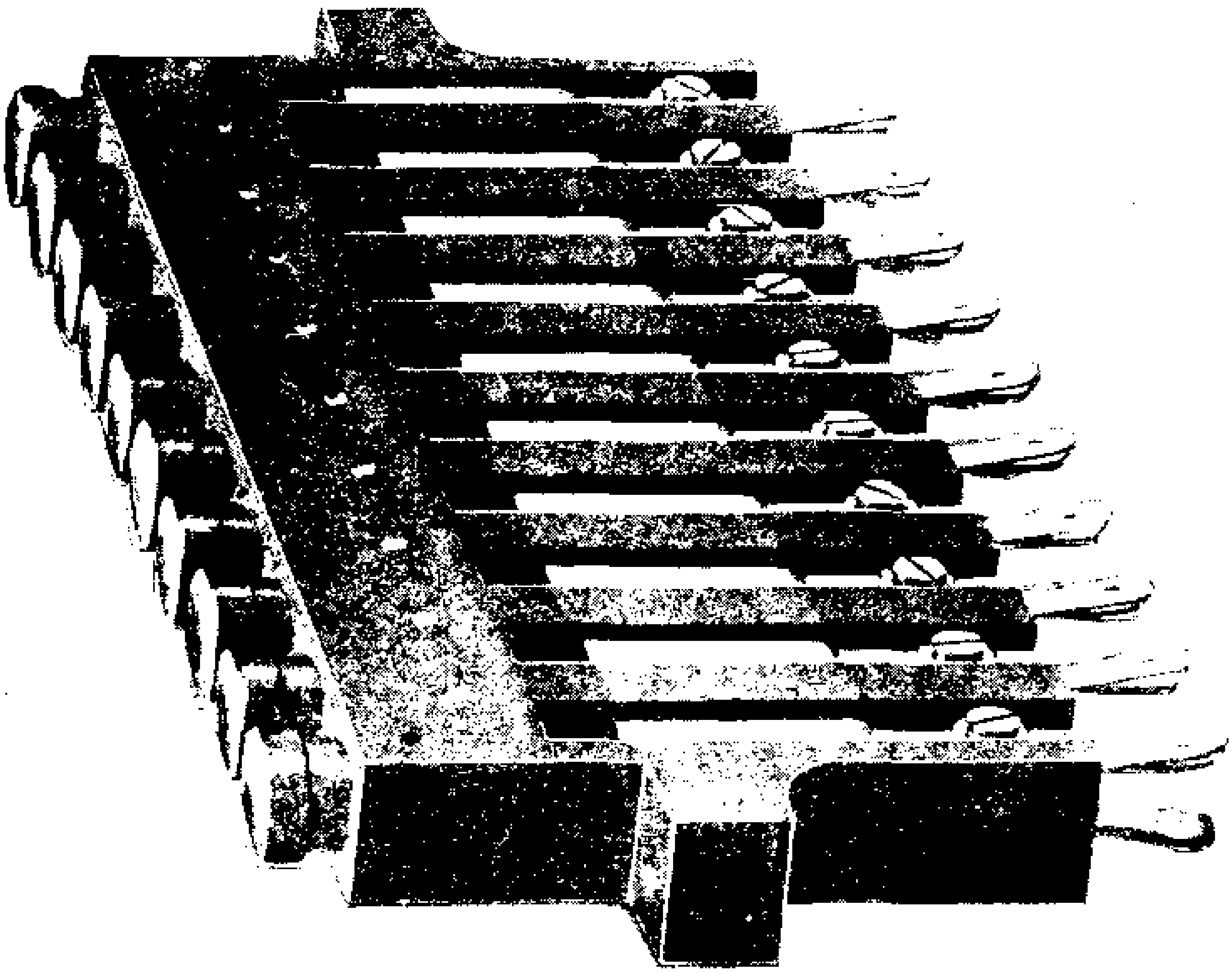


Fig. 53.—A Bank of Lamp Jacks.

its armature, completing circuit from the battery through the calling lamp, and back to the battery. When the operator inserts the answering plug, the tip lifts the springs and opens the lamp circuit, extinguishing the calling lamp, and removes the ground from one side of the line. As long as the plug is in the jack and the receiver is off the hook, the transmitter receives talking current as follows: From the battery through relay *R*, the substation set, the line to the spring of the jack, the plug tip to the battery. Hence the relay is excited, the armature attracted, the contact opened, and the answering lamp is not illumined. When the receiver is placed on the hook this circuit is broken, the armature closes its contact, completing the circuit through the answering lamp, thus illuminating the disconnect signal. The operator takes orders by bridging her talking set across the cord. This description applies to the left-hand side of the cord circuit, but it is evident from inspection that the cord is bilaterally symmetrical, and that the same functions will be performed by the other half.

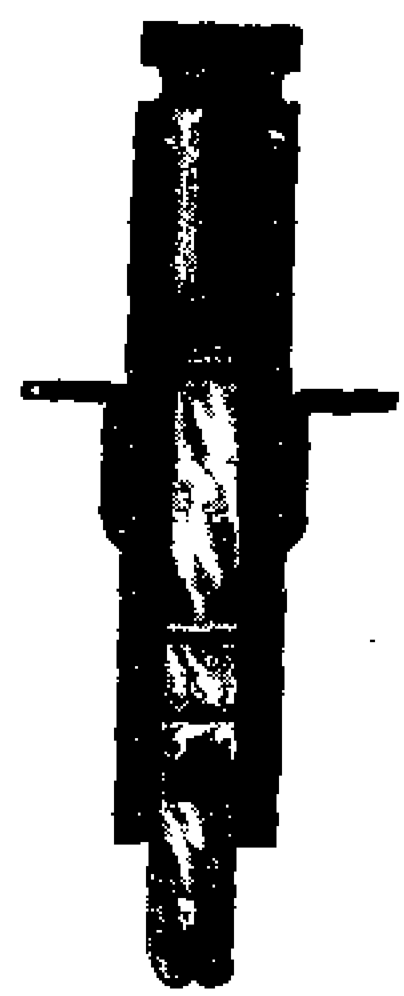


Fig. 54.—Cord Shelf Lamp Jack.

Sometimes it is desirable to operate magneto stations in a lamp-signal switchboard. The circuits *A*, *B*, and *C* in Fig. 57 show a successful method. *A* is the line of a grounded station, *B* a metallic one, and *C* the cord circuit.

When the subscriber calls by turning the generator crank, current passes through tip side of line to tip contact in the jack, through the 500-ohm winding of the relay to the ring contact to ground, and back to the substation. The line relay armature is attracted and current flows from the battery through the cut-off relay armature to the armature of the line relay, through the 100-ohm winding of the line relay to the battery. The line lamp is lighted, and the current passing through the 100-ohm winding of the line relay locks the armature.

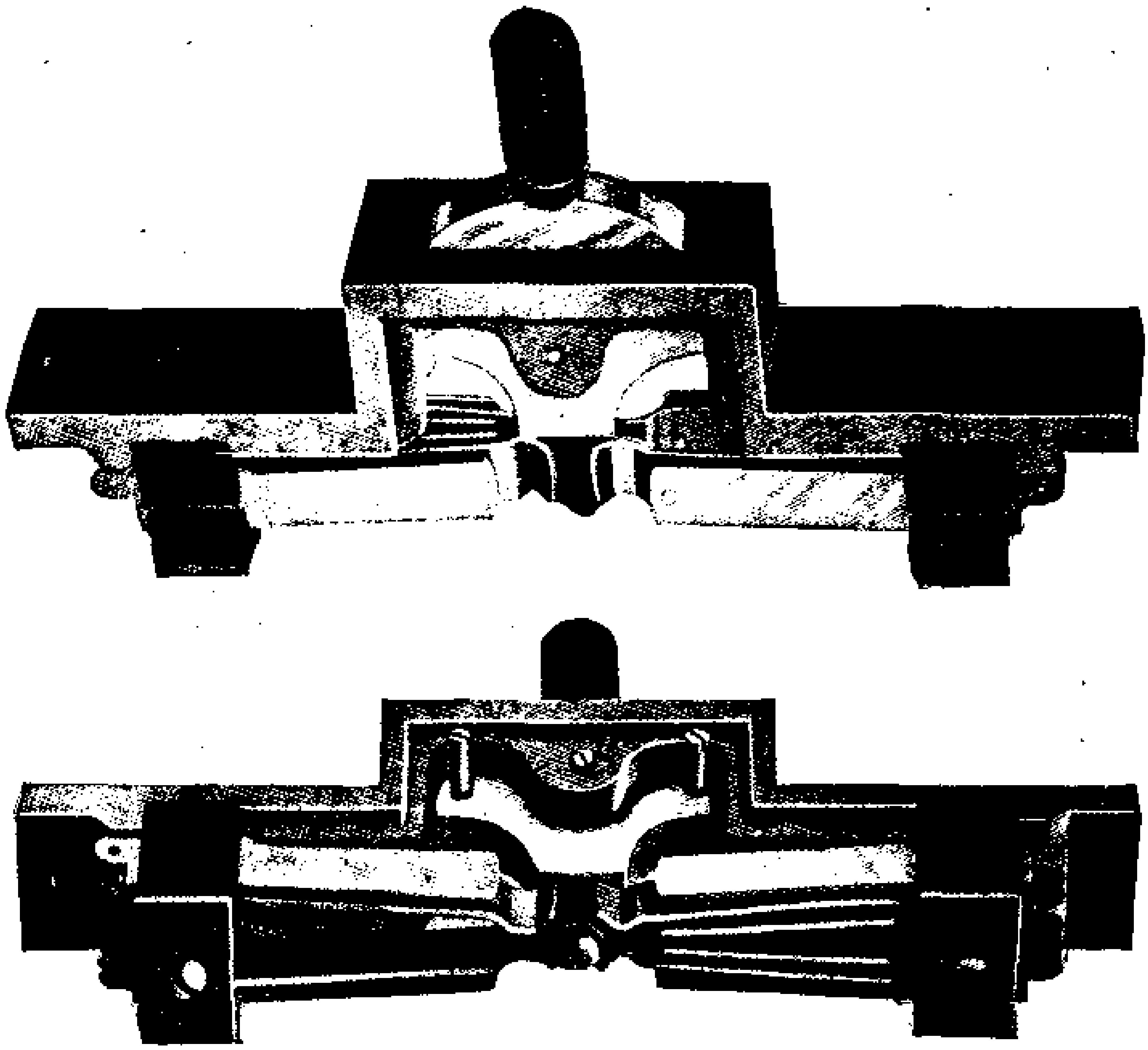


Fig. 55.—Horizontal Keys.

When the operator plugs with the answering plug (Fig. 57), current flows from the battery through the 200-ohm resistance coil, the back contact of the answering cord relay, the sleeve of the plug and the jack, through the 50-ohm winding of the cut-off relay to the grounded side of the battery. This operates the cut-off relay and extinguishes the line lamp. The insertion of the plug also cuts off the 500-ohm winding of the line relay.

When the subscriber rings off, current passes through the 500-ohm winding of the cord relay, which draws up its

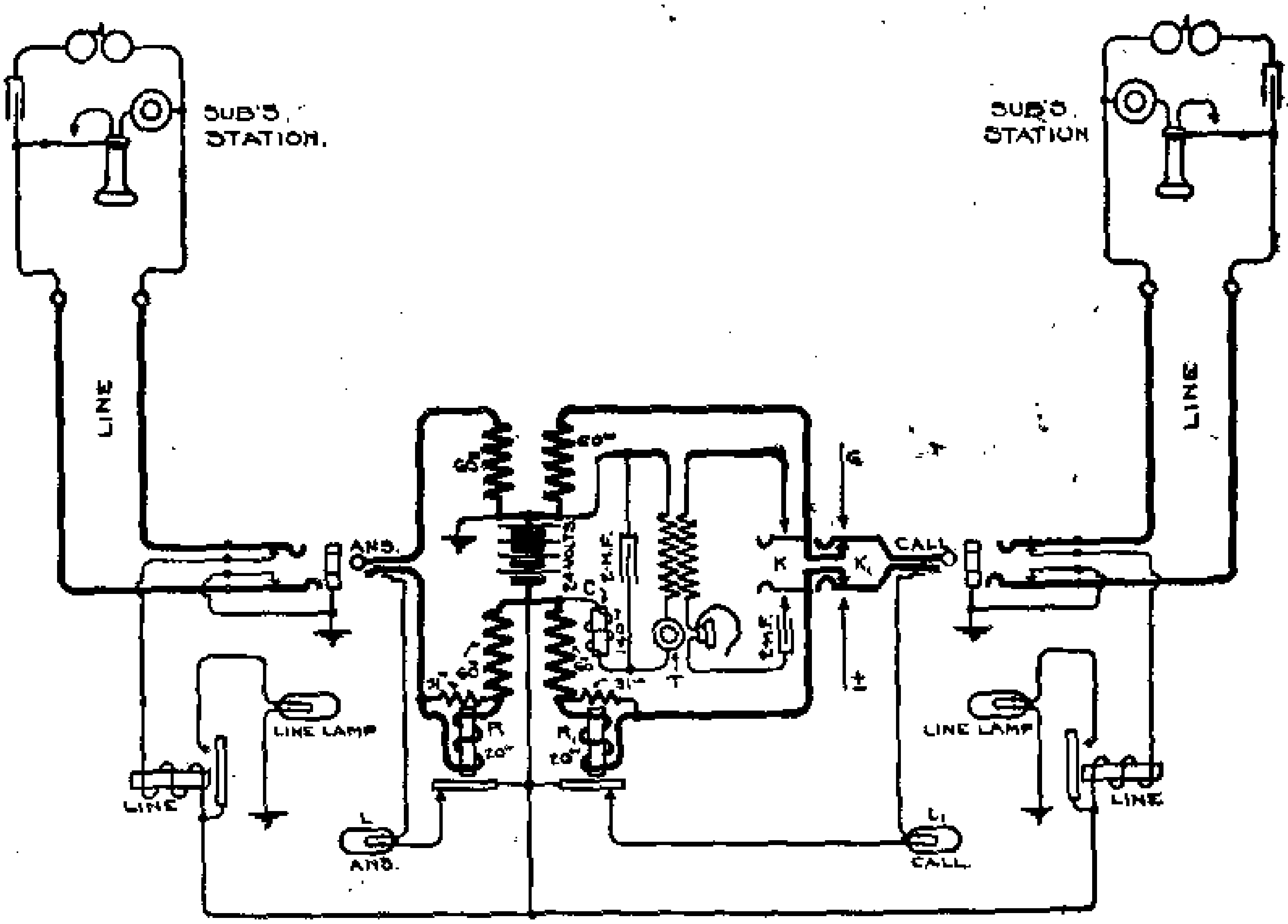


Fig. 56.—Non-Multiple Lamp Signal Switchboard Circuit.

armature, thus opening the 200-ohm resistance coil circuit and completing the circuit through the supervisory lamp, and 50-ohm winding of the relay. The relay armature is locked and the lamp lighted.

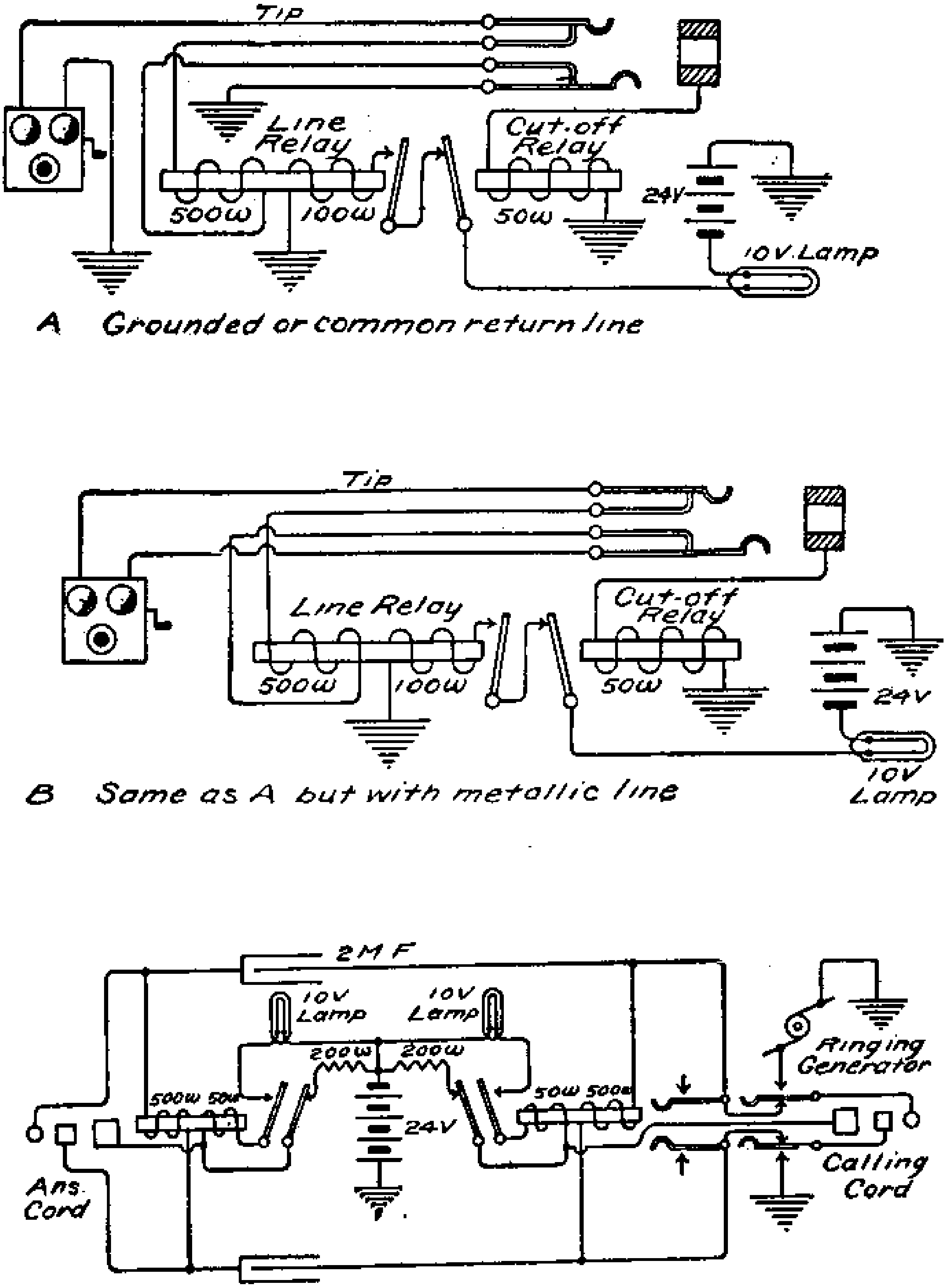


Fig. 57.—Circuits for Magneto Stations—Lamp Signal Switchboard. 74

CHAPTER IV.

TRANSFER SYSTEMS AND THE MULTIPLE BOARD.

THE switchboard illustrated in Fig. 31 consists of a single panel in which the subscribers' terminals are placed. As soon as this panel is filled the natural course of growth places a second frame beside the first, and when the second panel is exhausted a third is added. So long as three panels provide sufficient space for the jacks and drops, an operator seated before either can reach all subscribers, and if the traffic be sufficient to require the services of more than one operator, each can reach all lines. When, however, the exchange comprises more lines than can be placed in three panels, it is impractical on such a board for all operators to reach all jacks, and therefore impossible for each, unaided, to complete every connection that might be demanded. Two methods of solving this problem are current — *the transfer system* and the *multiple switchboard.*

The transfer system is the earliest method and still used for small offices. In addition to subscribers' lines each operator is provided with a number of jacks and drops, from which lines extend to every other position in the switchboard. When an operator is requested to connect a calling party with a subscriber located in a panel out of her reach, she inserts the connecting plug into a jack communicating with the panel in which the desired subscriber jack is located, and rings upon this line in precisely the same manner as if she had plugged into the jack of the subscriber desired. The falling shutter of the drop associated with this jack notifies the operator before whom it is placed that a call is to be answered, exactly as if this drop was the original signal of the subscriber. The second operator inserts the answering plug of a pair of cords into the jack indicated, asks the subscriber for number, and completes the connection in the ordinary manner. As by this plan a call is *transferred* from one operator to another, this system is known as the transfer system, and the lines which connect different positions in the switchboard with each other are termed "trunk lines." There are many defects. As the services of two operators are required, the cost of operating is increased. Either the subscriber must repeat his order to the second operator, or, if the first attempts to transmit the number, mistakes are inevitable.

The number of calls transferred will depend upon the size of the switchboard, and assuming traffic to be equally distributed over all lines, it is easy to calculate this. Suppose N to be the number of sections in the switchboard, H the total number of messages, and that each operator can reach the section in front of her and over one section at each side. The number of calls arriving at each section is $\frac{H}{N}$, and $\frac{1}{N}$ of these messages must be completed at each panel of the whole board. Consider first the $\frac{H}{N}$ calls made at any section excepting an end one, then $\frac{H}{N} \times \frac{1}{N}$ or

$\frac{H}{N^2}$ will be answered on each panel, and as each operator can reach three panels, each one can complete unaided $\frac{3H}{N^2}$ of the calls that originate in the panel in front of her. Discarding the two end panels, whose operators can only reach two panels instead of three, there will be $N - 2$ such sections each of whose operators can complete $\frac{3H}{N^2}$ of the calls she receives, or $3(N-2)\frac{H}{N^2}$ messages completely unaided. At each of the end sections each operator can complete $\frac{2H}{N^2}$ messages, hence the total unaided completed connection will be $3(N-2)\frac{H}{N^2} + \frac{4H}{N^2} = \frac{H}{N^2}(3N-2)$, and the percentage of unaided completed messages $\frac{3N-2}{N^2}$.

This formula shows that the number of unaided messages varies inversely as the square of the number of panels, and falls rapidly as the switchboard increases in size. For example, assume two boards respectively of 500 and 1000 lines, having the same traffic per line, arranged in panels containing 100 lines each. In the 500-line board 52 per cent of the calls could be handled unassisted, while in the 1000-line board only 25 per cent.

Under the system described all transferred messages are handled by two operators, and each one has to perform precisely as many operations as she would in connecting two subscribers that are within her reach; so cost of operating labor for all such messages is doubled, and in addition there are the interest, depreciation, and maintenance charges on the trunk-line plant, and the delay and inconvenience to which the subscriber is subjected, which cannot be measured in dollars. In spite of these defects the transfer system was for a long time the only method of operating, and under various modifications and guises it still survives, and claims many warm advocates, whose telephonic education and skill are of the highest order.

In a way, every large exchange may be said to be a transfer system, because whenever there is more than one office some messages must be handled over trunk lines, and except for the mere cost of the additional wire needed to join the panels, it makes no difference whether the sections are ten feet or ten miles apart. Essentially, therefore, all forms and devices for trunking may be classed as transfer systems, and, broadly speaking, toll and long distance lines and operation fall in this category. Technically, however, the transfer system is usually understood to cover only methods of handling telephone traffic between the sections of a non-multiple switchboard located in the same office.

The early transfer circuit, using a drop and jack at each end of each trunk line, is exceedingly slow and cumbersome in operation.

For small exchanges a simple and inexpensive transfer circuit, using incandescent lamps as signals, is shown in Fig. 58. Each panel is provided with enough jacks, so that sufficient lines may extend to every panel out of the operator's reach. These jacks are usually mounted in banks. Each consists of a sleeve *S* (Fig. 58), and spring *t*; these form the talking circuit and are connected to the trunk line wires. There are three other springs, 1, 2, and 3. Spring 2 is normally in contact with spring 3, resting upon an insulating block which connects it to spring *t*. Upon the insertion of the plug, spring *t* is raised, and spring 2 is separated from spring 3 and forced into contact with spring 1. Inspection shows that springs 1 of each pair of jacks are connected with one pole of the battery, while springs 3 are connected to the other pole. Springs 1 are respectively connected to one of the poles of the incandescent lamps *l* and *l*; when both jacks are

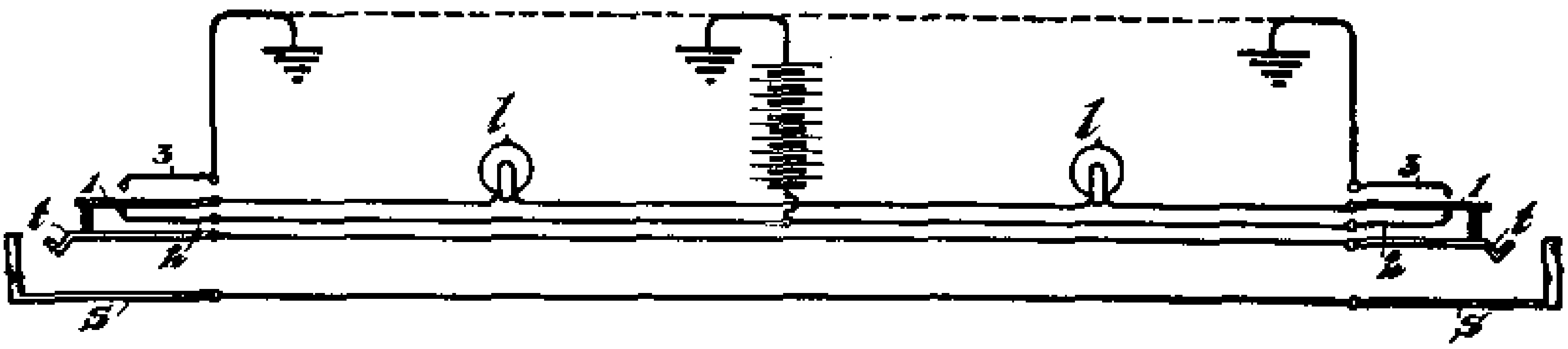


Fig. 58.—Simple Transfer Circuit.

unplugged, both of the lamps *l* and *l* will be extinguished. If either operator inserts a plug into the jack in front of her, both of the incandescent lamps will light; and when both plugs are inserted, both lamps will be dark. The operation is as follows: Suppose the "A" operator receives a call for a subscriber located in the panel *B*, she inserts a plug into the jack, illuminating the lamps *l* and *l*. The "B" operator seeing the illumination of lamp *l* inserts an answering plug into the jack. This extinguishes both lamps and informs the "A" operator that the "B" operator plugged into the jack. The "B" operator asks the subscriber for his order and completes the connection. As soon as the subscribers have finished conversation, and actuate their clearing-out signals, either the "A" or "B" operator removes the plug from the trunk jack; the incandescent lamps light, giving a clearing-out signal to the other operator. As soon as the remaining plug is removed both lamps become dark, indicating that the trunk is free.

Such a transfer system is simple and efficient. The objections lie in the expensive and complicated jack and that each trunk line requires five wires. When few lines are needed and the distance between the panels short, the cost of the jack and expense of trunk line cable and the space required become unimportant. But when long trunking circuits are to be used, economy in the wire plant is paramount, and has led to the invention of many ingenious trunking circuits.

In the discussion of trunking, it has become customary to denote the operator who receives the subscriber's call as the "A" operator, or originating operator, while the other who coöperates in completing the connection is termed the "B" or incoming trunk operator. Either the "A" operator must tell the "B" operator the number of the desired line, or else the "B" operator must ask the subscriber to repeat. Modern methods adopt the first course. Two plans are in use. Both operators may bridge their talking sets across the trunk line and use it to give and receive the order. For the transfer systems employed in small and medium-sized offices this is sufficient, but in large offices the volume of business is so great as to overcrowd the trunk lines and render a separate circuit, called an order wire, economical.

The order wire is a pair of conductors which extend from all of the "A" operators to a head telephone placed upon the ear of the "B" operator. Each "A" operator is supplied with an order wire key that by touch of the finger connects her talking set with the call wire, so each one can instantly speak to the "B" operator. The order wire greatly simplifies the trunk circuit, for if the "A" operator can speak at once to the "B" operator there is no need of any calling signal, hence the lamps, the extra springs in the trunk jacks, and three wires of the trunk circuit may be omitted. Consider a set of several trunk lines, each one starting in jacks placed in front of a number of "A" operators, and ending in a plug on the cord-shelf in front of a "B" operator. If any "A" operator receives an order for a line out of her reach, she touches the order-wire button, extending to the operator ("B" operator), before whom the desired line does appear. For an instant the "A" operator listens to see if any other "A" operator is speaking, and finding the call wire clear, pronounces the number of the line desired. The "B" operator replies by speaking the number of the trunk line that the "A" operator is to use. Simultaneously the "A" operator inserts her connecting plug into the trunk line jack designated by the "B" operator, and the "B" operator inserts the same numbered trunk line plug into the jack of the called subscriber, the whole operation being completed in two or three seconds. This system is usually known as the *reversed call trunking system*, and is now universally employed between the offices of all large exchanges. The same method may be used for clearing out. When the subscribers display their disconnect signals, either operator may order, over the call wire, the other one to disconnect. But this method has been found cumbersome and confusing, so present practice equips trunk lines with automatic disconnect signals, so arranged that when the "A" operator removes the plug a signal is given the "B" operator to disconnect.

The theory of all transfer systems is that of conveying the *message* to the *called* subscriber's line; the *multiple board*, which forms the alternative solution of the problem, reverses this and carries the *called* subscriber's *line* to the *message*. Consider the diagram of Fig. 59, which illustrates a switchboard of say 400 lines, divided into four

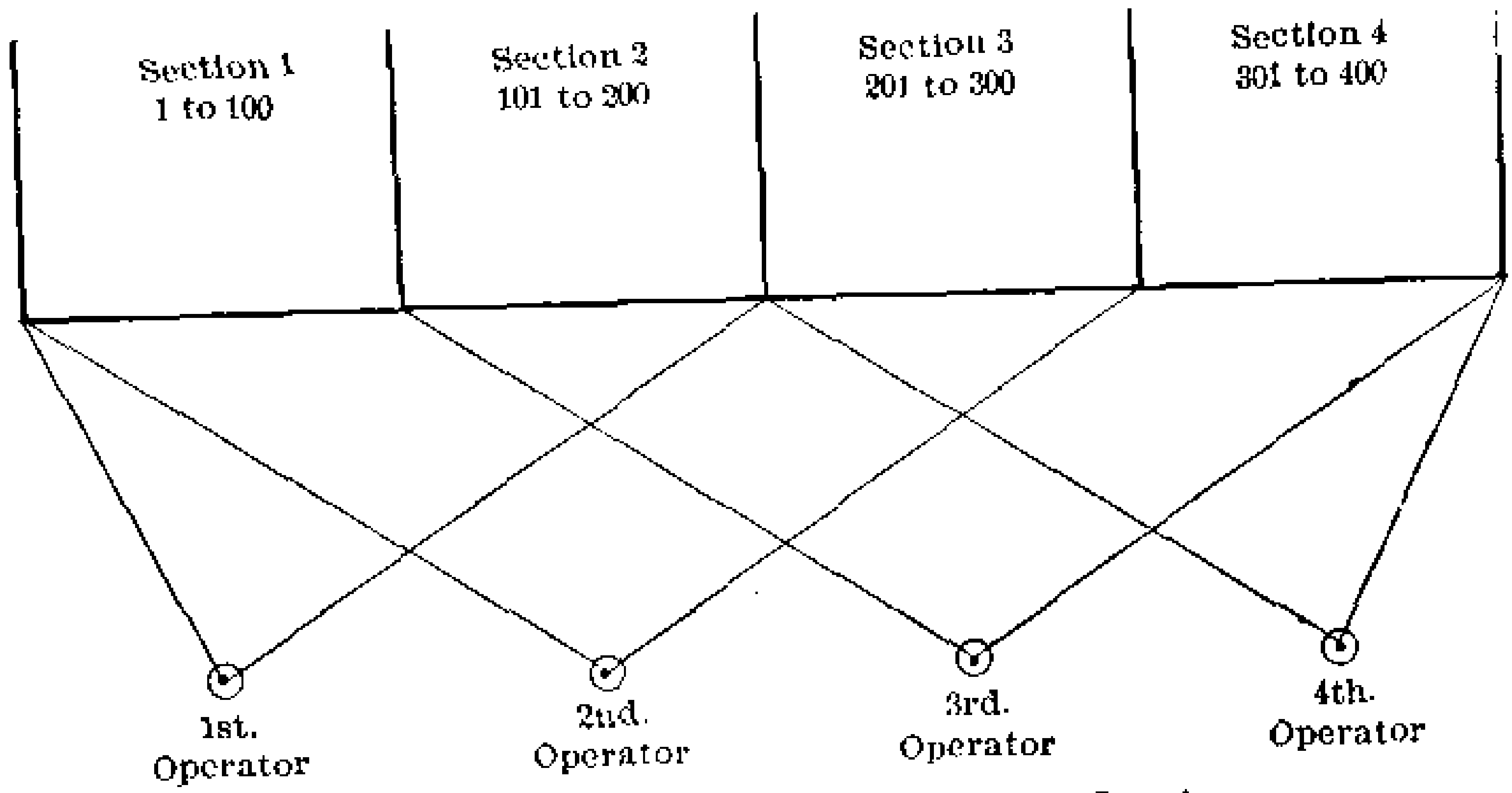


Fig. 59.—Diagram Illustrating Multiple Board.

panels of 100 lines each, served by four operators. The diagram shows that if the subscribers' lines terminate as shown, the various operators can complete connections as follows:

Operator 1.	To all lines between	1 and 200
Operator 2.	To all lines between	1 and 300
Operator 3.	To all lines between	101 and 400
Operator 4.	To all lines between	201 and 400

The operators are unable to reach lines as follows:

Operator 1.	Cannot reach lines	201 to 400
Operator 2.	Cannot reach lines	301 to 400

Operator 3.	Cannot reach lines	1 to 100
Operator 4.	Cannot reach lines	1 to 200

Now suppose that in the various panels a lot of surplus jacks be placed, and that the various subscribers' lines be extended and connected to several jacks in such a manner that there is a jack attached to every line within the reach of each operator. Manifestly each operator can complete a connection with every subscriber, and no transfer is necessary. This is the principle of the *multiple* board, which takes its name from the fact that every line has its jacks *multiplied* a sufficient number of times to give every operator access to it. It is unnecessary to multiply the subscriber's calling signal, for when he calls the office the attention of *one* operator amply suffices. Hence in a multiple switchboard the subscriber's line consists of two parts: A calling signal and jack associated therewith (the answering jack), placed before the operator commissioned to attend to the particular subscriber, and a string of other jacks varying in number, depending on the size of the switchboard, and so arranged as to give all other operators access to the line.

Fig. 60 gives a typical series multiple switchboard circuit. Three operators' positions are represented, Nos. 1, 2, and 3, and three lines, Nos. 101, 304, and 508. The drawing shows that each jack consists of two springs, *a* and *c* normally in contact, and a ring *b*. Each subscriber's line may be traced as follows: taking line 101 from the point *e* where each line enters the board, to spring *a* of jack *A* in position 1 to spring *c*. thence through the springs of each of the other jacks in positions 2 and 3, thence to the drop *D*, and thence out by the wire *f*. To the *f* side of the line a branch wire is carried from the jack rings in each section, so the rings are all in parallel, while the *e* wire of the line runs through the jack contacts in series. The drop is placed last on the line, hence when a plug is introduced it lifts the spring *a* away from spring *c*, and so opens the circuit and cuts off all apparatus connected to spring *c*, relieving the line of all superfluous parts during conversation. The signal and jack associated there-

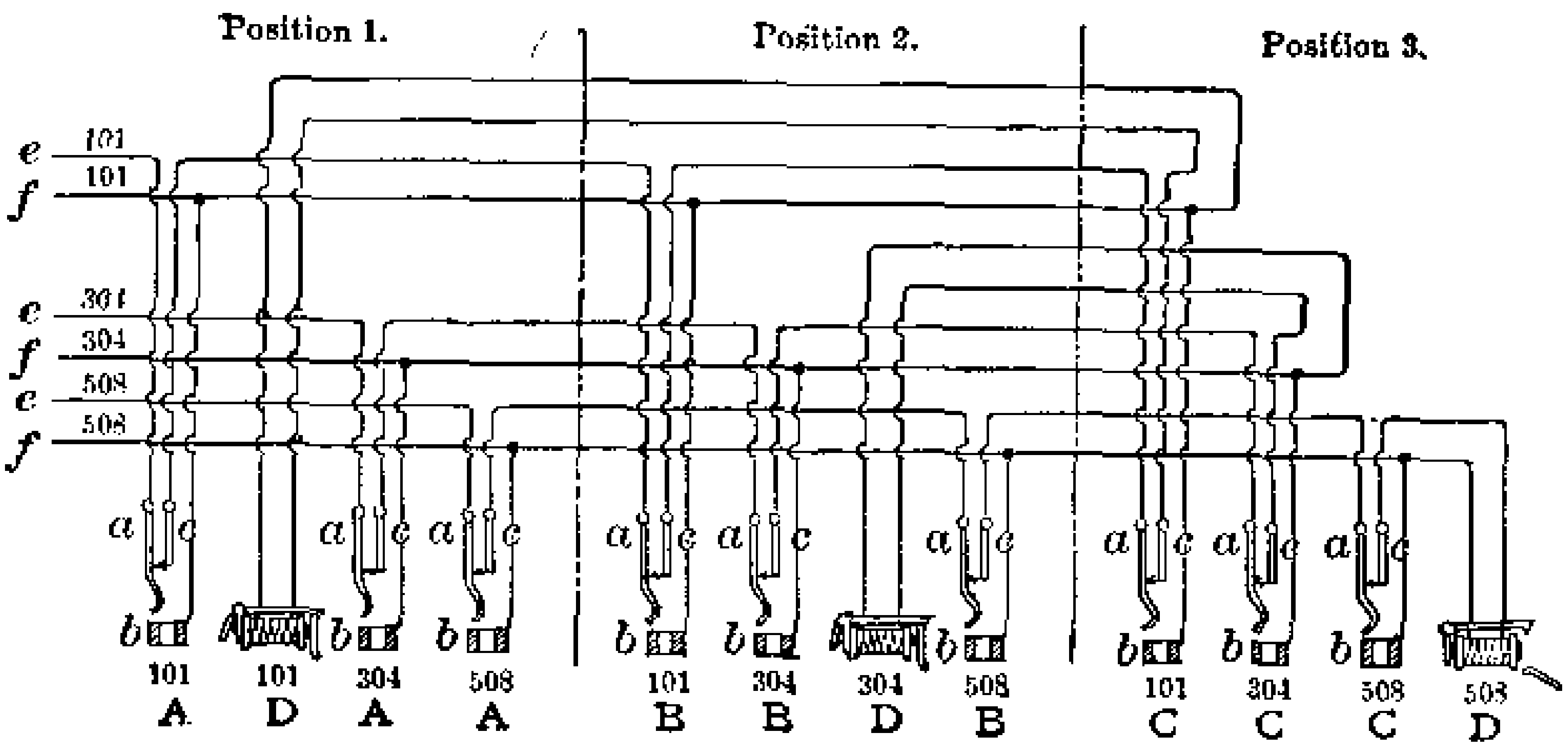


Fig. 60.—Series Multiple Board Circuit.

with at the end of the line (including the distributing-board outfit) are usually called the subscriber's terminal. For each subscriber there must be one complete terminal. The other jacks are termed the *multiple*, and will vary in number depending on the size of the board.

Fig. 61 shows a cord circuit in which *P* is the answering plug, *P″* the connecting plug, and *K* and *K′* the respective ringing keys, enabling the operator to ring either subscriber at pleasure. The clearing-out drop, wound for from 500 to 1000 ohms, is bridged across the line. K'' is the listening key wherewith the operator bridges her telephone set across the line, to take the subscriber's order. This cord circuit contains a condenser, a retardation coil and the battery. When key K'' is pressed, the condenser is placed in series in the tip conductor. The object is to provide the so-called busy test. In the non-multiple switchboard each subscriber's line has but one jack, always in sight of the operator who serves it, consequently the operator can at a glance tell whether a

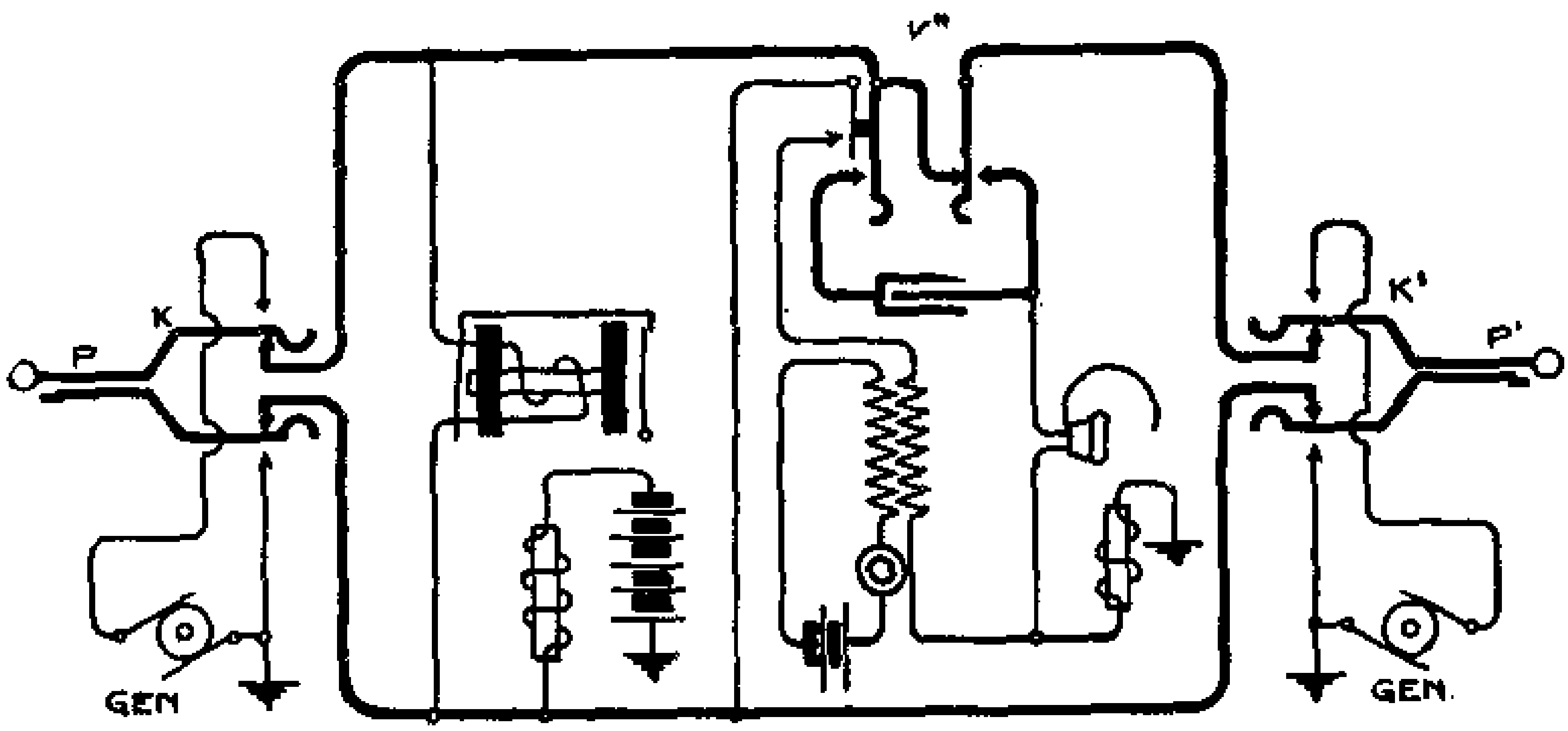


Fig. 61.—Cord Circuit Multiple Board.

line is engaged in conversation or not, by noticing whether its jack contains a plug. In the multiple board each line has many terminals which may not be within the operator's sight, and it is impossible to tell by inspection whether a line is free, so means must be provided whereby each operator can quickly ascertain whether she may use the jack within her reach without interrupting a prior conversation.

According to Fig. 60, every jack is provided with a ring *b*. Fig. 61 shows that when two lines are joined by the cord circuit, the battery becomes connected to the ring of the jacks into which the plugs are inserted, and as all the jack rings in each line are in multiple, the insertion of the plugs raises the potential of the rings to that of the battery. One pole of this battery is grounded or connected to a common wire. The operator's receiver is grounded, through a retardation coil, or similarly connected; if, therefore, an operator touches the tip of the connecting plug to the ring of any jack which is at a higher potential than that of the earth, current will flow through the tip side of the line and charge the condenser. Charging this condenser causes the receiver to emit a loud click. If, on the contrary, the tip of the answering plug be touched to the ring of a jack at earth potential, there is no click; hence after an operator at a multiple board receives the subscriber's order, the first operation is that of testing the desired line. The operation is illustrated in Fig. 62. Lines 304 and 508 are shown as engaged in conversation in position 3. In position 1 the operator has inserted the answering plug into line 101, has received an order to connect with line 304, and touches the tip of the connecting plug to ring 304. Then there will be a flow of current from positive pole of the test battery in cord circuit of panel 3 to the ring of jack 304, thence to the ring of jack 304 in panel 1, thence to tip of plug touching this ring to the operator's condenser which is charged, the negative charge set free returning to the negative pole of the test battery. The receiver clicks, indicating that the line is busy. The condenser prevents a continuous flow of current, beyond that necessary to charge the condenser.

The series multiple switchboards possess a grave objection — one side of the line is extended through the jack contacts in series; and as there may be many jacks, there will be as many contacts in series. Whenever a plug is introduced the springs are separated, and frequently a small particle of dust lodges itself between the contact points. When the plug is withdrawn, the contact fails to close, and the line remains open. It is then impossible for

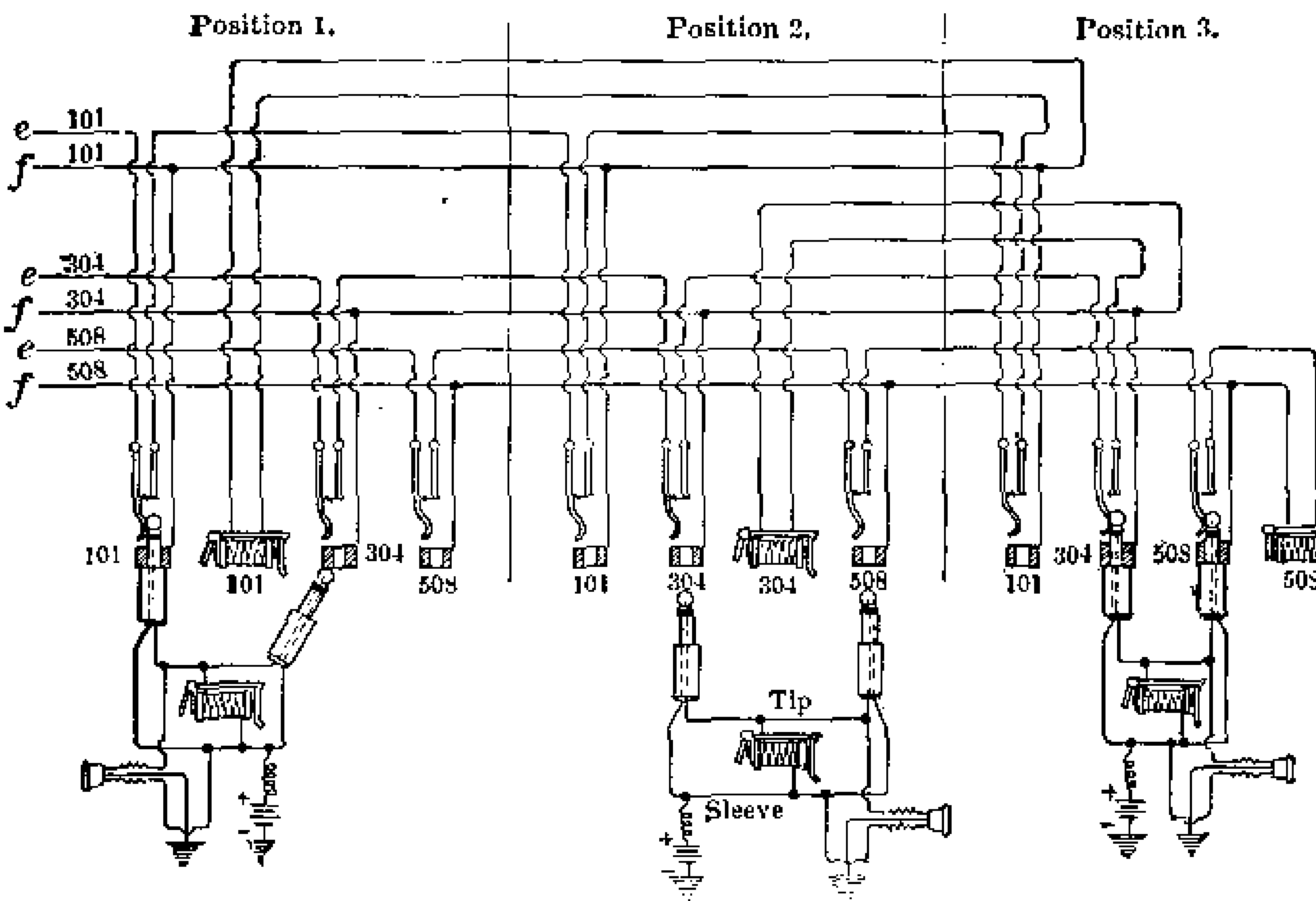


Fig. 62.—Busy Test Series Multiple Board.

the subscriber to call the office, and his only recourse is to hunt up some other telephone station and complain. The branch terminal, or bridging-multiple switchboard, was invented to remedy this defect. Fig. 63 shows the circuit of one type of this board, positions 1, 2, and 3 being represented, containing lines 99, 304, and 510. One side of each line *T* is connected with the ring *f*. All the *e* springs of each line are in multiple with each other, and are connected to tip side *T* of each line; and similarly all of the *f* rings of each line are in parallel with each other and joined to the sleeve *S* of the line, hence the name of *branch terminal* or *bridging board*, because there are no contacts in the jacks, and consequently subscribers' lines cannot be opened by particles of dirt. Each jack contains two other springs *b* and *b′*, and a ring *g*. All the *b* springs

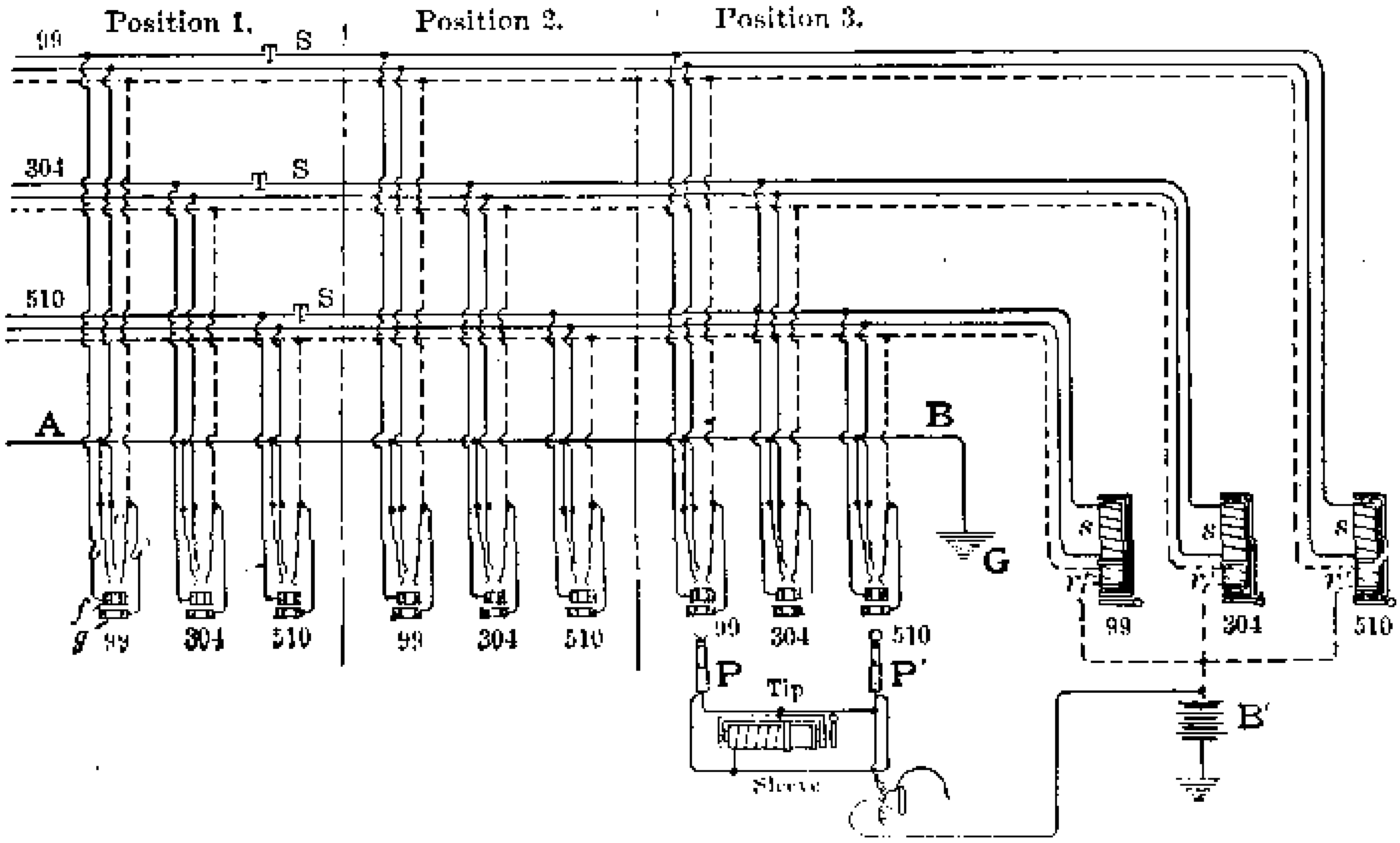


Fig. 63.—Branch Terminal Multiple Board.

of each line are connected in parallel to a ground, or wire *B*, common to the whole office. Each *g* ring is in series with the *b′* spring of its jack, and all the *b′* springs of each line are connected in parallel to a third wire belonging to that line. Therefore this type of board is often called a *three-wire board*.

The subscriber's signal is a drop having two windings *s* and *r*. The *s* coil has a resistance of 500 to 1000 ohms, and is bridged across the line. When the subscriber rings, this winding actuates the drop mechanism and displays the signal; as the drop cannot be cut off by the opening of a jack contact, the signal winding must possess sufficient impedance to avoid shunting-voice current. The resistance of the r winding varies from twenty-five to fifty ohms. One end of this winding on each drop goes to one pole of the office battery B'. The other end of this winding on each drop is connected to the third wire of the line to which the drop belongs, runs through the board and to the b' spring and the g ring of each jack of the line in question. Fig. 64 shows the mechanism of the drop.

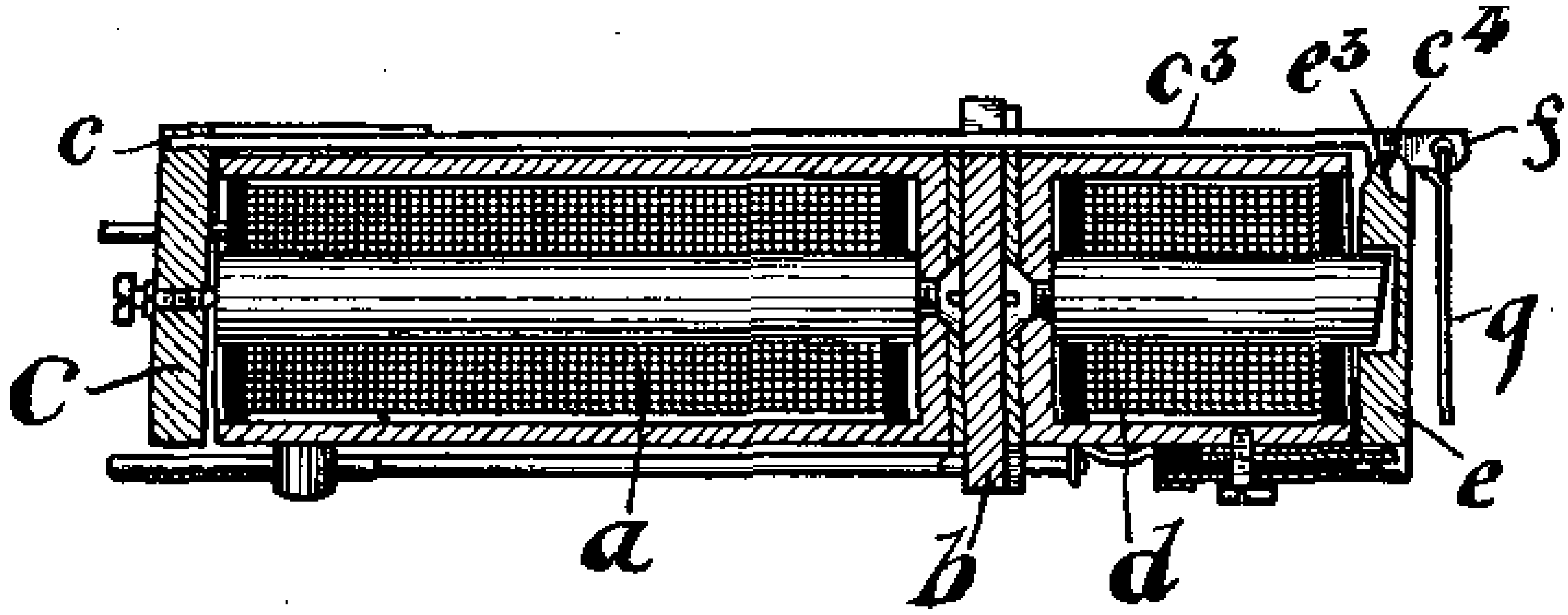


Fig. 64. —Self-restoring Drop.

When the subscriber rings, the coil a is excited, the armature C attracted, and lever c^3 raised in the usual manner, allowing the shutter e to fall by gravity. Instead of being a thin piece of brass, shutter e is a thick block of iron having a hole in its center into which the core of the drop protrudes. In front of this shutter is a very light aluminum flap g. As e falls, g is raised disclosing a signal painted on the front of e. Shutter e moves but a short distance, so if coil d is excited, the magnetism developed in the core will retract e to its normal position, and allow g to drop, concealing the signal. Further, so long as coil d is excited, e is locked in place, and no false signals can be displayed.

Fig. 65 shows an enlarged sectional view of the plug,

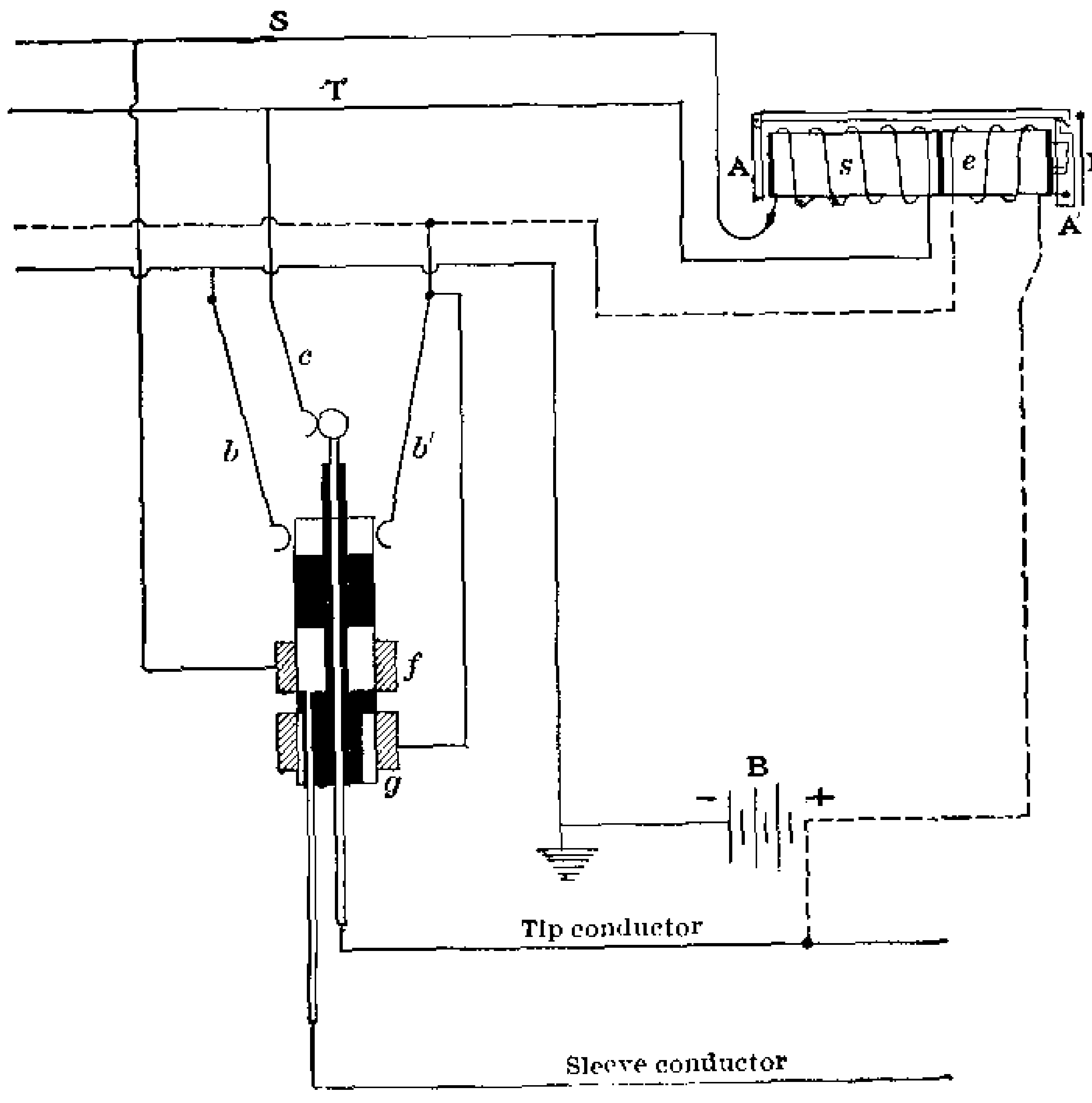


Fig. 65.—Restoring Circuit Branch Terminal Board.

jack, and drop, from which the circuit which restores and locks the drop shutter may be readily traced.

The cord circuit of the branch terminal switchboard is illustrated in Fig. 66, from which with Figs. 63 and 65 the busy test may be traced. These illustrations show that the tip of each plug and the g ring of every jack are nor-

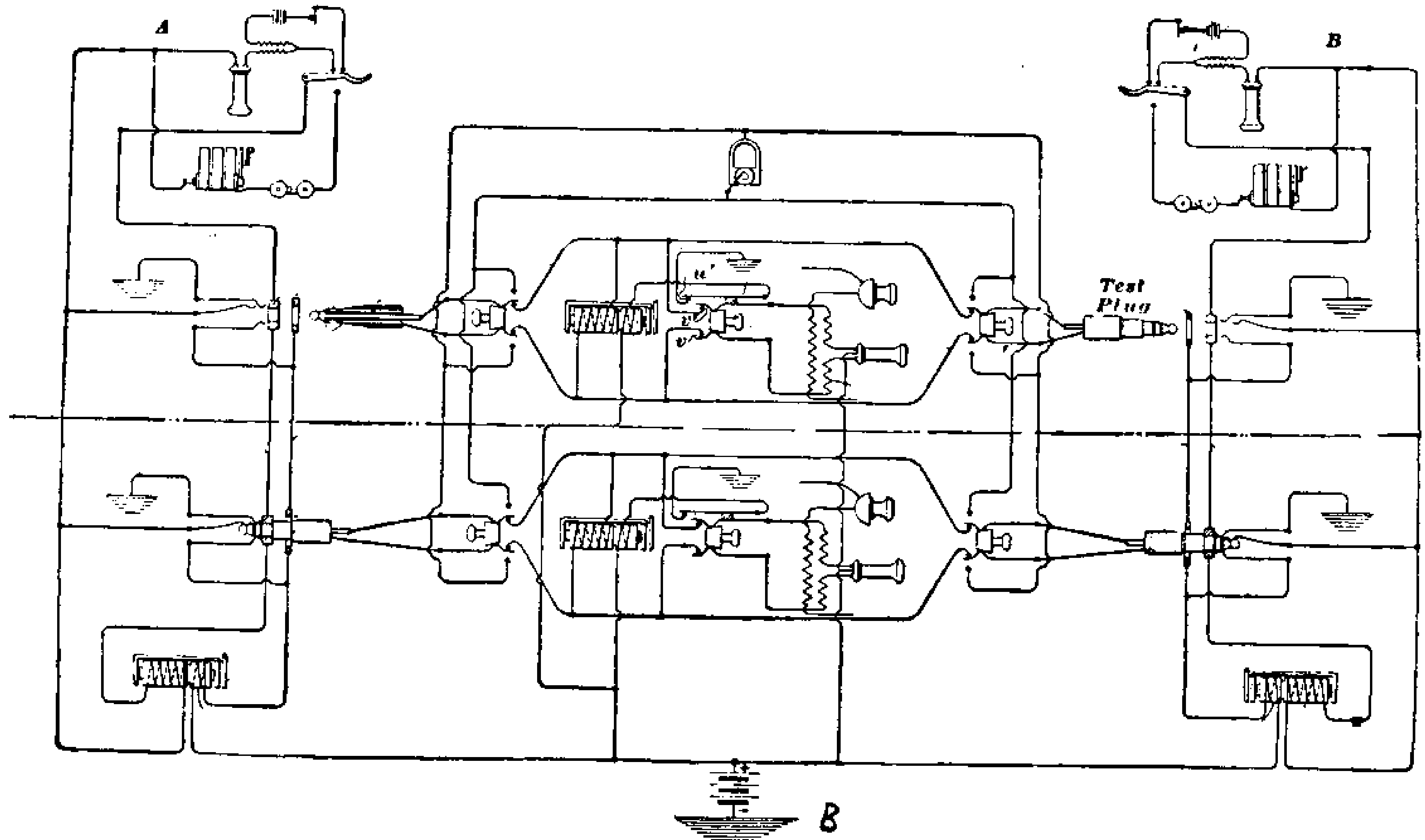


Fig. 66.—Cord Circuit Branch Terminal Board.

mally connected to the same pole of the battery *B*. Hence if the tip of a plug touch ring *g* of an idle line no sound

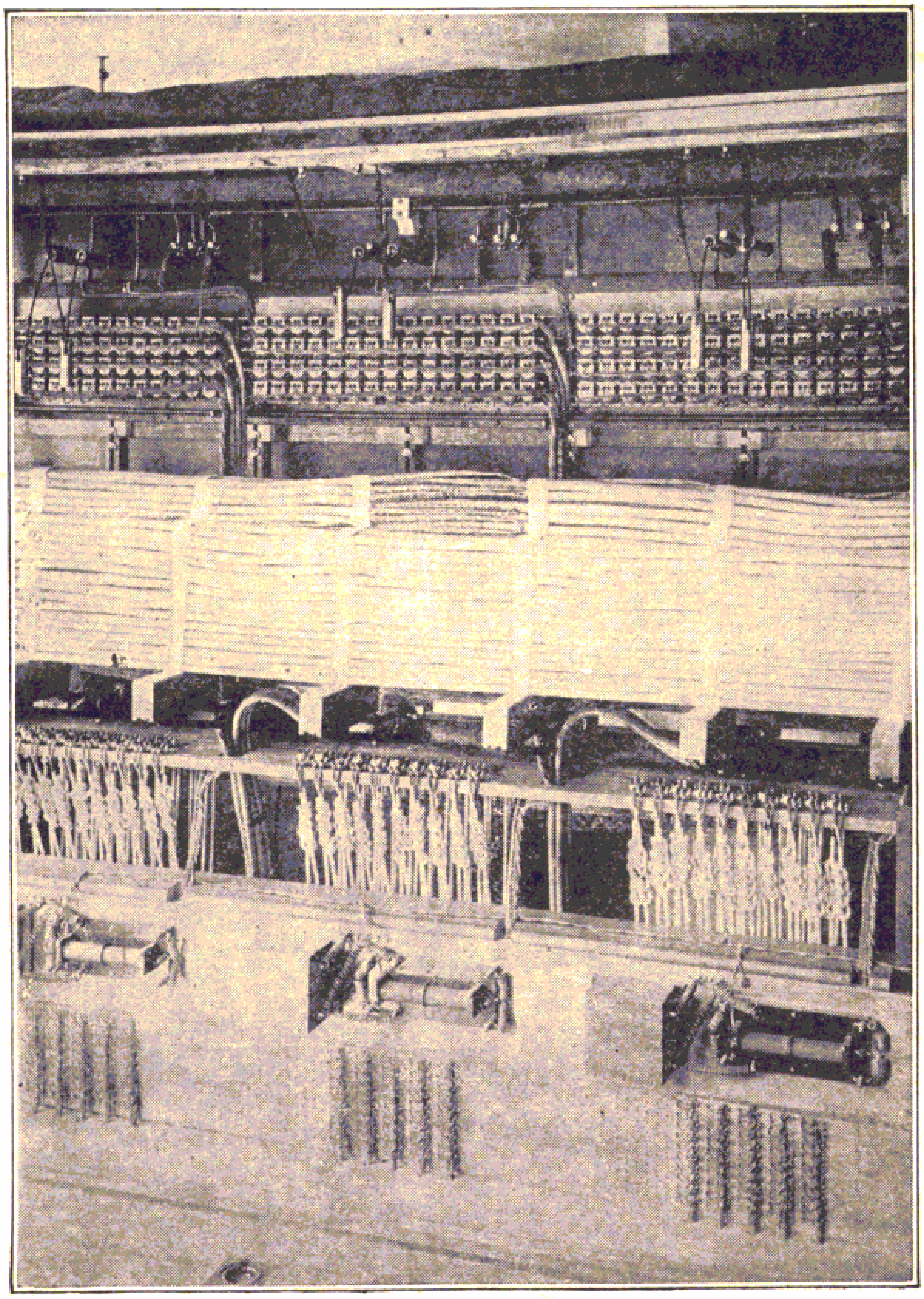


Fig. 68.—Rear View of a Branch Terminal Board.

will be emitted by the receiver, for both ring and tip are at the same potential. When a jack is plugged, springs *b* and *b′* are connected by the jack ring. But spring *b* is

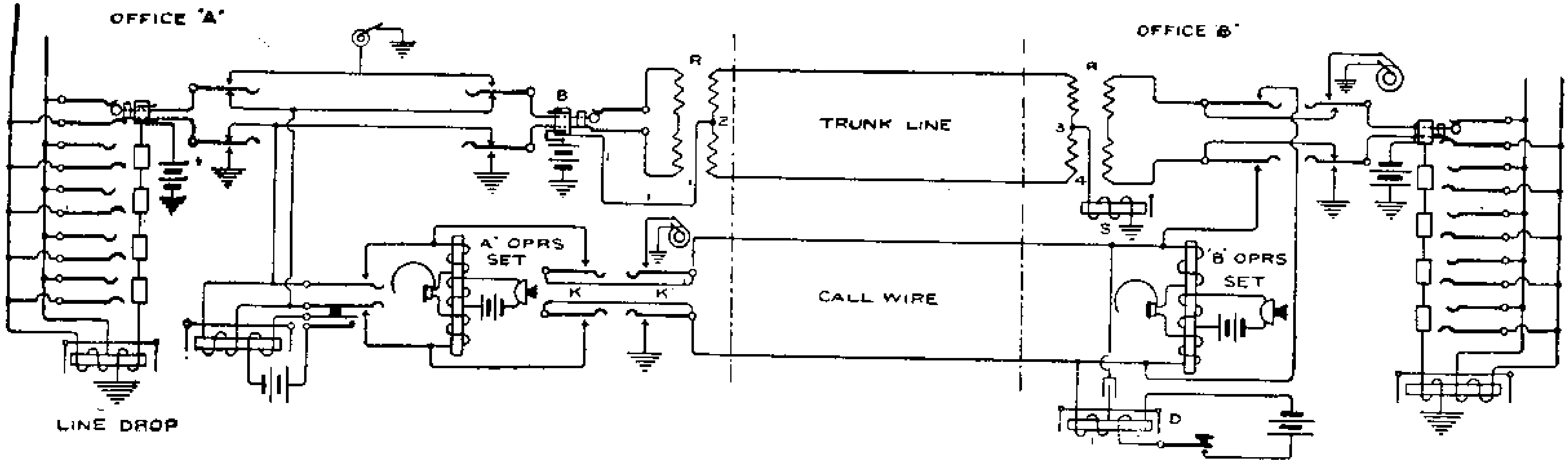


Fig. 69.—Trunk Circuit Branch Terminal Board.

grounded, hence ring *g* will be grounded and its potential lowered. The operator's receiver is bridged across the line, when testing, with a grounded center, hence when the tip of the plug touches a grounded ring the receiver clicks.

Fig. 68 shows the rear view of a branch terminal board.

Fig. 69 shows a trunk circuit frequently employed with the branch terminal system, and a modification employing simpler jacks, having two springs and one ring. The long springs are bridged to one side of the line (the sleeve), the short ones to the other (the tip), forming the talking circuit. The rings are in series with the drop, restoring winding and the ground. One pole of the office battery goes to the plug ring, the other to ground, so as soon as the operator inserts an answering plug the restoring winding is excited and the drop locked. Normally the rings are grounded, and the plug tip is neutral. A busy line has battery on the ring, and the test is made as usual with a split receiver. Each cord is supplied with an order-wire key *K*, whereby the operator may bridge her telephone upon the order wire which ends in the talking set of the "B" operator at the incoming trunk office. The order wire is also supplied with a self-restoring drop *D*, which may be operated by the key *K′*, so that at night, or when the "B" operator is not wearing her receiver, the "A" operator may signal.

The trunk line is split into three parts by means of two repeating coils, *R* and *R′*, partly to render the line quiet when connected to grounded subscribers, and partly for ease in giving a disconnect signal by furnishing what has been termed a *phantom circuit*. From the trunk jack ring *B*, a conductor 1 runs to the center 2 of the trunk line side of the repeating coil in the originating office; while from the center 3 of the trunk line side of the repeating coil in the incoming trunk office, a conductor 4 passes to a signal 5 and to ground. After the "B" operator has assigned the trunk to the "A" operator, the "A" operator inserts the connecting plug into the trunk line jack. This connects battery and the ring, whence it flows to the center of the trunk line side of the repeating coil, divides, flows equally over both sides of the trunk line to

Fig. 70.—Target Signal.

the center of the coil in the incoming trunk office, then to the signal, to ground, and back to the originating office. The signal is the target type (see Fig. 70), consisting of an electro magnet furnished with a pivoted armature. When the magnet is excited, the armature is attracted and a disc conspicuously colored made visible. So long as the connecting plug is in the trunk line jack at the originating office, this busy signal will be displayed because the battery current flows over the trunk. But as the current splits equally over both sides there is no interference with conversation. When the clearing-out drop in the "A" office indicates that the subscribers have finished, the "A" operator removes both plugs; the target signal disappears, indicating to the "B" operator that the trunk is free.

The invention of the multiple board produced a marked effect in economizing cost of operation and in improving service. So telephony developed with great rapidity, with a tendency to concentrate large numbers of subscribers in single offices. But there is a limit, because, as soon as the number of jacks becomes so great as to make it impractical to place all lines within the reach of every operator, the multiple system fails, and some transfer method becomes necessary. To carry the multiple principle as far as possible, the greatest ingenuity has been exercised in devising jacks to occupy the smallest space, and in packing them with great compactness in strips, so that a very large number can be concentrated in front of the operator.

Figs. 71, 72, and 73 are examples of modern methods of jack construction. Fig. 71 shows two-point jacks, designed for multiple switchboards, mounted in strips of 20. The strip is of hard rubber, drilled and slotted to receive the rings and springs, which are respectively of brass and hard German silver. Such jacks are mounted on $\frac{1}{2}$-inch or $\frac{3}{8}$-inch centers or may be even reduced to $\frac{5}{16}$-inches. Fig. 72 shows four-point jacks of the cut-off type, having platinum contact German silver springs. The illustration shows the mounting used for answering jacks, ready for association with the line signal jacks. Fig. 73 is a five-point jack, but economy of design has been carried far enough to arrange these upon $\frac{1}{2}$-inch centers.

The quantity of equipment of a multiple switchboard depends upon two different factors, the number of answering jacks and signals depends solely upon the number of lines, while the number of multiple jacks depends upon the number of operators, which varies as the amount of traffic.

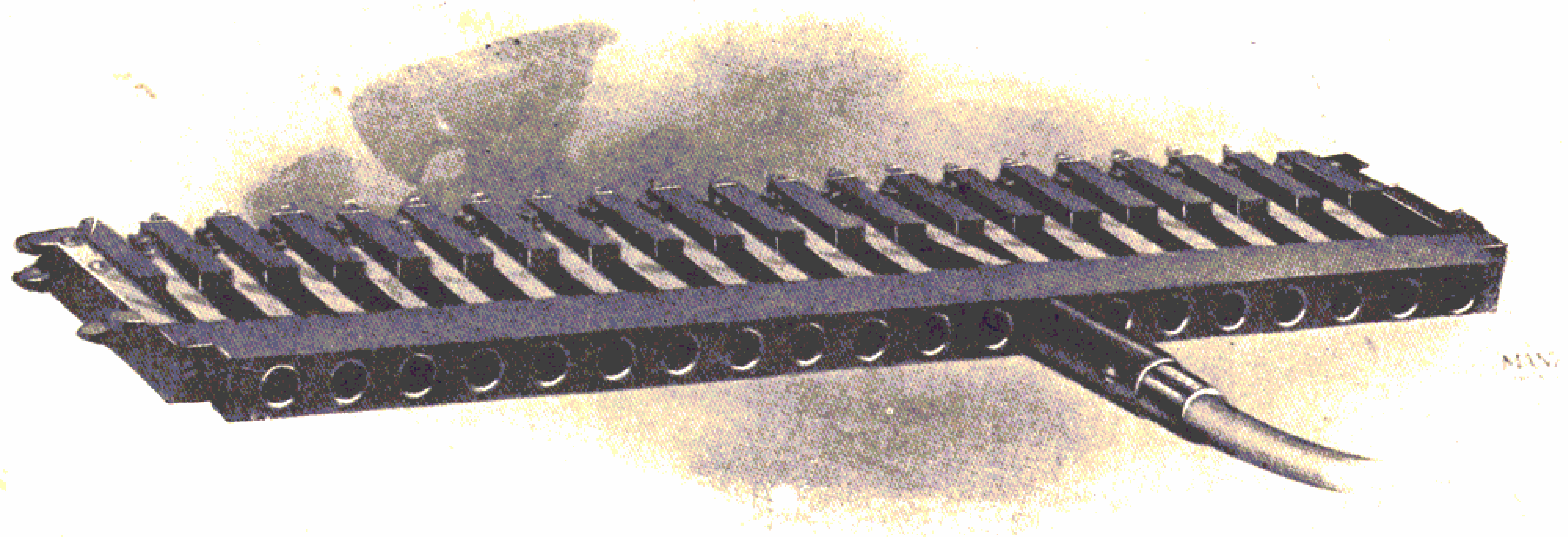


Fig. 71. — Two-point Multiple Jacks.

For example, assume an exchange of 1000 lines in which the average rate of originating calls is 6, and suppose that each operator can answer 1000 calls per day. As there are 1000 lines there must be 1000 answering jacks and signals. The total number of originating calls per day will be 6000, and if each operator answers 1000 calls, six operators will be needed. Suppose that the originating calls average 16 instead of 6, there will then be 16,000 calls per day, and at the same rate 16 operators will be required. Evidently the number of line signals and answering jacks has not been changed, but the number of multiple jacks must be increased to place each line within the reach of 16 operators instead of 6.

Modern switchboards consist of a substantial iron frame which is subdivided into panels into which the apparatus is placed. It is customary to design the frame so that a full multiple will occupy either 5, 6, or 7 panels, depending upon size and style of jack, and hence switchboards are frequently designated 5, 6, or 7-panel boards, indicating thereby the number of panels which are required for one multiple. Practice has settled to the idea of arranging the multiple to cover the space occupied by three positions, so that the middle operator sits in front of the second third of the multiple, has the first third on her left hand, and the third third on her right. Therefore, in order that all operators shall have access to every line, it is essential to provide an extra one-third section of multiple jacks for each operator at the ends of the switchboard. To determine the number of multiple jacks required, it is necessary to estimate the number of operators. This number divided by 3 gives the total number of complete

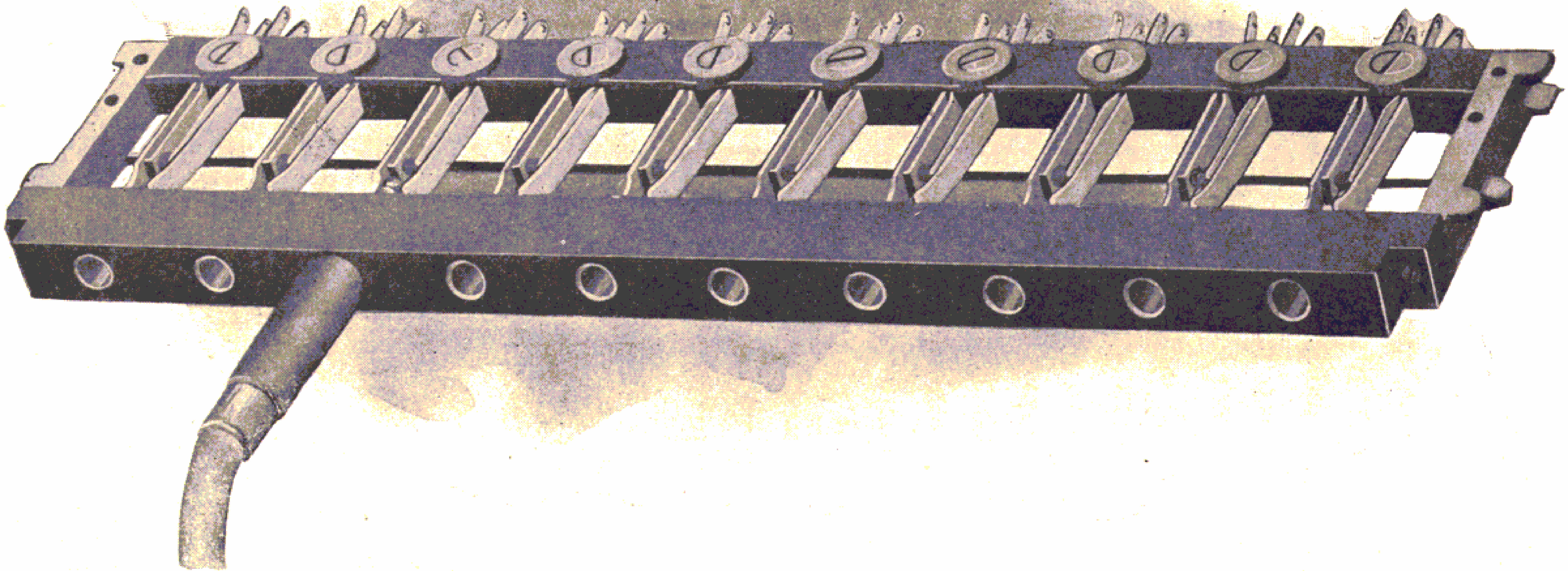


Fig. 72.—Four-point Answering Jacks.

multiples; to this add two-thirds of a multiple to care for the end sections, then the number of lines multiplied by the number of multiples plus two-thirds of one multiple will give the total number of multiple jacks. For incoming trunk service, where operators work at higher rates of speed, it is sometimes customary to use a two-operator multiple in order that there shall be less interference between adjacent operators.

The chief objection to the multiple board is the expense of the large number of multiple jacks which are required in offices of magnitude. To economize, all sorts of transfer systems have from time to time been devised. In some instances the board has been cut into two parts, half of the subscribers being located in one section and half in the other. In each section a subscriber's answering jack and signal is provided, and the substation is so arranged that the subscriber can signal either section at pleasure. By this means the number of multiple jacks is reduced, but double the number of answering jacks and signals are required, and experience has shown that subscribers are so prone to signal the wrong section of the board as to make this method of doubtful expediency.

Experience has shown that "B" operators can handle more calls per day than "A" operators, so the expedient has been tried of placing the subscribers' terminals before an "A" operator who shall answer, take the order, and transfer the call to "B" operators placed in front of a multiple. This produces an economy in cost of installation, but is open to the disadvantages of any transfer system. It has been usually argued that as a transfer system requires the coöperation of two operators, service is more

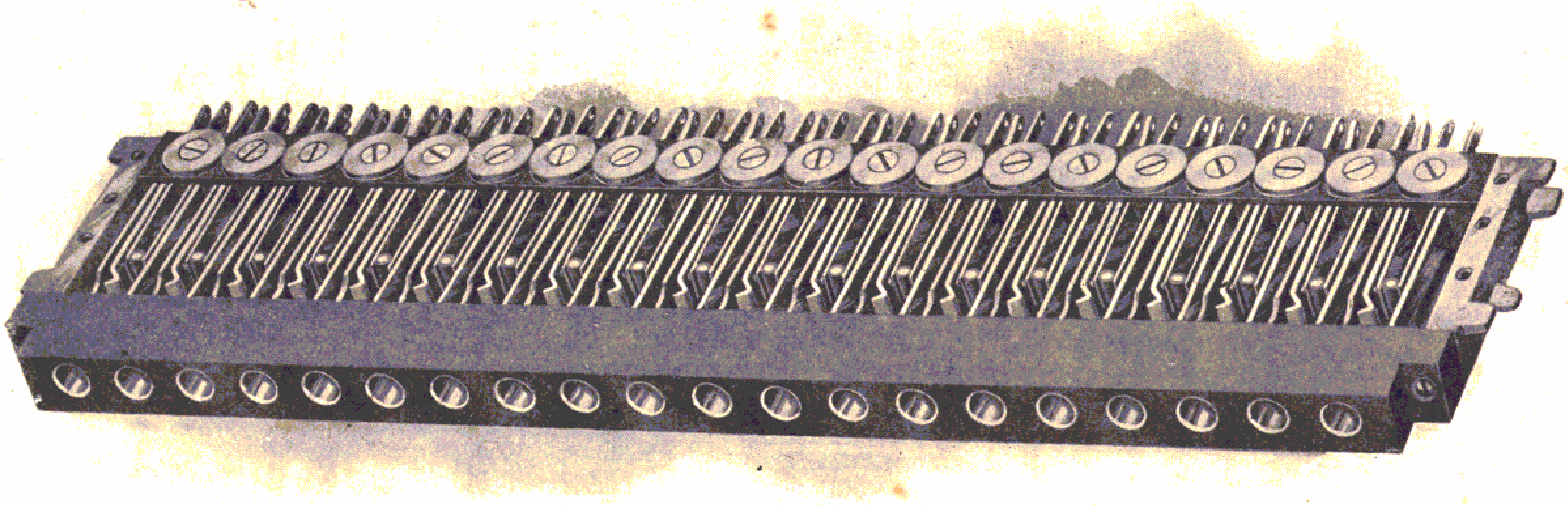


Fig. 73.—Five-point Multiple Jacks.

expensive; but it is found that office management is a more important factor in regulating expense than the coöperation of two operators versus the interest and depreciation on the cost of multiple jacks, for careful statistics show that the expense of handling calls in offices of approximately the same size, whether on a multiple board or a divided board, are closely the same.

The business of a telephone exchange varies from minute to minute and from hour to hour, so if a method could be devised whereby the load on each answering operator could be equalized, enabling all to work at a steadier rate, much more business could be accomplished at a lesser expense. Many transfer systems have been suggested for the solution of this problem, of which the most notable is the so-called *Sabin express system.* The subscriber's signal is placed before an operator, also furnished with trunk lines extending to the other operators. These are equipped with busy signals to indicate whether an operator is or is not engaged. When the subscriber's signal is displayed, the operator in front of whom it appears transfers the line to any disengaged operator. The first operator is often termed a "Y" operator, the second an "A" operator, because the latter takes the subscriber's order and by means of a trunk line extends the subscriber's line to a "B" operator, in front of whom the jack of the desired subscriber appears. Then the last operator completes the connection. Apparently, the operating load could be steadied, more work accomplished at cheaper rates, and the cost of the multiple jacks saved. But under the fire of experience neither this nor any other transfer system has succeeded in competition with the multiple. This is doubtless partially owing to a reduction in the cost of multiple jacks. Formerly jacks and cable were rated at $1.00 to $1.25 each, whereas now the price has fallen to 25 cents. This has reduced installation expense and consequently stimulated the development of multiple switchboards.

CHAPTER V.

COMMON BATTERY CIRCUITS.

THE most radical change in telephonic engineering was accomplished by the introduction of the common battery automatic-signal switchboard. One of the earliest installations, on a large scale, was operated in Philadelphia six to eight years ago. Since that time nearly all large switchboards have been replaced by or changed to common battery boards. As the common battery board supplies the substations with electrical energy from a central battery, the expense of installing and maintaining local batteries is removed, the cost of substation maintenance largely reduced, the station simplified and cheapened by the omission of the magneto generator, and the operation of calling and clearing-out reduced to the mere removal and replacement of the receiver. In the switchboard the clumsy and inconspicuous drops have changed to lamps; the operator relieved from the work of replacing the shutter, and provided with a signal whose conspicuousness is far superior, thus reducing cost of operation and improving and expediting service.

The circuits now largely used by the Western Electric Company are shown in Figs. 74, 75, and 76. Consider Fig. 74 the subscribers' line circuit. From the substation the line proceeds to the exchange, passes through main distributing board, and thence to the intermediate board.

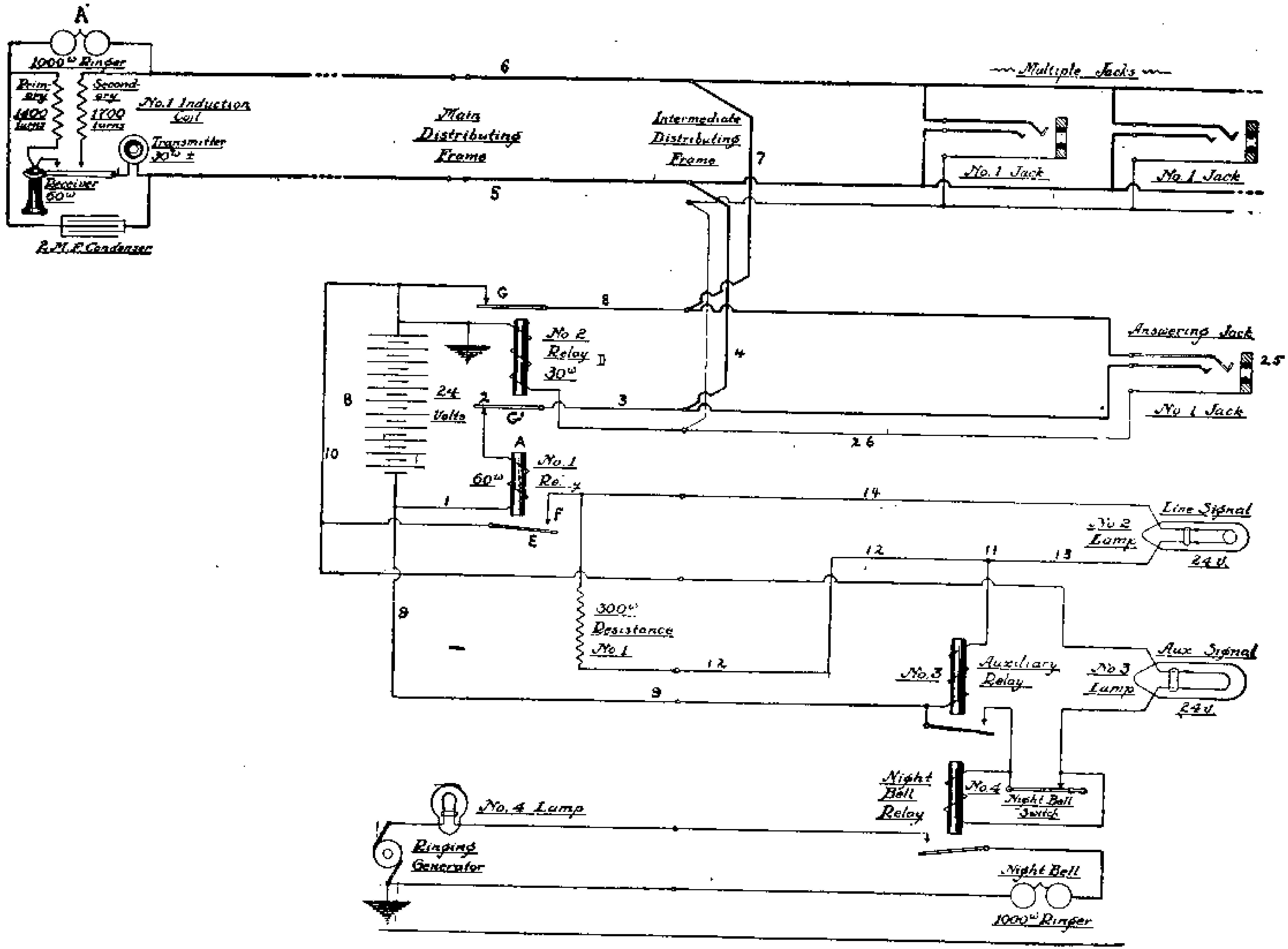


Fig. 74.—Subscribers' Circuit Common Battery Board.

Here there are three terminals, and thence each line consists of three conductors. One side extends to the tip spring of the jacks, the other to the sleeve spring, while the third wire runs to the jack ring. The line equipment consists of an answering jack, a line relay *A* and a cut-off relay *D*. So long as the receiver is on the hook, the line is opened to continuous currents by the condenser. When the receiver is removed, current flows from battery *B* through conductor 1, the winding of line relay *A* contact 2, conductors 3, 4, and 5 to substation, returning by conductors 6, 7, and 8 to contact *G* to battery. The relay *A* is excited, armature *E* attracted, contact *F* closed, completing a circuit from battery *B* by conductor 9 and the auxiliary relay to point 11. Here the current divides, one portion returning to the battery by conductor 12, the 300-ohm resistance, contact *F*, and conductor 10, while the other passes by conductor 13, the line signal lamp, and conductor 14 to contact *F* and to the battery. Thus the line signal lamp is illumined. The auxiliary relay closes the circuit through the night bell relay and auxiliary lamp signal. As the auxiliary relay is in parallel with the line signal the operation of this relay is entirely independent of the lamp, so if this lamp fails the auxiliary relay is still operative and illumines the auxiliary signal, hence every call signal is in duplicate, and the probability of the operator failing to receive a call due to imperfect apparatus reduced to a minimum. The night bell switch short-circuits the night bell relay, which may thus be out of commission during the day.

The cord circuit is in Fig. 75. When the operator perceives a signal lamp, she inserts one answering plug *P* in

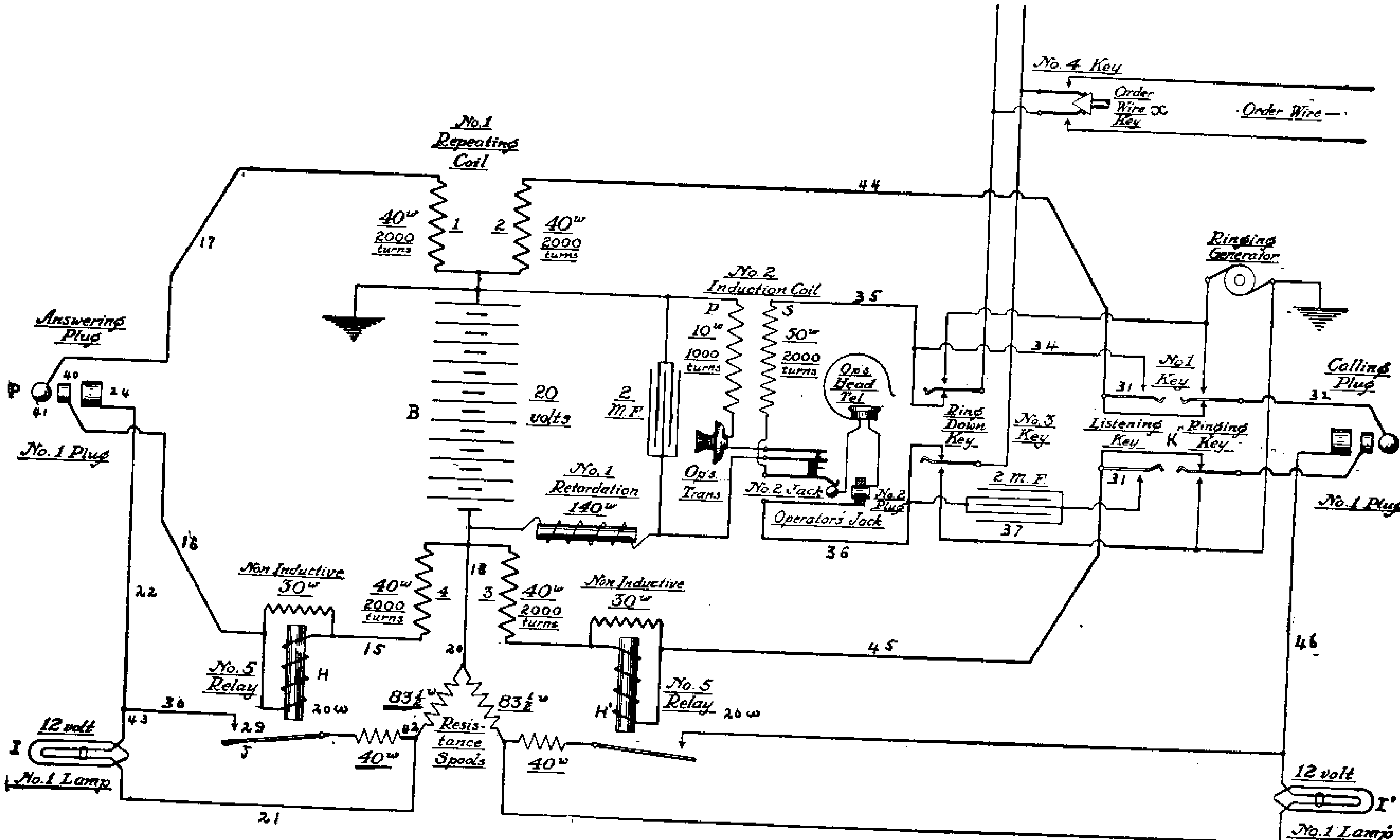


Fig. 75. — Cord Circuit Common Battery Board.

the jack associated with the lamp. When the plug reaches the jack springs, current flows from battery *B*, through the repeating coil winding 4, conductor 15, supervisory relay *H*, conductor 16, the sleeve of plug 40, and the sleeve spring of the jack to the substation and through the set, because the receiver is off the hook, back through the tip of plug 41, the conductor 17, winding 1 of the repeating coil to the battery. Current in this circuit excites relay *H*, which attracts its armature *J*, closes contact 29 to conductor 30. There is also a circuit from battery *B* through conductor 18 and resistance 20 to point 42. Here current divides part, passing by the 40-ohm resistance to armature *J*, contact 29 and conductor 30 to point 43, the rest passing by conductor 21, lamp *I* to point 43, where uniting with the current in conductor 30 it passes through conductor 22, the ring of plug 24 to conductor 26, Fig. 74.

The current in conductor 26 excites relay *D* which attracts its armatures *G* and *G′*, opens the circuit and cuts off the line, relay *A*, the line lamp, and all other apparatus. Furthermore, as relay *H* closes contact 29, it places a shunt around supervisory lamp *I* which is thereby prevented from lighting. After the operator inserts the answering plug, she bridges her telephone across the circuit by the listening key 31 and takes the order. She then tests by touching the tip of the connecting plug *P′* to the ring of the jack of the called line. So long as a line is disengaged all the rings are grounded through conductor 26 and the relay *D*, the plug tip is grounded through conductor 17 and the winding 1, hence to touch a plug tip to an idle line produces no sound in the receiver. If a line is busy, battery is placed upon the rings of all the

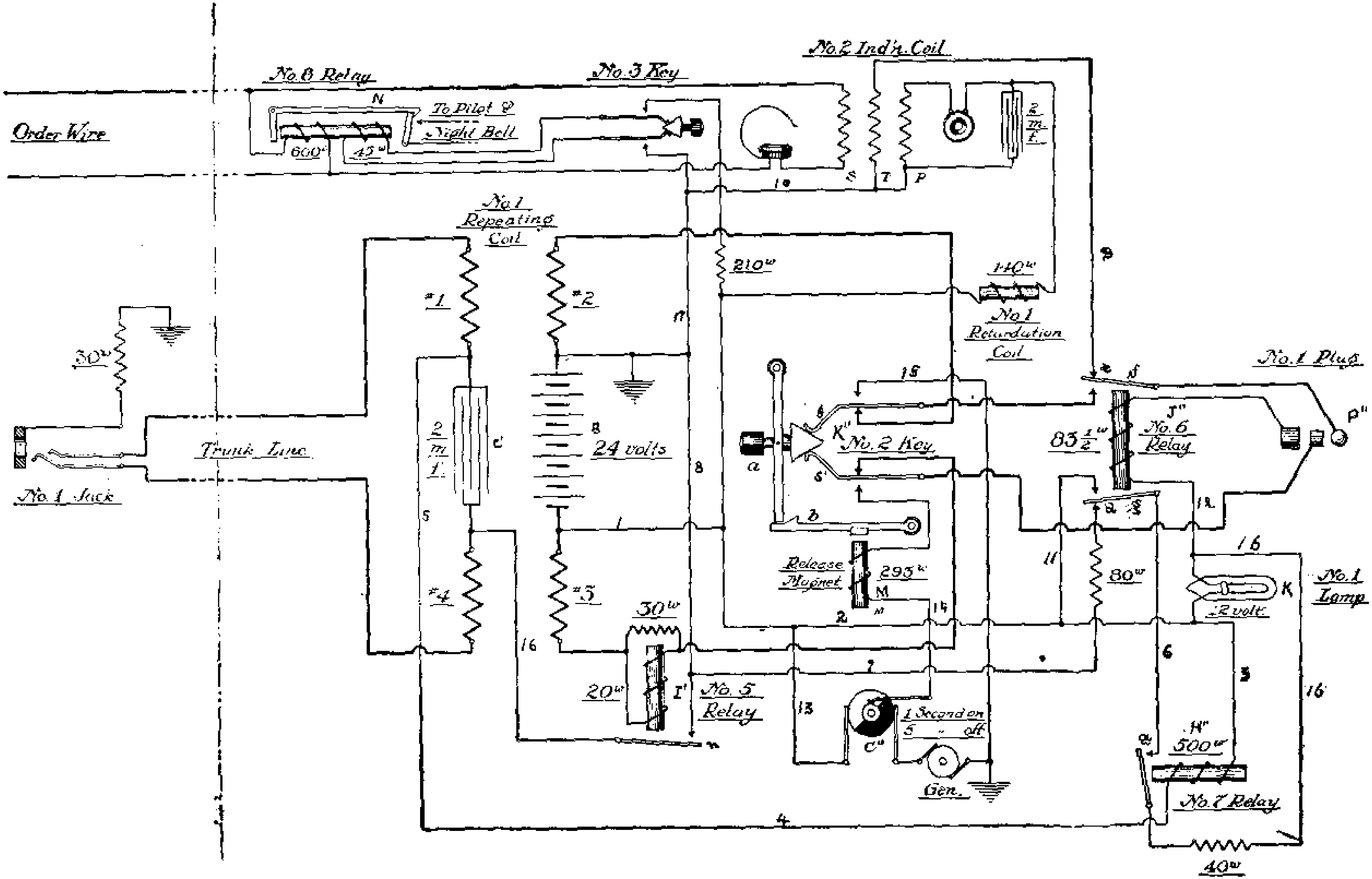


Fig. 76. — Trunk Circuit Common Battery Board.

jacks through the conductors 22, 21, and 30, resistance 20, and the conductor 18, so the potential of the rings of an engaged line is raised, and if one is touched with the tip of a connecting plug, there is a circuit from the plug tip P'' by conductor 32, listening key 31, conductor 34, conductor 35, secondary S of operator's telephone set, the head receiver, conductor 36 to condenser 37, thence to key 31, conductor 45 to the battery, and the operator's telephone emits a click. Assuming the desired line to be disengaged the operator inserts the calling plug P'.

This actuates the cut-off relay of the called line, cutting off the line relay and signaling apparatus. The operator then presses the ringing key K'', bridging the ringing generator across the line. So long as the called subscriber's receiver remains upon the hook, the supervisory lamp I' is illumined, because the circuit through conductor 45 is open at the substation condenser, the relay H' is unexcited and the lamp I' is not shunted. When the receiver is removed H' is excited and I' extinguished. As soon as either subscriber replaces his receiver the corresponding supervisory lamp lights, and when both are illumined the operator removes the cord. A consideration of this circuit shows: first, that the signaling apparatus is of a most conspicuous kind; second, its operation is only dependent upon the position of the subscriber's receiver; third, as it is in duplicate there is little possibility for error; fourth, as each subscriber has an independent supervisory signal, he completely controls the operator; fifth, that one battery supplies all the electrical energy to the substation, the signals, and the switchboard; sixth, all signaling is completely automatic.

The trunk circuit is shown in Fig 76, the operation being as follows: A subscriber in the "A" office calls a party in the "B" office. After the "A" operator obtains the order, she presses the order wire key *X*, Fig. 75, and speaks the number desired. The "B" operator nominates the trunk, and the "A" operator inserts the connecting plug *P'* into the jack designated. There is then circuit from battery *B* in the "B" office over conductors (Fig. 76) 1, 2, and 3, the 500-ohm relay *H''*, conductors 4 and 5, winding 1 of the repeating coil over the tip side of the trunk line to the tip of plug *P'*, Fig. 75, from there by conductors 32 and 44, winding 2 of the repeating coil to the grounded side of battery in the office "A." The 500-ohm relay *H''*, Fig. 76, is excited, attracts its armature, closes contact *a*, making the circuit from battery *B* by conductors 1, 2, and 12 volt lamp *K*, conductors 16 and 6, back contact *d* of relay *J''*, the 80-ohm resistance coil, and conductors 7 and 8 to the battery. Lamp *K* is illumined, notifying the "B" operator that the "A" operator has inserted the connecting plug into the proper trunk. The "B" operator then tests. If the line is engaged, current will flow from the jack ring to the tip of plug *P''*, back contact *e* of relay *J''*, conductor 9 through the tertiary winding *T* of "B" operator's induction coil, conductors 10 and 17 to the ground, causing the busy click. If disengaged the "B" operator inserts the connecting plug *P''*, making a circuit from the battery through conductors 1 and 2, lamp *K*, relay *J''* and the ring of plug *P''*, through the cut-off relay of the called line to the ground and the battery. The cut-off relay is excited and removes the subscriber's line relay and signal. Also relay

J'' is excited, its armatures f and g attracted, completing their front contacts. The armature f completes the tip side of the line from the battery through winding 2 of the repeating coil and spring s of the machine ringing key K''. The armature g completes a circuit from the battery via conductors 1, 2, 11, 6, and 16 around lamp K, forming a shunt about this lamp and extinguishing it. At office "A" the ring of the outgoing trunk jack is grounded through 30 ohms, so when the connecting plug is inserted into the jack its ring is grounded through this coil, which takes the place of the subscriber's cut-off relay, and causes the supervisory lamp I' of the "A" to light. After the "B" operator inserts the connecting plug, she pushes button a of the machine ringing key K''. The springs s and s' then bridge the ringing generator and interrupter across the line by conductors 14 and 15.

The interrupter c'' consists of a revolving disc containing a conducting and an insulating segment, the object being to give the called subscriber an intermittent ring, for a continuous one is annoying. The segments are usually proportioned to ring for two or three seconds, and interrupt for from five to eight seconds so subscriber's bell will ring intermittently. So long as the receiver is in place the bell and condenser offer a resistance of about 13,000 ohms. When the receiver is removed the resistance is reduced to from 80 to 100 ohms. There is a circuit from battery by conductors 1 and 13, the interrupter, conductor 14, release magnet M, to the sleeve side of the line and return by the tip side, spring s, and conductor 15 to the battery and the ground. Consequently, when the subscriber removes the receiver the release magnet M is instantly excited, key K''

tripped, and the ringing current shut off. So long as the receiver is on the hook the line is opened by the substation condenser, and the 20-ohm supervisory relay I' will not be excited; when the receiver is removed, current flows through winding 3 of the repeating coil, through the 20-ohm relay I' over the sleeve side of the line, back over the tip side through winding 2 of the repeating coil to the battery. When relay I' is excited, closing contact n, current flows from the battery in office "A," Fig. 75, through relay H', conductor 45 to the sleeve of the plug P'', over the sleeve side of the trunk line, through winding 4 of the repeating coil, conductor 16, to the armature of relay I', conductor 8 to the ground and back to the "A" office battery. This causes the supervisory relay H' in office "A" to shunt out the supervisory lamp I' informing the "A" operator that the subscriber in the "B" office answered. When either party replaces his receiver a corresponding supervisory lamp lights in front of the "A" operator. When both lamps light the "A" operator removes the plugs, then the ground at the "A" office is taken off of the 500-ohm relay H'', its armature retracts, removing the shunt from the supervisory lamp K which is illumined, giving a disconnect signal to the "B" operator, who then removes the trunk line plug. The order wire is furnished with a relay N whereby the "A" operator can ring, in the usual manner, the "B" office in case the head telephone has been removed from the ear of the "B" operator. The various relays included in the talking circuit are shunted with non-inductive resistances, usually of 30 ohms, thus their presence does not impair its conversational powers, while the shunts possess sufficient resistance to secure to the relays the necessary sensitiveness.

The objections to the preceding common battery circuit are: the employment of a jack requiring three contacts;

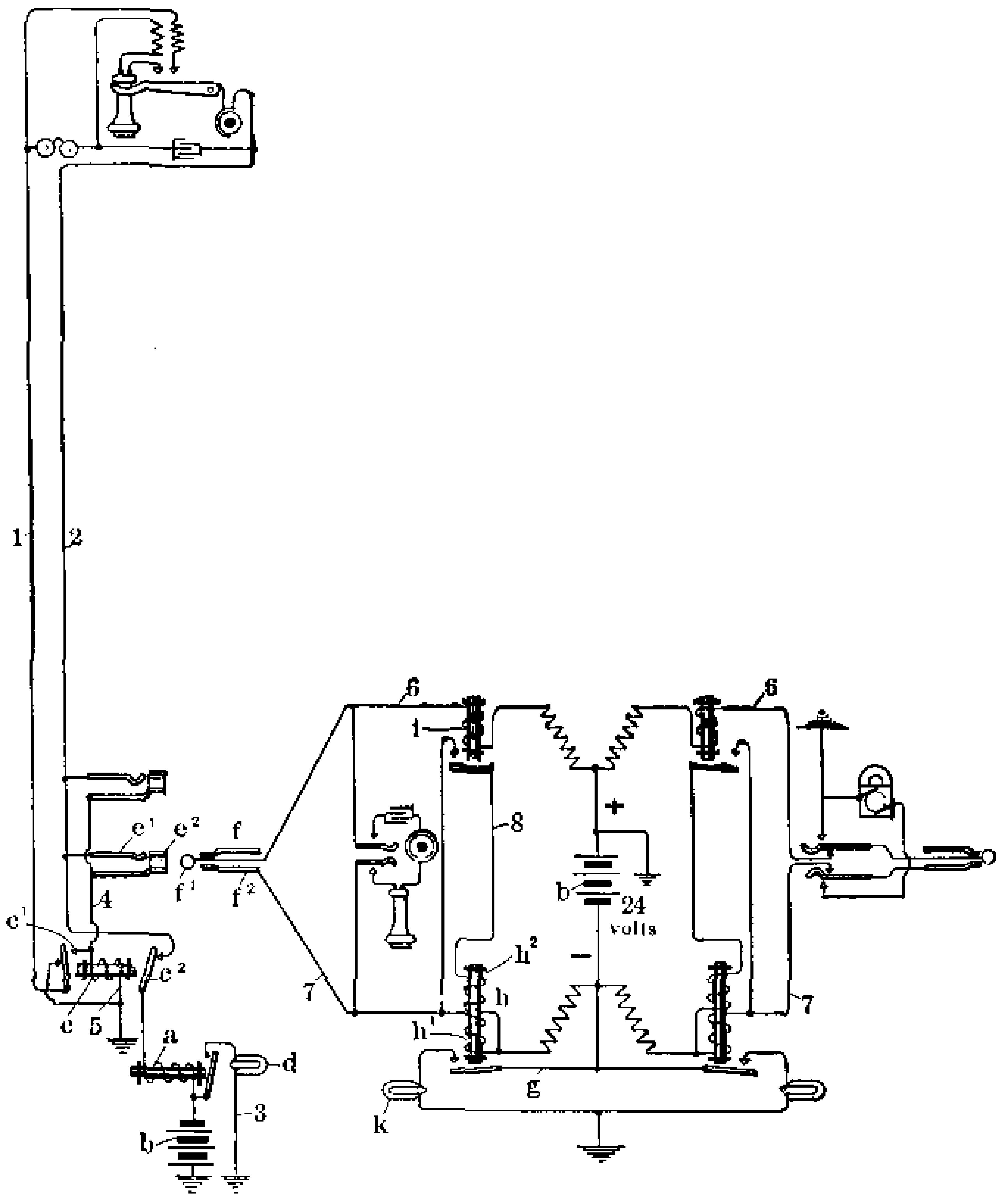


Fig. 77.—Two-wire Common Battery Circuit.

the use of triple-wire cable; the circuit necessitates three conductors with correspondingly complicated plugs and cords; the extinguishment of the supervisory lamps by shunting them; loading the battery heavily during conversation. Many attempts have been made to simplify this system, a typical example being shown in Fig. 77. The jacks are of the two-point type having a spring e' and a sleeve e^2. The cut-off relay c has two armatures c' and c^2, and three contacts. The cords and plugs have two conductors. There are two supervisory relays in each cord conductor, those in the sleeve conductor being differentially wound. The operation is as follows: The subscriber calls by removing the receiver, thereby closing signaling circuit over conductors 1 and 2, the relay a is energized and completes the local circuit through conductor 3 and illuminating the line lamp d. The operator inserts answering plug f, completing a circuit from battery b, through conductor 7, the sleeve f^2 of plug, jack ring e^2, conductor 4, cut-off relay c which attracts its armatures. Armature c^2 opens the circuit of relay a, extinguishing the line lamp. Contact c' of the cut-off relay closes the talking circuit from the rings e^2 through conductor 4 to contact c', and conductor 1, thus short-circuiting the cut-off relay. A metallic circuit can now be traced from the positive pole of battery b through conductor 6 of the cord circuit, the tip f' of the plug, springs e' of the jacks, limb 2 of the telephone line, the substation apparatus back over conductor 1, contact c' of the cut-off relay, conductor 4, the ring e^2 of the jack, the sleeve f^2 of the plug, and conductor 7 to the negative poles of battery. When the receiver is on the hook the only circuit is from battery b through winding h', conductor 7, sleeve f^2, ring e^2, conductor 4, relay c, conductor 5 to the battery, hence relay h' is excited, its armature attracted, and disconnect lamp k illumined. If the receiver is off the hook the current from conductor 7 divides when it reaches c', a part going to the battery by the path already traced, and part going to the substation by conductor 1, returning by conductor 2, spring e', tip f'', conductor 6, relay i, which is excited and completes a circuit through conductor 8, including winding h^2 of relay h. Then as windings h' and h^2 are differential, relay h is neutral and lamp k extinguished. Normally the ring contacts of the jacks are grounded through cut-off relay c and hence at zero potential. The tip of the connecting plug is also grounded through relay i, hence touching the ring of the jack of the free line produces no sound in the operator's receiver. When the line is engaged, battery is placed upon the rings of the jack through conductor 7, and a test thus provided.

A still further simplified common battery circuit is shown in Fig. 78. The line conductor 1 includes winding of line relay a, shunted by the non-inductive resistance a' and runs to the battery b. Conductor 2 passes through winding d' of repeating coil d. An armature is added to this coil so that it is made to operate as a relay and hence is termed *a repeating coil relay*. From winding d' conductor 2 passes through resistance c and to battery b. The repeating coil relay contains two other windings d^2 and d^3 which are serially in conductor 3, from the jacks e to ground or a common return. One of these windings d^2 is normally short-circuited by the closed contact of relay a. The jacks consist of one spring and a ring. The repeating coil relay d is so designed that a certain magnetizing force will attract the armature d^6 and cause it to make contact with the lever d^4 without moving the latter. If this magnetizing force be augmented, the armature d^6 will be still further attracted and will cause lever

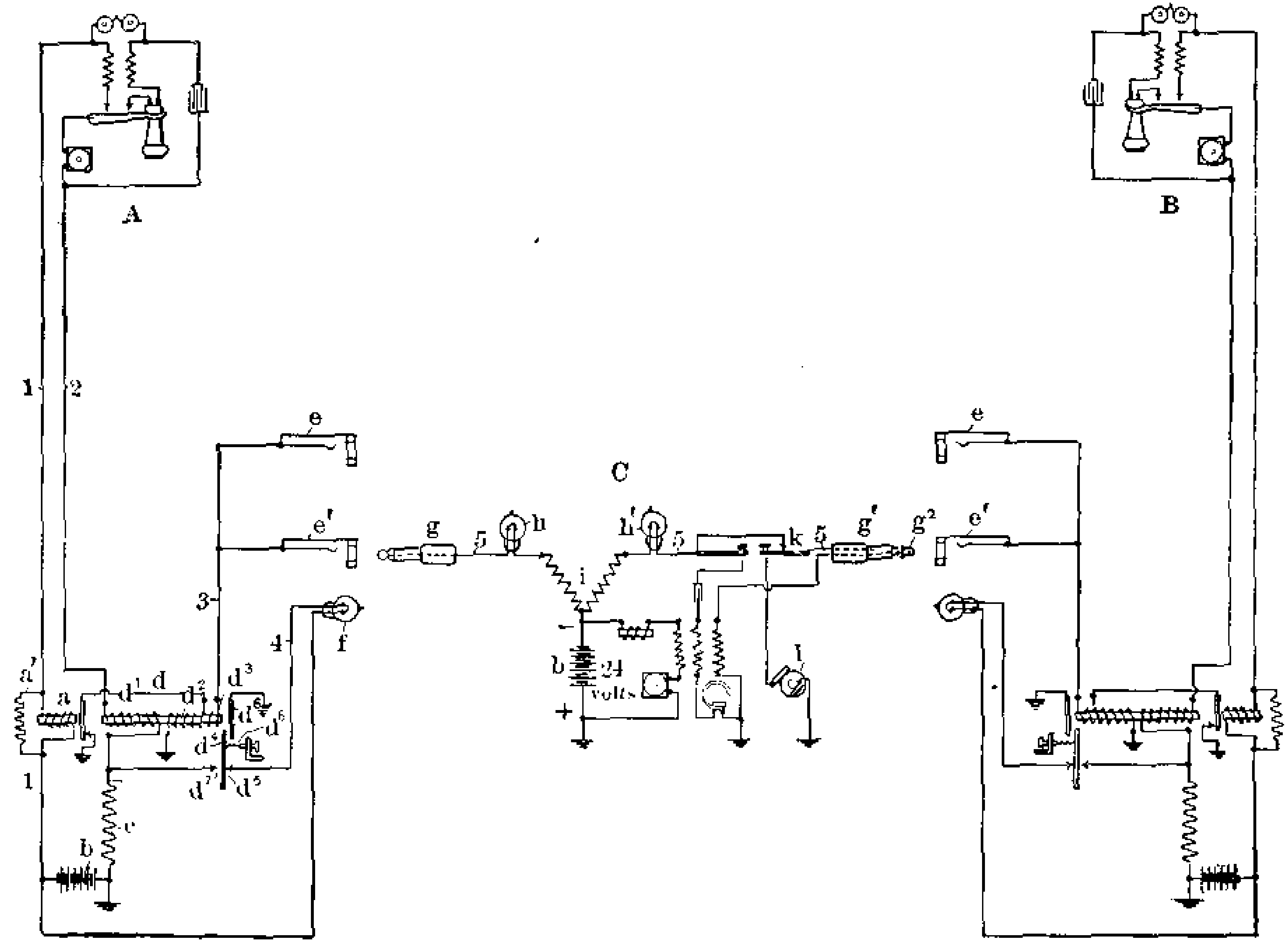


Fig. 78.—Single Wire Common Battery Circuit.

d^4 to move, opening contact d^5 and closing contact d^7. Proper adjustment is provided by a spring attached to lever d^4. Normally the rings of the jack are grounded through winding d^3. A test is provided by supplying the connecting plug g' with a special tip g^2, which is permanently grounded through the operator's head telephone. Touching this tip on a free line produces no sound. The insertion of the connecting plug places the battery on the rings, and then the touch of the contact point g^2 produces the usual click. The operation is as follows: The removal of the receiver provides a circuit from battery b through conductor 1, relay a to the substation, thence through conductor 2, to winding d' of repeating coil relay d, resistance c and to battery. Relay a attracts its armature and removes the short-circuit about winding d^2 of the repeating coil relay d. There is then only sufficient magnetizing force to attract armature d^6 into contact with lever d^4 without moving this lever from the point d^5. The signal lamp circuit is then completed from the battery via conductor 4, lamp f, contact d^5, armature d^6, and lamp f illumined. The operator inserts answering plug g into jack e, then there is a circuit from the battery via lamp h, conductor 5, conductor 3, winding d^3 and d^2 of the repeating coil relay in series with the battery. The magnetism of this relay is then augmented sufficiently to attract armature d^6 strongly enough to sever contact with d^5, opening the circuit of the line signal lamp f and short-circuiting the resistance coil c, thus diminishing the resistance of the circuit and further increasing the attractive power of the repeating coil relay. Under these circumstances the current which flows through conductors 3 and

5 is insufficient to illumine the supervisory lamp *h*. The windings d^2 and d^3 of the repeating coil relay are in magnetic relations with the winding *d'*, which is included in the substation circuit so the operator, by the listening key, can communicate with the subscriber and obtain the number desired. She tests, as already explained, and if the called line is free, inserts the connecting plug and rings by key *k*. The ringing current flows through winding d^3

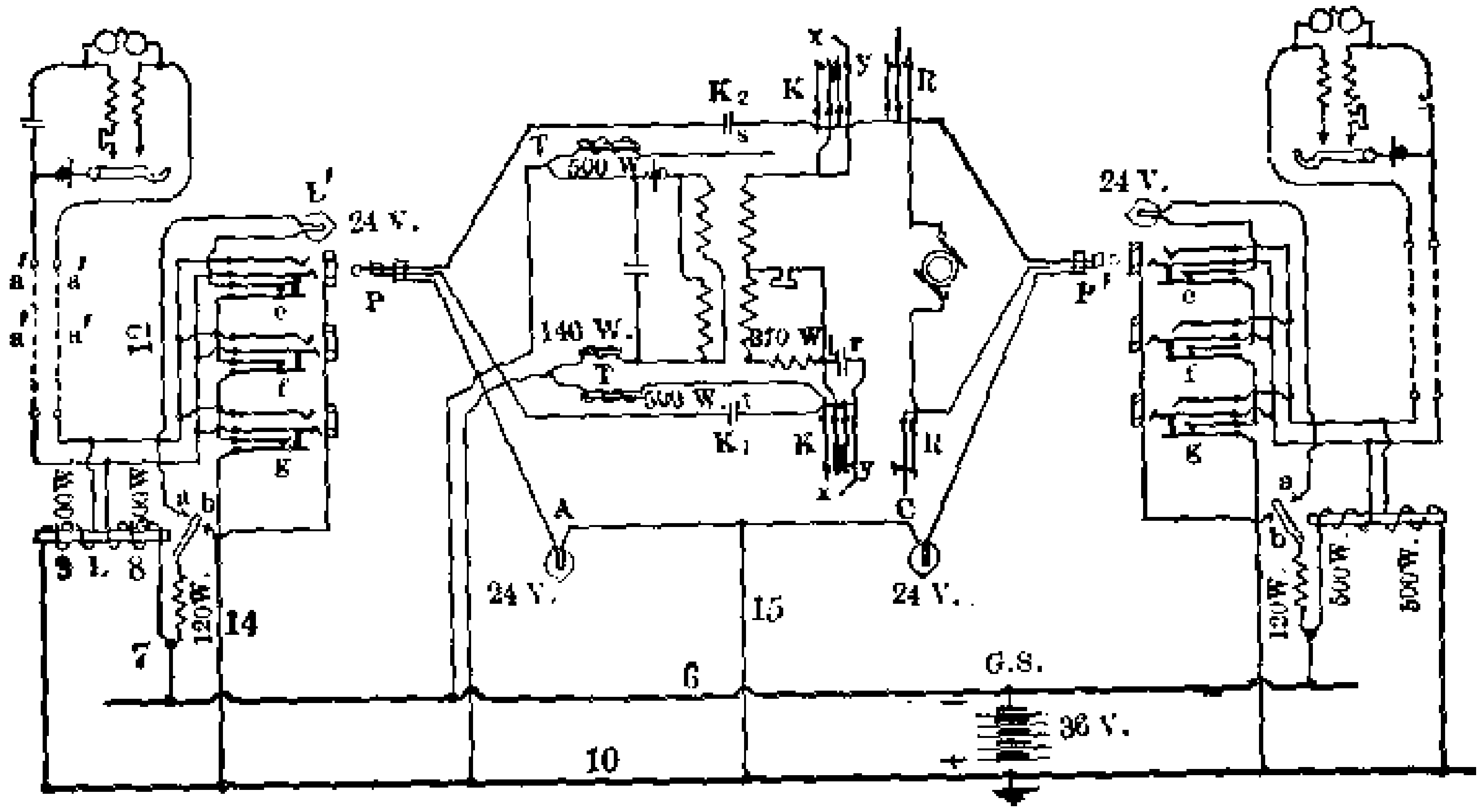


Fig. 79. — Jack Cut-off Common Battery Circuit.

of the repeating coil relay *d*, and produces current in winding *d'* which operates the bell at the substation. When the connecting plug is placed in the jack, and while the receiver is on the hook, current flows from the battery *b* through supervisory lamp *h'*, conductors 5 and 3, winding d^3 of the repeating coil relay and to the ground by the back contact of line relay *a*. The resistance is low, and sufficient current flows through supervisory lamp *h'* to illumine it. When the subscriber removes his receiver, relay *a* is excited, its back contact broken, winding d^2 of the repeating coil is inserted and the resistance of the circuit increased sufficiently to extinguish lamp *h'*.

Another circuit is in use among the medium-sized exchanges controlled by the Bell company in which a 36-volt battery is employed, and one relay with jack contacts to extinguish the line signals. Fig. 79 shows the circuit. When the subscriber removes the receiver, current flows to buss bar 6 to conductor 7, winding 8 of line relay *L*, conductor *a* through the substation, conductor *a'*, winding 9 of line relay *L* to buss bar 10 to the battery. The line relay is excited, its armature attracted, and contact *a* closed, completing a circuit through conductor 12, signal lamp *L'*, the contacts in the jacks and conductor 14 to the battery. When the operator inserts the answering plug *P* the tip of the plug opens the jack contact and extinguishes the line lamp, but the line relay is not deënergized. The supervisory lamps *A* and *C* are directly in series with the third wire of the cord and conductor 15. When the plug is placed in a jack these lamps are connected to the ring. If the receiver is off the hook, the line relay *L* is excited, contact *a* closed, and contact *b* opened. Then the supervisory lamp will not light; when the receiver is on the hook, relay *L* is deënergized, contact *b* closed, and the supervisory lamp illumined. The operator rings by the ringing key *R*. Normally all the jack rings are connected with negative pole of battery, and when the listening key is pressed the tip of the plug is connected with the same pole, hence an idle line causes no sound in the receiver. The ring of the plug connects the positive pole of the

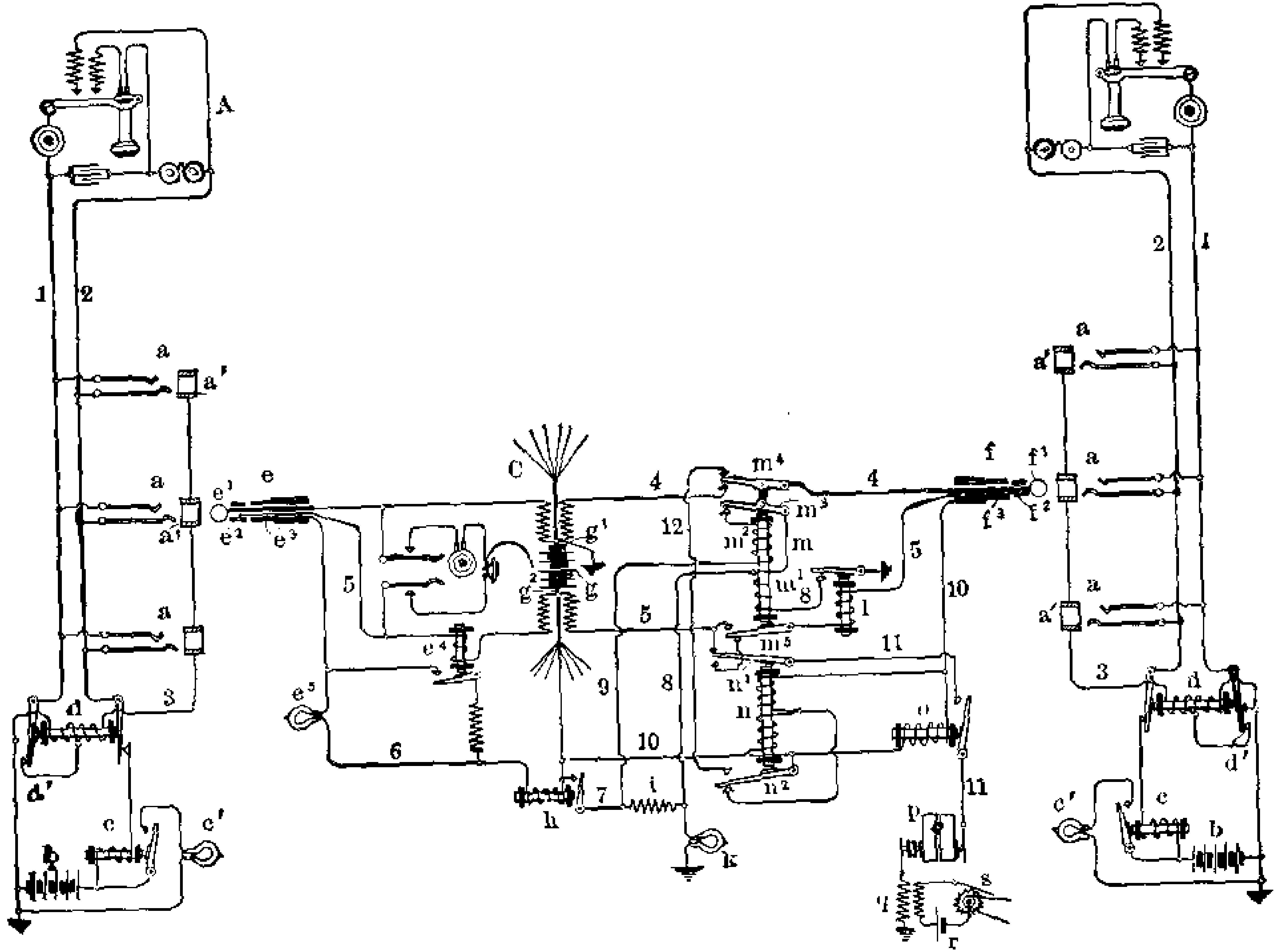


Fig 80.—Automatic Ringing and Testing Circuit.

battery to the rings of an engaged line and hence produces a busy signal.

The automatic signal-board soon proved itself so desirable that there has been a constant and an increasing tendency to devise circuits which should render its operation more and more automatic, simplifying and reducing the number of operations required of the operator, quickening her work, increasing her load, and cheapening cost of service.

The circuit shown in Figs. 80, 81, and 82 relieves the operator from testing, and reduces her work to three functions — the insertion of the plug; the taking of the order; and the removal of the plugs. Fig. 80 shows two subscriber's circuits and the connecting-cord circuit, while Figs. 81 and 82 show the path of the ringing current under different conditions. The substations *A* and *B* are connected in the usual manner, equipped with a cut-off line relay *c*, a signal lamp *c′*, and a cut-off relay *d*, similarly to the preceding circuits, excepting that the cut-off relay *d* is wound to a higher resistance, and is provided with back contact *d′* to one of its armatures which is tapped to the middle of the winding of the relay, so normally a portion of the winding is short-circuited. The answering plug *e*, the connecting plug *f*, the repeating coils and the battery are arranged as already described. A supervisory relay e^4, inserted in ring conductor 5, controls a shunt about the supervisory signal lamp e^5. Sleeve conductor 6 includes a relay *h*, which, when excited, closes a branch circuit 7 from battery *g* to the ground, through resistance *i* and supervisory lamp *k*. Four relays *l*, *m*, *n*, and *o*, are provided to control the automatic ring-

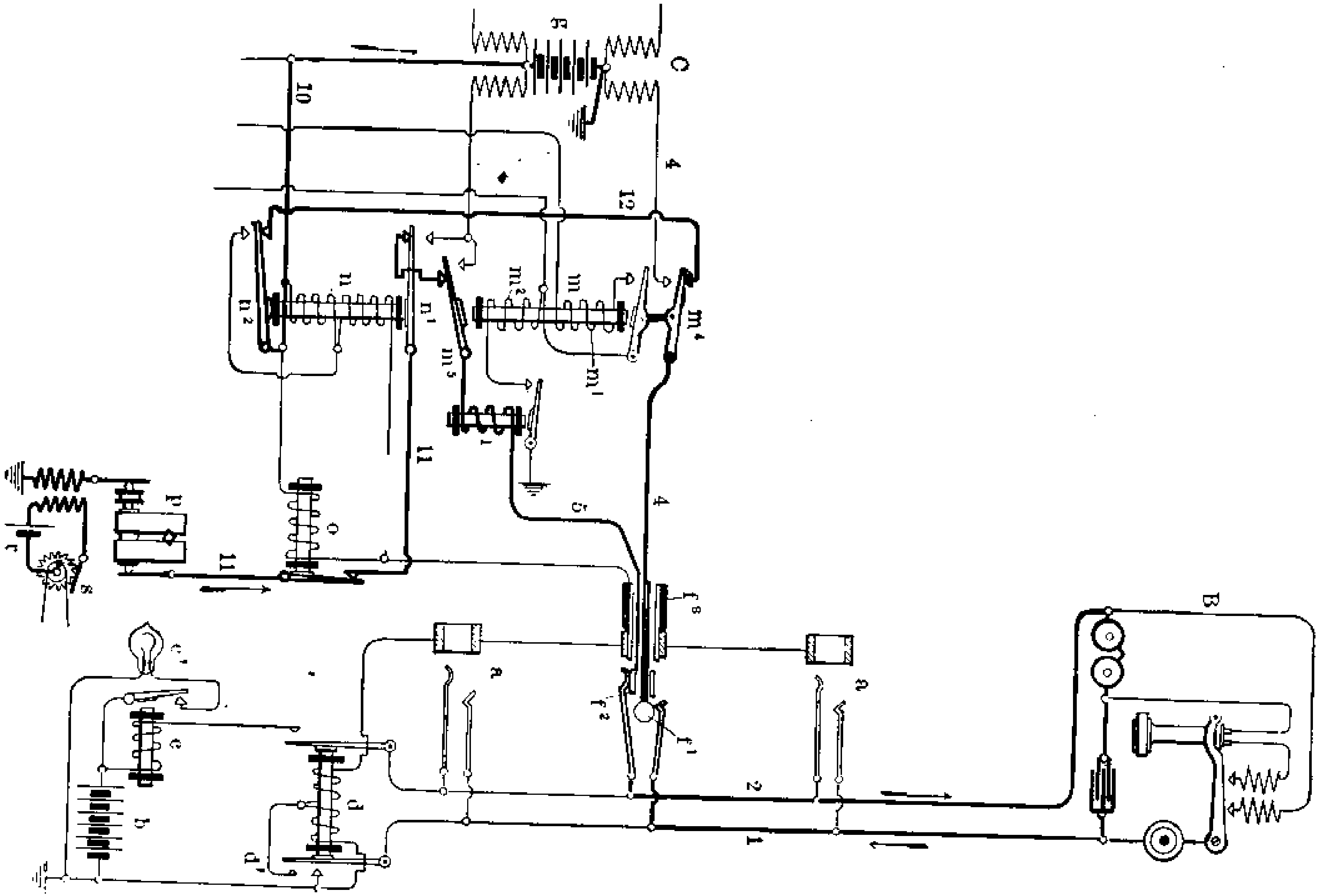


Fig. 81. — Automatic Ringing and Testing Circuit Ringing the Subscriber.

ing and busy signal circuits. Relay l is a supervisory relay, and is in the ring conductor 5; relay m controls the continuity of the tip and ring conductors, and is an automatic ringing key. It has two windings, m' and m^2, winding m' is in circuit with conductor 8, and when relay l is excited, m' shunts lamp k. As relay l is included in ring conductor 5, it is responsive to current in the line with which plug f may be connected. When l is excited it closes ground branch 8, through winding m', extinguishing lamp k by shunting it, and exciting relay m. When relay m is excited it attracts its armatures m^3, m^4, and m^5; m^3 closes circuit of conductors 8 and 9, through the winding m^2. When relay h and winding m' are excited, current can flow from battery g through conductors 7 and 9, winding m^2, conductor 8 to ground, thus winding m^2 forms a *sticking* winding, locking the armatures m^3, m^4, and m^5, as soon as relay m has once been excited. This relay then becomes independent of relay l. The armatures m^4 and m^5 of relay m control the continuity of the tip and ring conductors 4 and 5 of the cord circuit; normally these conductors are broken, and the ends leading to the tip and ring of the calling plug f, can, by means of the relays o and n, be connected to the ringing generator p as will be described. Relays o and n are in multiple in sleeve conductor 10, leading from battery g to the sleeve contact f^3 of plug f. Relay n has two armatures, n' and n^2; n' is connected with the front contact of relay o, whose armature is connected by conductor 11 to the ringing generator and to ground. The front contact of armature n' is connected to the back contact of armature m^5, so when relay m is inert and relays n and o are excited,

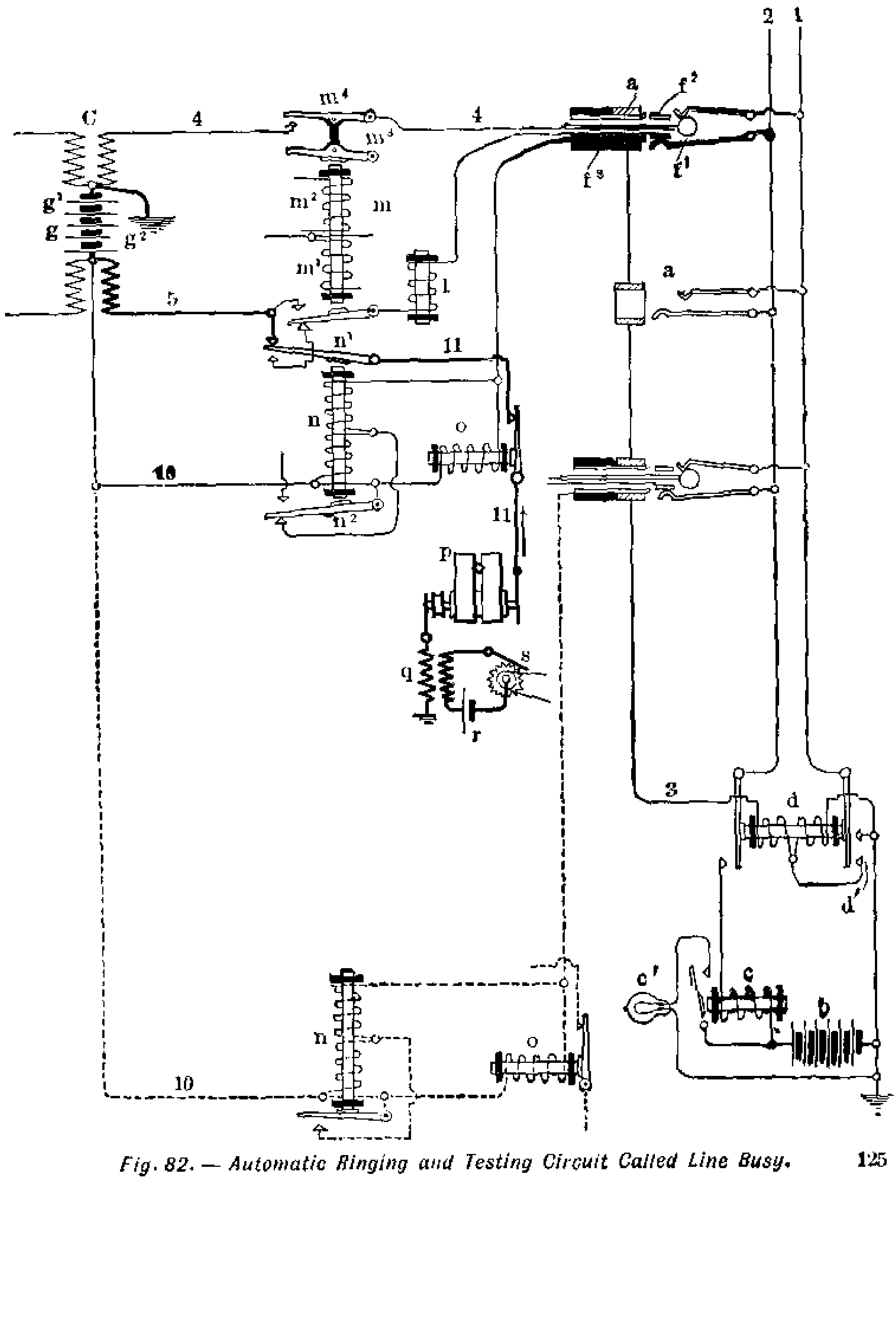


Fig. 82. — Automatic Ringing and Testing Circuit Called Line Busy.

ringing current from the generator will find its way to the ring conductor of plug f. Armature n^2 of relay n is connected to conductor 10, and its front contact by conductor 12 with back contact of armature m^4. When relays n and o are excited, ringing current from generator p can pass through ring contact of the calling plug, limb 2 of the subscriber's line, thence through the substation, returning by limb 1, the tip of the plug, conductor 4, armature m^4, conductor 12, armature n^2, conductor 10, and thence to ground through the battery g. Armature n^2 is connected to an intermediate point of the winding of relay n so that normally a part of this relay is short-circuited. Relays n and o operate whenever the calling plug f is inserted in the jack of a free line, because in order to excite these relays the current passes from battery g through conductor 10, relays o and n to sleeve f^3 of the connecting plug, and thence to ground by way of the test-ring of the jack, conductor 3 and winding of cut-off relay d. Relay o is extremely sensitive and always attracts its armature, whether the line be free or not. Relay n is less sensitive; a part of its winding is normally short-circuited, so if plug f be inserted in the jack of an engaged line, relay n will not operate because the plug already connected to this line shunts the circuit of any plug afterward inserted, and also the cut-off relay of the engaged line has drawn up its armatures, broken the shunt around its winding, and increased the line resistance by the additional turns thus inserted. Relay n has a portion of its winding short-circuited, in order that when it is once excited sufficiently to draw up its armatures, this circuit may be broken and the armatures locked in place.

When relay *o* is excited and relay *n* is unexcited, the circuit may be traced from the ground through the ringing generator *p*, conductor 11, conductor 5, the winding of the repeating coil to the battery and the ground. Under these circumstances a pulsating current in this circuit will produce current in the other windings of the repeating coil. The drawing shows an interrupter and a transformer coil *q* in the generator circuit, and by these a peculiar signal current may be imposed upon the repeating coil, which will produce a buzz or other tone test at the substation of the calling subscriber. The operation of this system is as follows:

Having ascertained the order from the calling subscriber in the usual manner, the operator without testing inserts the connecting plug *f* into the jack of the called subscriber *B*. If the *B* line is idle, the insertion of the plug will cause the ringing current to be automatically applied. Under these circumstances the operator's plug circuit assumes the condition shown in Fig. 81, the path of the ringing current being shown by heavy lines. When the called subscriber removes the receiver, the resistance of the line is reduced sufficiently so there is an increase in the current flowing through relay *l* which attracts its armature, closing the circuit through winding m^2 of relay *m* to the ground, and shunting out the signal lamp *k*. This causes relay *m* to become sufficiently excited to attract its armatures, thus cutting off ringing current and establishing the circuit of the tip and ring conductors 4 and 5, and connecting the subscribers for conversation. Relay *l* acts as a supervisory relay and is excited by current from battery *g* so long as "B's" receiver is off the hook.

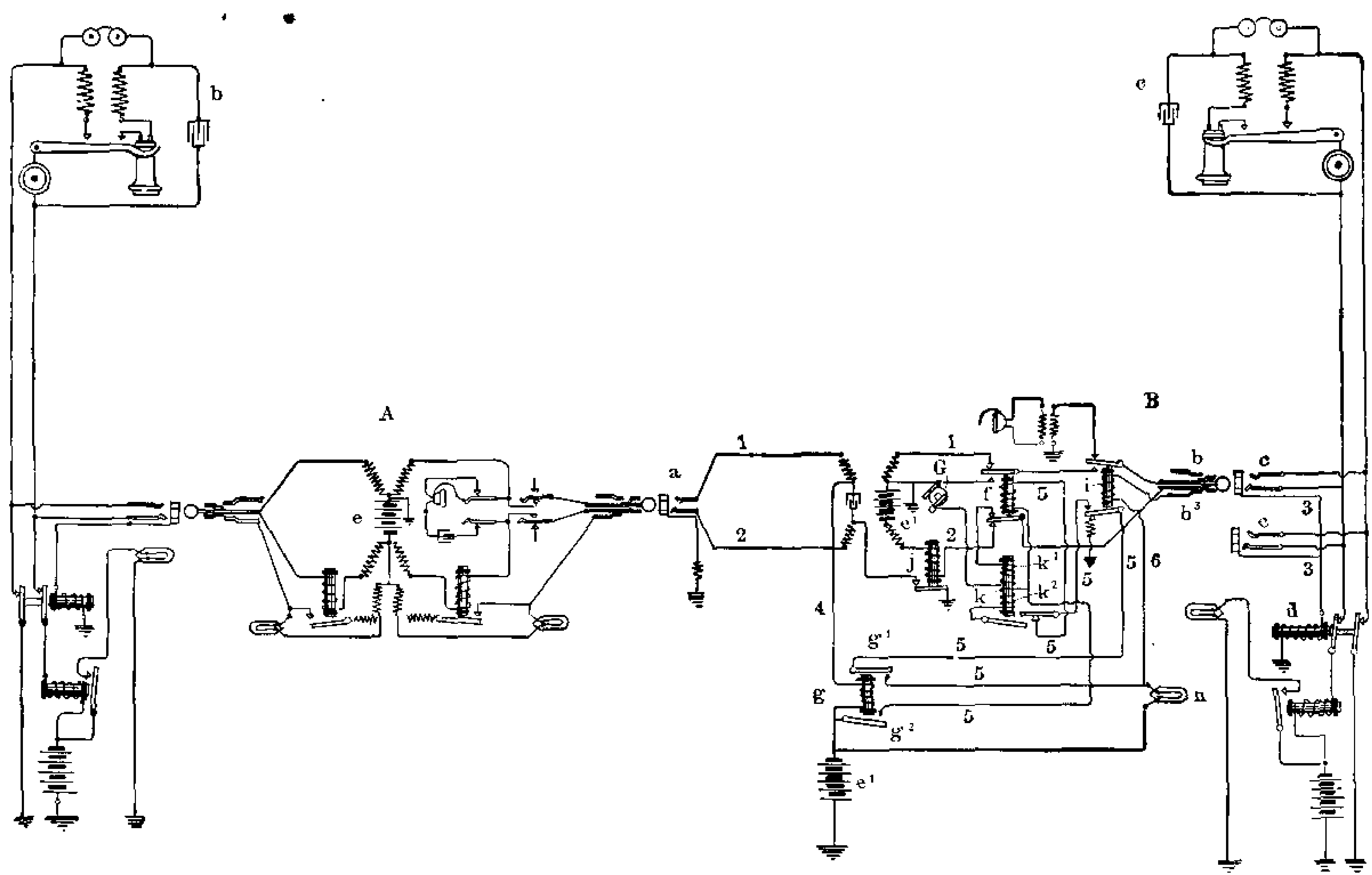


Fig. 83. — Automatic Ringing Trunk Circuit.

When conversation is finished and the subscribers replace their receivers, the shunts about the supervisory lamps e^5 and *k* are opened. When the operator disconnects she must first remove the calling plug *f*, and then the answering plug *e* to avoid a false signal. If "B's" line is busy when the operator desires to connect therewith, the full winding of the cut-off relay *d* is included in conductor 3. The operator plugs in without testing, and only the sensitive relay *o* will be excited. The condition of the apparatus is then shown in Fig. 82, in which the path of the ringing current is shown in heavy lines. As relay *o* is alone excited, current from generator *p*, upon which is superimposed the tone current, passes through one winding of the repeating coil, and notifies the calling subscriber that the line asked for is busy. The calling subscriber then replaces his receiver, and the illumination of both disconnect lamps notifies the operator to remove the chords.

The trunk circuit previously described required the "B" operator to ring the subscriber. To make ringing automatic, and relieve the "B" operator from this function, produces an economy in operating expense. This is accomplished by circuit of Fig. 83. Substation *b* is tributary to office "A," while substation *c* enters office "B." The substation apparatus, the subscribers' terminals in both offices, and cord circuit in office "A," are the same as already described. Automatic ringing is accomplished by an electromagnetic key composed of relays *g*, *f*, *i*, *k*, and *j*. The operation is as follows: After the "B" operator nominates the trunk, the "A" operator inserts the calling plug into the trunk line jack *a*; relay *g* will be excited by current from battery e', through conductor 4, conductor 1 of the trunk line to ground by the tip conductor of the "A" operator's cord circuit. Relay g will attract its armatures g' and g^2, illuminating lamp h by current from battery e' through conductor 5, armature g', armature of relay g, conductor 5, armature of relay i, thence to ground and the battery. The illumination of lamp h shows the "B" operator that the "A" operator has taken the right trunk, and she will insert the connecting plug b into the spring jack c of the line ordered. Upon the insertion of this plug, current flows from battery e' through lamp h, conductor 6, relay i, ring contact of plug b, conductor 3, and cut-off relay d to the battery. Relay i is excited, attracts its armatures, forming a shunt circuit from armature g^2 through conductor 5, relay f, conductor 3 and conductor 5 to the ground; this excites the winding of the automatic ringing key, whose armatures are attracted, forming a circuit from the ringing generator g to the tip of plug b, thence over the subscriber's line back to the sleeve of the plug, and thence through the winding k' of relay k. So long as the receiver is on the hook there is insufficient current to energize relay k, but when the receiver is removed, more current passes and relay k is excited, attracts its armature, shunting out magnet f, and substitutes its own winding k^2. Ringing magnet f being deënergized, the talking circuit over the tip and sleeve conductors will be reëstablished, and ringing key f will be locked, so far as any changes in the circuit of the called lines are concerned, but it will remain subject to being reset over the cord circuit of the "A" office. The other functions of this circuit are similar to those already described.

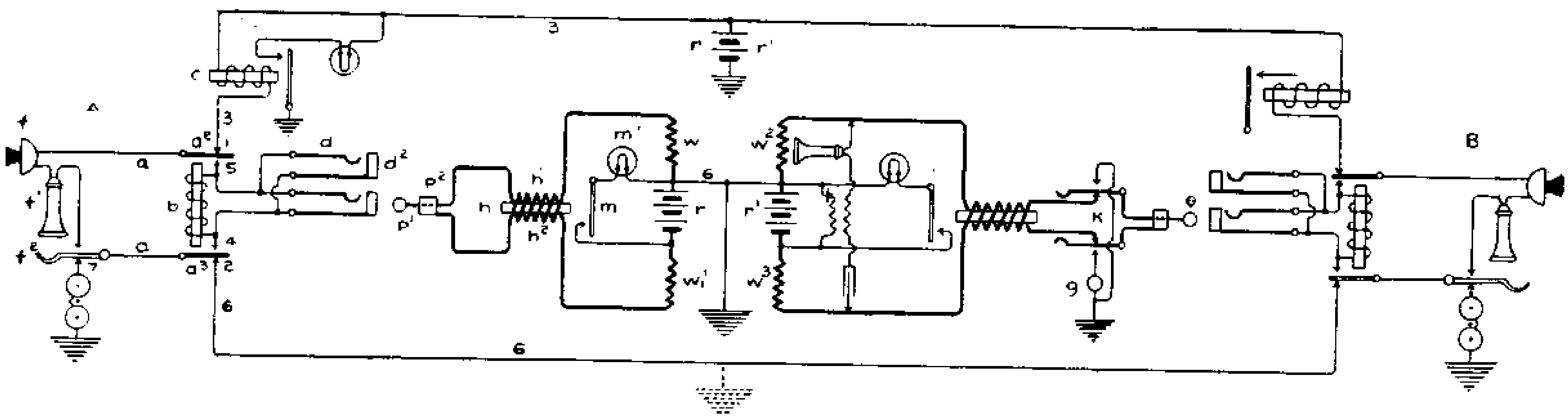


Fig. 84. — The Dunbar Circuit.

The salient characteristics of the previous circuits are: First, one battery at the central office; second, a repeating coil in the cord circuit to transfer voice currents from one subscriber's line to the other; third, the line signal normally associated with the line and removed during conversation by cut-off relay; fourth, the permanent connection of all jacks to the line; fifth, the employment of a third wire in the switchboard and cord circuit wiring, to provide means for testing and to actuate the cut-off relay. The Kellogg Switchboard and Supply Company use common battery circuits which possess distinctly different features. Fig. 84 shows what is often known, from the name of the inventor, as the Dunbar Circuit. The substations are represented at A and B in which f is the transmitter, f' the receiver, f^2 the hook switch which rests upon contact 7 and extending through a low-resistance ringer to ground. The line extends to the office by the limbs a and a', terminating in the relay armatures a^2 and a^3. These normally rest upon contacts 1 and 2, contact 1 extending by conductor 3 through relay c to the free pole of office battery r. Spring a^3 rests upon contact 2, connected to conductor 6, which is either ground or a conductor common to all lines.

The switchboard contains the multiple jacks, consisting of a spring d' and ring d^2. All the d' springs of one line are connected in multiple to contact 5, and all of the d^2 rings to contact 4. Across 4 and 5, relay b is bridged. Inspection shows that normally all jacks are disassociated from the line, which contains only the line relay c. There is no cut-off relay, because relay b connects the jacks to the line when excited, and hence is a *cut-on* relay.. The cord circuit contains two batteries r and r', which are entirely distinct. The same pole of both batteries is grounded or connected to the common conductor 6. From one battery a conductor extends through winding w of the repeating coil, thence through winding h' of differential relay h and thence to the tip p' of the answering plug. From the other pole of this battery a conductor extends through winding w', thence through winding h^2 of the differential relay h and the sleeve of the plug. The other half of the cord is similar, excepting that the operator's transmitter is bridged across the battery, and the receiver, condenser, and listening key bridged between the tip and sleeve, ringing generator g and ringing key k provided for signaling. The operation is as follows: When a subscriber removes his receiver, line limbs a and a' are closed, current from battery passes through conductor 3, relay c, contact 1, armature a^2, limb a, substation apparatus, limb a', armature a^3, contact 2, conductor 6 to battery. Relay c is excited, its armature attracted and the line lamp illumined. The operator inserts the answering plug, then there is circuit from battery through winding w of the repeating coil, winding h' of differential relay h, tip p' of the answering plug, winding of relay b to ring d^2, sleeve of plug p^2, winding h^2 of relay h, sleeve conductor of cord circuit, winding w' of the repeating coil to the battery. When relay b is excited, armatures a^2 and a^3 are attracted, opening contacts 1 and 2, extinguishing the line signal, closing contacts 4 and 5 and connecting the switchboard jacks. The closure of contacts 4 and 5 places the substation circuit in parallel with relay b, and thus enables the battery to supply the substation circuit with talking current. All the current from battery *r* flows out through winding *h'* and back through winding h^2 of relay *h*. As both windings exactly balance each other, the core is not magnetized, armature *m* is not attracted and the supervisory signal lamp *m'* not illumined. The operator takes the order and tests in the usual manner. If the line is disengaged, the jacks are entirely disconnected from all other apparatus, and hence the receiver emits no test click. If line is engaged, battery is placed upon the rings by the sleeve conductor of some other cord, and the operator's telephone gives the customary signal. *Finding the line* disengaged, the operator inserts the connecting plug *o*. This excites relay *b*, its armatures a^2 and a^3 are attracted, cutting off the line signal and connecting subscriber *B* with his string of jacks, thus rendering the rings busy. The operator then presses the ringing key *k* which connects the line with generator *g*. Current then flows over the sleeve side of line to the substation, through the ringer to ground and back to office. The relays *b* are designed to be responsive to alternating current, hence while the manipulation of ringing key *k* cuts the battery off of the called line, the ringing current from generator *g* splits at contact 4 and 5, a portion returning to the office through relay *b* and the tip of the plug, while the remainder travels to the substation and actuates the signal bell. When either receiver is replaced the line is opened. The circuit still remains through relay *b*, but there is a new path from the battery through winding *w'*, the sleeve conductor, winding h^2, spring d^2, armature a^3, limb *a'*, the substation ringer, and the ground to the battery. The current in windings *h'* and h^2 is no longer

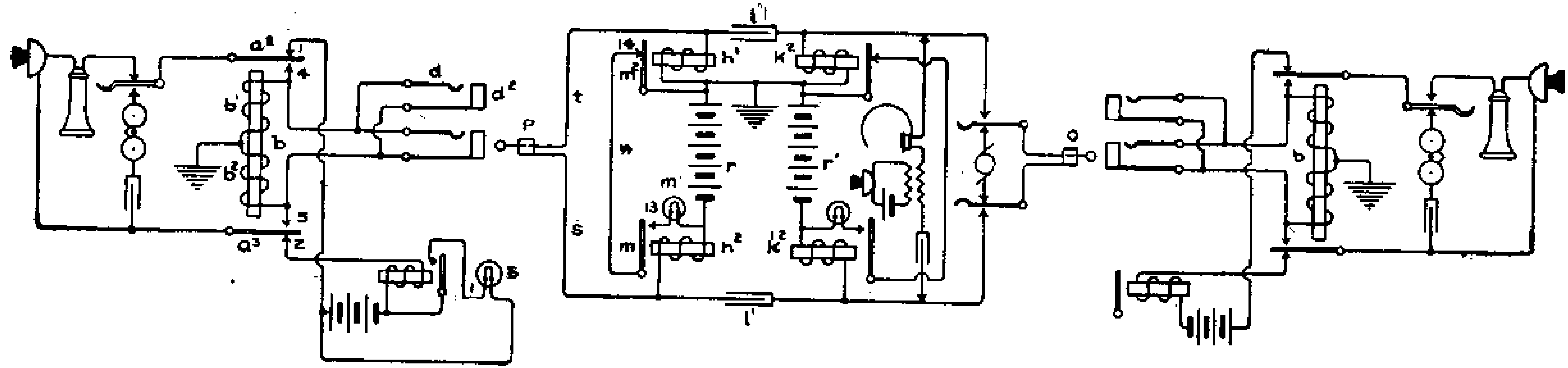


Fig. 85. — Dunbar Circuit Modified.

equal, as there is more current in h^2. The relay is excited, armature m attracted and disconnect lamp m' illumined.

There are some objections to grounding one side of the subscriber's line through a low-resistance ringer. Fig. 85 shows another Kellogg circuit devised to obviate this. The relay b has two differential windings b' and b^2, and is grounded at the center. The office contains two batteries, but the repeating coil has disappeared; the halves of the cord circuit being connected by condensers l and l', and the differential supervisory relays are replaced by four relays h' and h^2 and k' and k^2, which operate as retardation coils, preventing the battery from short-circuiting the voice currents, compelling them to traverse the condensers and travel from station to station. The operation is as follows: The subscriber signals as described. When the operator inserts the answering plug P there is circuit from battery r through relay h^2, sleeve conductor s, jack ring d^2, and coil b^2 of relay b to the ground and battery. The relay is excited and attracts its armatures a^2 and a^3, cutting off the line signals, closing contacts 4 and 5 and connecting the line to its jacks. The operator takes the order in the usual manner, tests the called subscriber as described for Fig. 84, and if disengaged inserts the connecting plug o, which operates relay b in the called line as already described. Ringing the subscriber is the same as for Fig. 84, excepting that for bells which are not grounded the ringing circuit is metallic throughout.

The relay b is wound to have a large impedance in order not to short-circuit talking currents from the substations.

The main object of the coil b' is to completely balance both sides of the talking circuit. The two windings are differential with respect to each other. When substation instruments are provided with metallic bells, ringing current must be sent over both sides of the line, and as it passes in series through both windings, the relay will not be deënergized. Also the portion of the current through coil b', when the receiver is off its hook, is in such a direction as to assist that in coil b^2. The coils are placed upon opposite ends of the cores in order to secure as great an impedance as possible. So long as a receiver is off its hook, current from the battery traverses the winding of the supervisory relay h^2 or k^2, to the substation and back through the h' or k'. Then both relays are excited, relay h^2 has attracted its armature m, closed contact 13, and placed supervisory lamp m' in circuit with the battery and conductor n; simultaneously relay h' has been excited, has attracted its armature m^2 and opened contact 14, so the disconnect lamp m' is not lighted. When the subscriber replaces the receiver, current continues to flow through relay h^2 to the sleeve of the plug, jack ring d^2, winding b^2 and to ground, so that the armature m^2 remains attracted and contact 13 closed, relay h' is short-circuited, armature m^2 is retracted, closing contact 14 and illuminating supervisory lamp m'.

Mr. W. W. Dean has devised some interesting substation circuits which may be used in connection with circuits of Figs. 84 and 85, or those which are similar. The one shown in Fig. 86 utilizes in a most ingenious manner the principle of the Wheatstone-Bridge. There is a coil with four windings A, B, C, and D. These are arranged

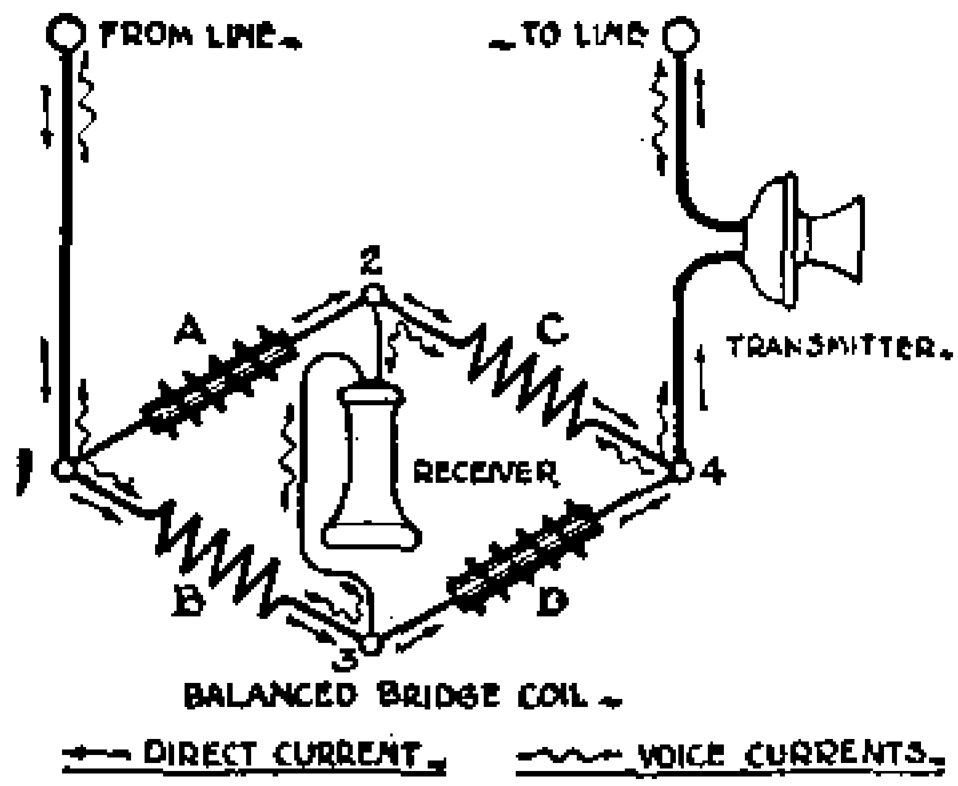


Fig. 86. — Wheatstone-Bridge Substation Circuit.

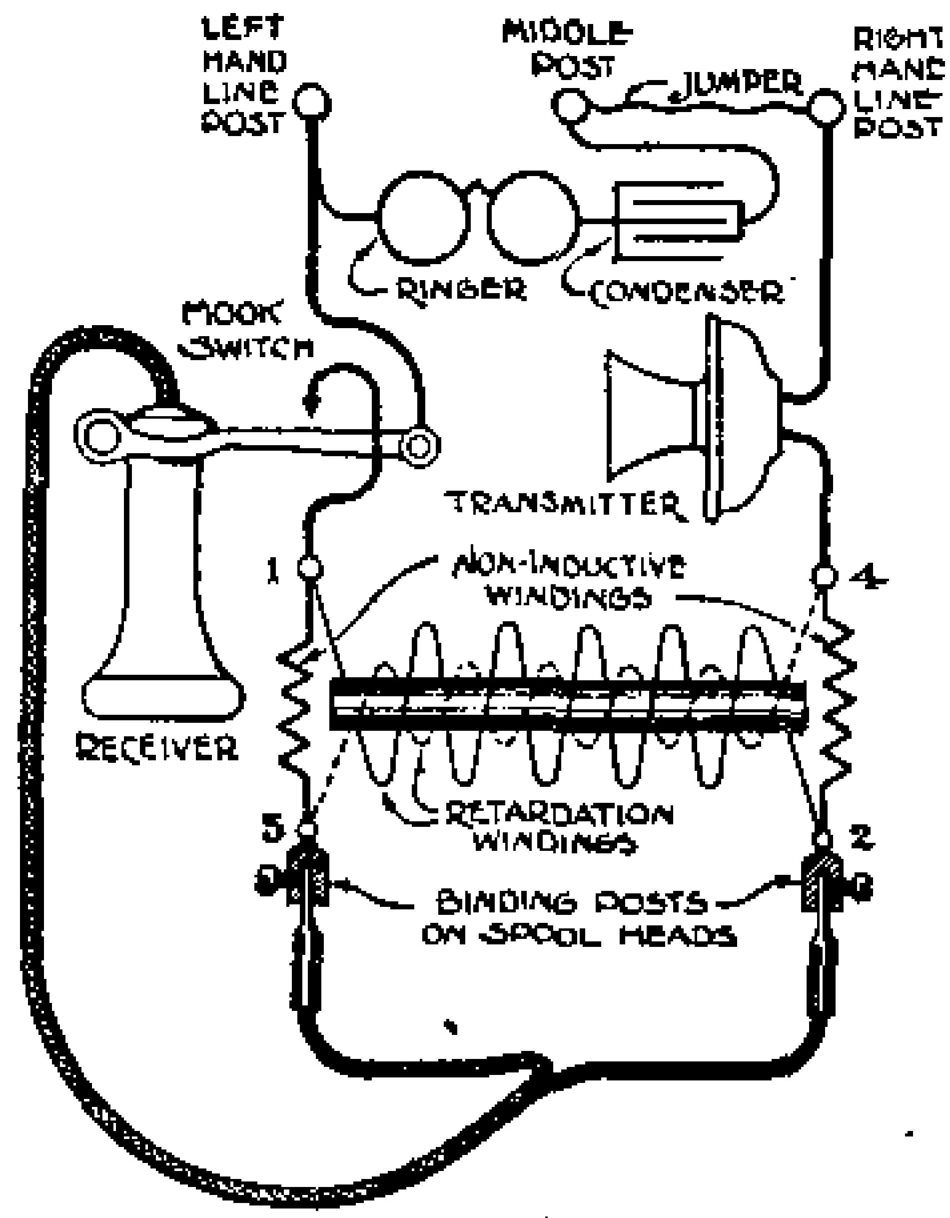


Fig. 87 — Wiring of Circuit of Fig. 80.

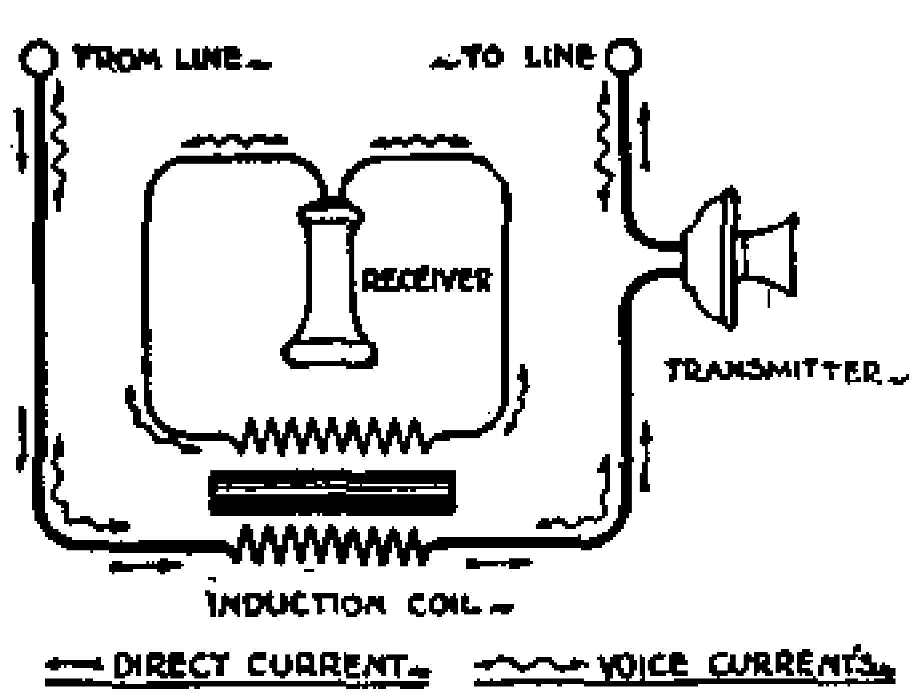


Fig. 88. — Induction Coil Substation Circuit Used with Dunbar Circuit.

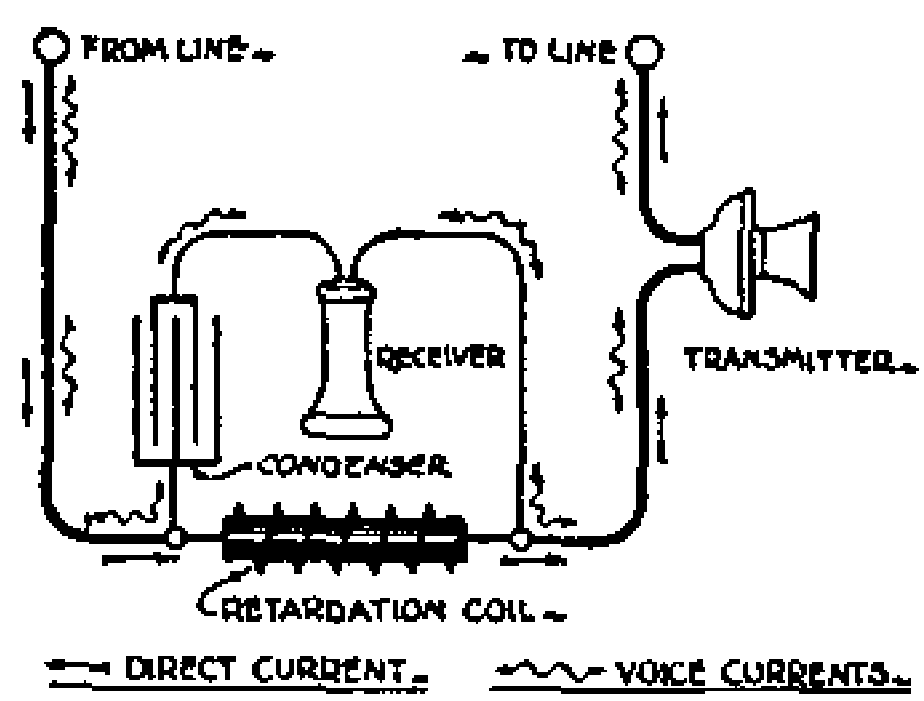


Fig. 89. — Retardation Coil Substation Circuit Used with Dunbar Circuit.

to form the circuit of a Wheatstone-Bridge, arms *A* and *D* are impedance coils, while arms *C* and *B* are non-inductive resistances. All four arms have precisely the same ohmic resistance. The receiver is bridged between the points 2 and 3, while the transmitter is placed in series with the line and points 1 and 4. Current from the office battery will traverse the transmitter to point 4 and then split, passing equally over the two circuits formed by the two arms of the bridge. As the receiver is bridged across the neutral point, no current will traverse it. The high frequency alternating voice currents reaching point 1 will be opposed by the impedance coils *A* and *D*, and will find an easier path through coil *B* to point 3, thence through the receiver and coil *C*. Fig. 87 is a diagrammatic view of the instrument wiring, adopting this circuit. Figs. 88 and 89 are diagrams of the induction coil and retardation coil substation circuit, which are frequently used by the Kellogg Switchboard and Supply Company. These circuits are sufficiently self-explanatory to need no further description.

The Kellogg circuit has been still further modified by Mr. A. D. T. Libbey, as is shown in Fig. 90. The stations *A* and *D* may be supplied either with grounded ringers or any other form of common battery substation circuit. The relay *R* has no ground, and the supervisory relays r and r^2 are differentially wound with coils placed at the ends of the cores so that they may act as impedance coils as well as relays. In other respects the operation of this circuit does not differ materially from the Dunbar circuits previously described.

Having the "A" operator's circuit, it is not difficult to

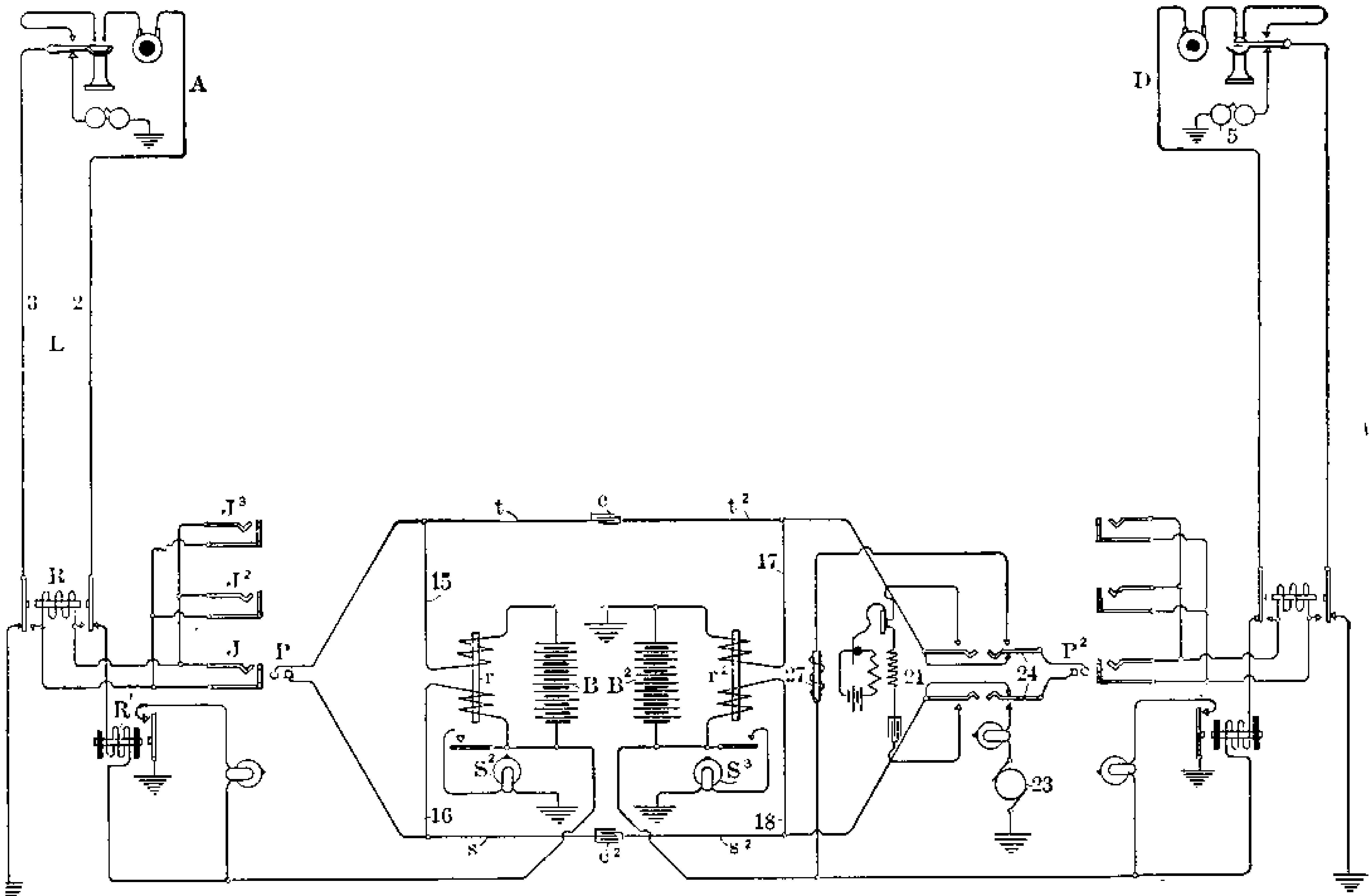


Fig. 90. —Libbey Circuit.

devise a trunk circuit to work therewith. A typical Kellogg form is shown in Fig. 91. After obtaining the number of the desired subscriber, the "A" operator by means of the key *o* transmits the order to the "B" operator. At the *B* end of the order wire a key *K* is placed, that when set it bridges the 500-ohm relay *e* across the order wire. If the "B" operator leaves the switchboard she sets this key, and then a touch on the order-wire button illumines the signal lamp *s* and operates a night bell. After the "B" operator nominates the trunk, the "A" operator inserts the connecting plug *C* into the trunk line jack *J*. Current from battery *r* at the "A" office then passes through disconnect relay *A* to the sleeve side of the cord and thence to the sleeve of the trunk line jack *j*. Here the current splits, a part passing through the 500-ohm resistance r' to ground. This is sufficient to cause relay *A* to attract its armature and illumine the disconnect lamp S'. The other portion passes over the trunk line to the winding 1 of the repeating coil, conductor 2, relay *B*, winding 2 of the repeating coil, over the tip side of the trunk line to the tip side of the connecting plug in the "A" office, and thence through relay *C* to the "A" office battery. As relay *B* is wound for about 15,000 ohms there will be insufficient current to excite relay *C*, and hence the "A" operator's disconnect lamp will remain illumined, but relay *B* will be excited, closing contact *a*. There is then circuit from battery e' in the "B" office to conductor 3, contact *a*, lamp 1, conductor 5, contact 6 of relay *b* to ground and thence to the battery. The illumination of lamp 1 informs the "B" operator that the "A" operator has taken the right trunk. The "B" operator tests the line in the usual

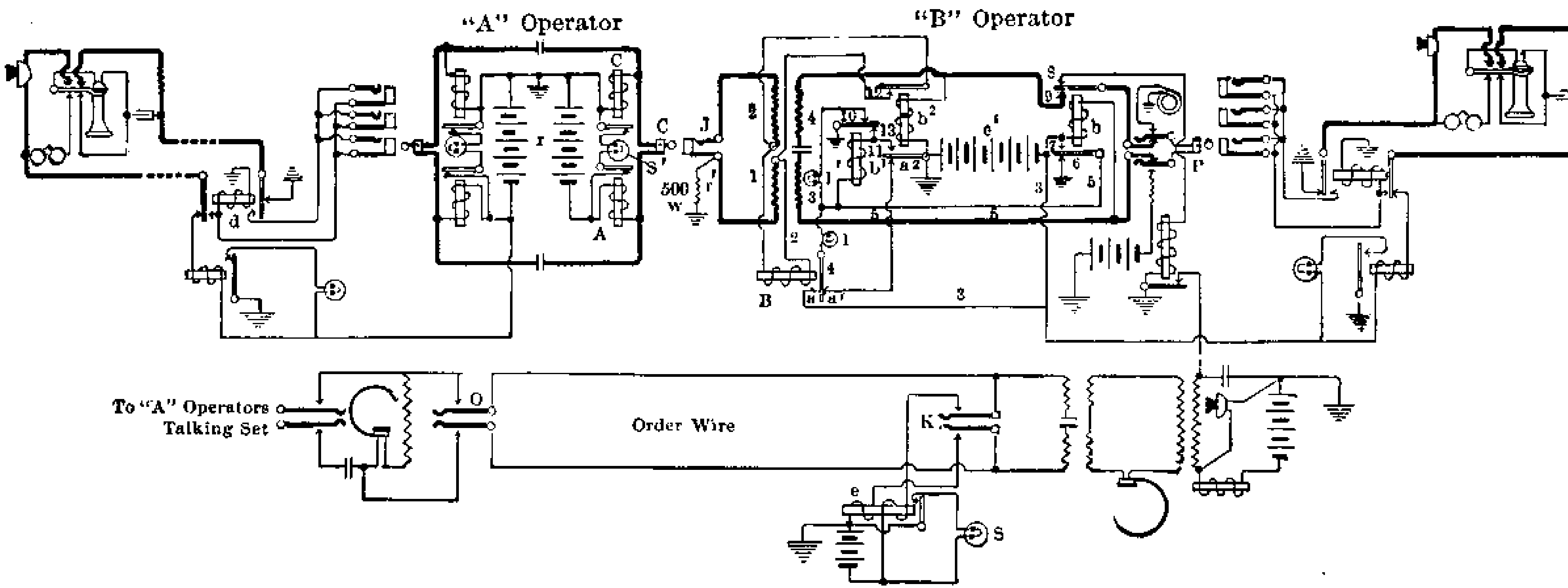


Fig. 91. — Kellogg Trunk Circuit.

manner, and finding it free inserts her trunk plug *P*. The insertion of this trunk plug excites relay *b* because it is connected with the sleeve side of plug *P*, which, when inserted in the jack of the called line, puts relay *b* in series with the relay *d* of that line and ground. When relay *b* is excited its armatures are attracted, contact 8 opened, and contact 9 closed. This completes the continuity of the tip side of the trunk line. Also contact 6 is opened and contact 7 closed. This extinguishes lamp 1 and lights lamp 1′, for there is a path from battery *e′* to contact 7 of relay *b*, conductor 5 through lamp 1′, contact 10 of relay *b′* to ground and to battery.

So long as the subscriber's receiver is on the hook, relay b^2 is unexcited because the condenser at the substation opens the tip side of the line. When the receiver is removed, relay b^2 is excited and attracts its armatures, closing contacts 11 and 12. Contact 11 makes a path from battery through conductor 5 and relay *b′* to the battery. This excites relay *b′* which attracts its armature, opening the contact 10 and extinguishing lamp 1′, and notifies the "B" operator that the subscriber has answered. When relay *b′* is excited, its armature closes contact 13. This locks the relay so that it will not release its armature and give a false signal until the circuit is broken by the removal of the plug. Contact 12 short-circuits relay *B*, hence this relay is deënergized, its armature retracted, closing contact *a′*. The shunt about relay *B* increases the battery current in the trunk sufficiently to cause relay *c* in the "A" operator's cord to operate, attract its armature, and extinguish the disconnect lamp, thus informing her that the called subscriber has answered. The contacts *a′*

and a^2 are connected, because, when the *B* subscriber removes his receiver, the contact 12 of relay b^2 short-circuits relay *B*, and a false signal would be given if the circuit were not opened at a^2. In case the called subscriber is busy, the "B" operator plugs into a busy back jack which informs the calling subscriber that the line is engaged. When conversation is finished, both parties re-

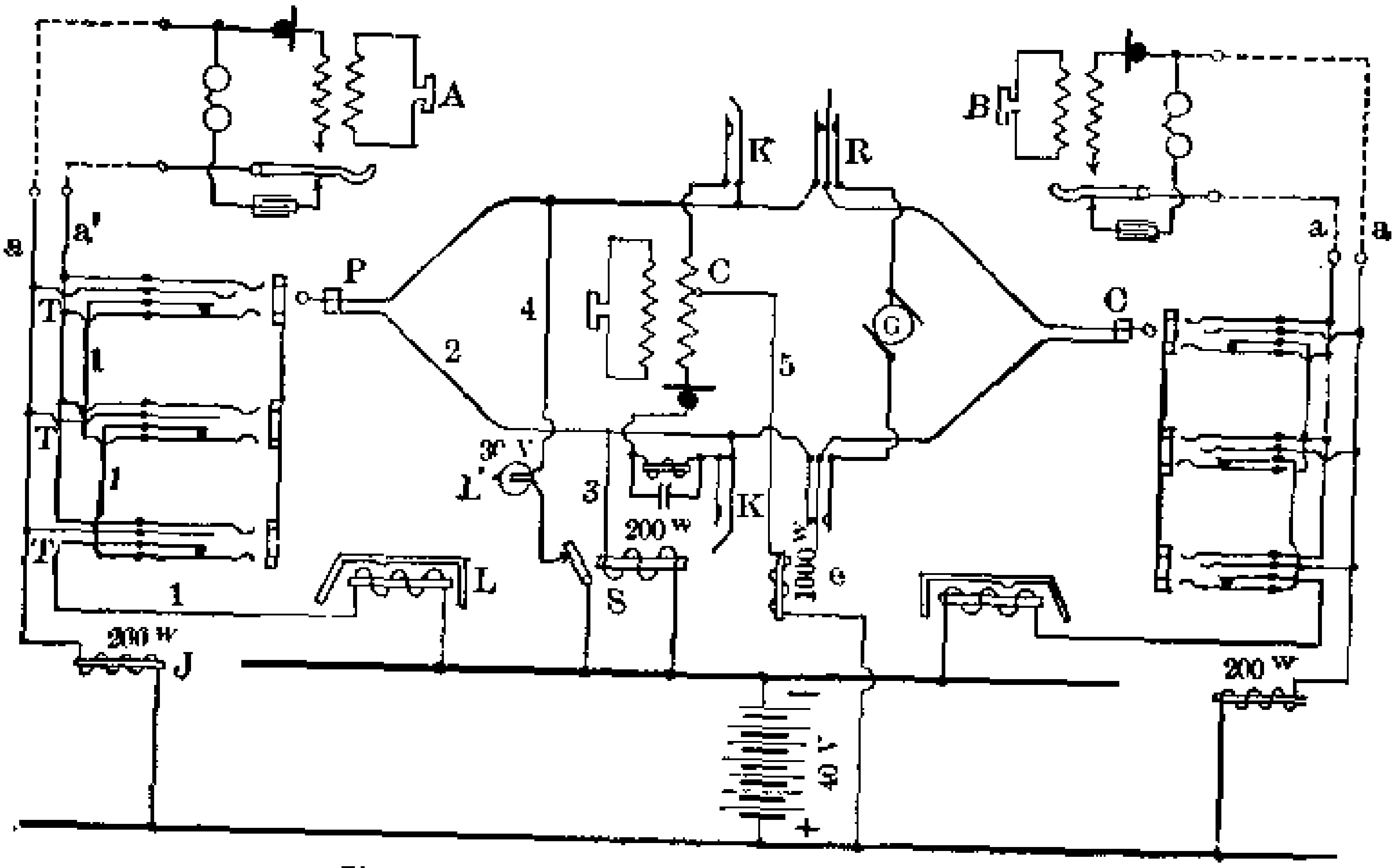


Fig. 92. — Stromberg-Carlson Circuit No. 1.

place receivers, this lights the "A" operator's disconnect signals, she then clears out, lighting the disconnect lamp 1′, signaling to the "B" operator to remove the trunk plug.

The Stromberg-Carlson Company depart from both the methods outlined. A circuit frequently found in their older boards is shown in Fig. 92. A notable feature is a 40-volt ungrounded battery, which unquestionably provides better transmission, particularly for toll and long-distance messages. The substations "A" and "B" may be of any of the common battery types and are connected with the office by limbs *a* and *a′*. Each jack contains a tip spring, two sleeve springs, and a ring. The tip springs *T* of all jacks on one line are in multiple with conductor *a*. One sleeve spring of each jack of every line is in multiple with conductor *a′*. The second bears against a contact point on the fourth spring, connected by conductor 1 in series through all the jacks of the line to the signal *L*, thence to the negative pole of the office battery. The tip side of the line is permanently connected to the positive pole of the battery through a 200-ohm retardation coil *J*. When the receiver is removed, current passes from battery through the retardation coil *J* over the *a* side of the line, through the substation, thence back over the *a′* side, through the jack contacts in series to the line signal and the battery. The signal is displayed. The operator inserts the answering plug *P*, whose sleeve opens the contact of the jack it enters, thus restoring the line signal. When the answering plug *P* is in the jack a new circuit is provided, current passing from positive pole of battery through retardation coil *J*, conductor *a*, the substation conductor *a′*, the sleeve spring, the sleeve of the plug, conductor 2, conductor 3, supervisory relay *s* to the negative pole of the battery. The current in this circuit excites the supervisory relay which attracts its armature and opens the circuit of supervisory lamp *L′*, otherwise formed through conductor 4, the tip of the plug, conductor *a*, and the retardation coil *J*. By key *k* the operator bridges her telephone and takes the order. The operator's talking circuit differs from those described. The primary winding is in series with the key springs and an impedance coil and condenser connected in parallel. This winding is tapped at point *c*, and conductor 5 taken through retardation coil *e* to the positive pole of the battery. When a line is disengaged the rings of the jacks are insulated, and touching such a ring with the tip of the connecting plug causes no sound in the receiver. When the connecting plug is inserted, negative pole of battery is connected to the rings through supervisory relay *S* and conductors 3 and 2. By tapping the winding of the primary at *c*, a path is provided from the tip of the plug through a portion of the primary winding, and conductor 5 to the positive pole of the battery, hence when the tip of the connecting plug touches an engaged line the operator's telephone will emit the customary busy-test click. The object of the retardation coil is to reduce the potential of the test so that the sound may not be uncomfortable. Finding a line disengaged the operator inserts the connecting plug *C* and rings in the usual manner; on completion of conversation the subscribers replace their receivers, but the disconnect signal does not appear until both receivers are on their hooks, because there is a path through the supervisory relay and the line of each subscriber, so long as either receiver is off the hook, and hence the armature of *S* having once been attracted, sufficient excitation of the relay will be produced by the current through either line to prevent the armature from retracting. The size of the jacks required for this circuit formed a serious objection, and a single disconnect signal did not enable the operators to exercise adequate supervision.

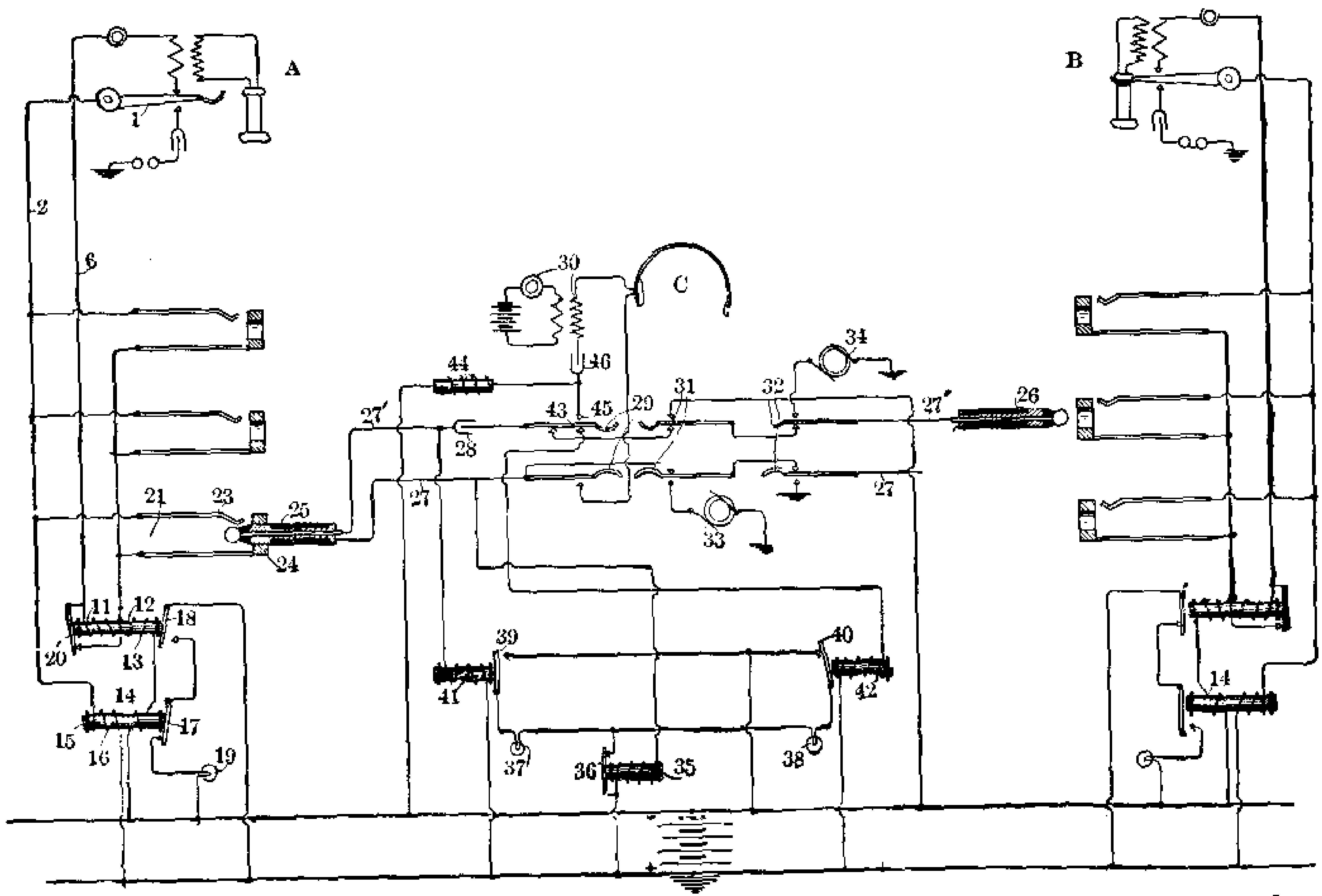


Fig. 93. — Stromberg-Carlson Circuit No. 2.

A preferable circuit is shown in Fig. 93. Its operation is thus: Substations "A" and "B" may be wired according to any common battery plan. When the subscriber removes his receiver the hook switch closes the line, allowing current from battery to pass through winding 16 of line relay 15, conductor 2, the substation, conductor 6, through both of the differential windings 11 and 12 of cut-off relay 13, and winding 14 of the line relay to the negative pole of the battery. The cut-off relay is not energized owing to the opposing action of its two windings, but the windings of the line relay are cumulative; when it is excited, its armature 17 is attracted and line signal 19 illuminated. The operator inserts answering plug 25 into answering jack 21, completing a circuit from the positive pole of the battery, through the supervisory controlling relay 35, sleeve conductor 27, sleeve 24 of the answering jack, winding 12 of the cut-off relay, and winding 14 of the line relay to the negative pole of the battery. Winding 11 of the cut-off relay is by this means partly short-circuited and the current in winding 12 reinforced, consequently the relay is excited and its armatures attracted. Armature 18 opens the circuit of the line lamp 19 and extinguishes it. Armature 20 puts a shunt around winding 11. Simultaneously relay 35 is excited, its armature attracted, connecting supervisory lamps 37 and 38 to the positive pole of the battery. Supervisory relay 41 is excited by current from the positive pole of the battery to the tip conductor 27, tip contact 23, line limb 2, the substation, line limb 6 through the shunt, around winding 11 of the cut-off relay, through winding 12, winding 14 of the line relay to the negative pole of the battery; relay 41 is excited, its armature attracted, contact 39 opened, and disconnect lamp 37 does not glow. When the connecting plug is inserted, disconnect lamp 38 lights because relay 40 is not excited. By key 29 the operator bridges her telephone set across the line and takes the subscriber's order. So long as a line is idle, all the rings 24 are connected through winding 12 and winding 14 to the negative pole of the battery. When a plug is inserted there is a circuit through winding 14 of the line relay, winding 12 of the cut-off relay through relay 36 to the positive pole of the battery, and thus the potential of the test rings is raised. When the operator uses the listening key she connects contact 45 through impedance coil 44, with the negative side of the battery, and causes the tip of the connecting plug to assume the same potential. If this plug touches the ring of an idle line the receiver will emit no sound, but when it touches the ring of a busy line the usual click will be produced. Finding the desired line idle, the operator inserts the connecting plug 26 and rings by means of generator 33, whose current may be either grounded or metallic. The insertion of the connecting plug 26 closes a circuit from the positive pole of the battery through controlling relay 35, sleeve conductor 27, sleeve of plug 26, jack ring 24, winding 12 of the cut-off relay, and winding 14 of the line relay to the negative pole of the battery. Relays 13 and 14 are excited, and line lamp 19 does not light. So long as the substation receiver remains on the hook there is no circuit through relay 42, and hence disconnect lamp 38 remains illumined until the subscriber answers. The replacement of either receiver

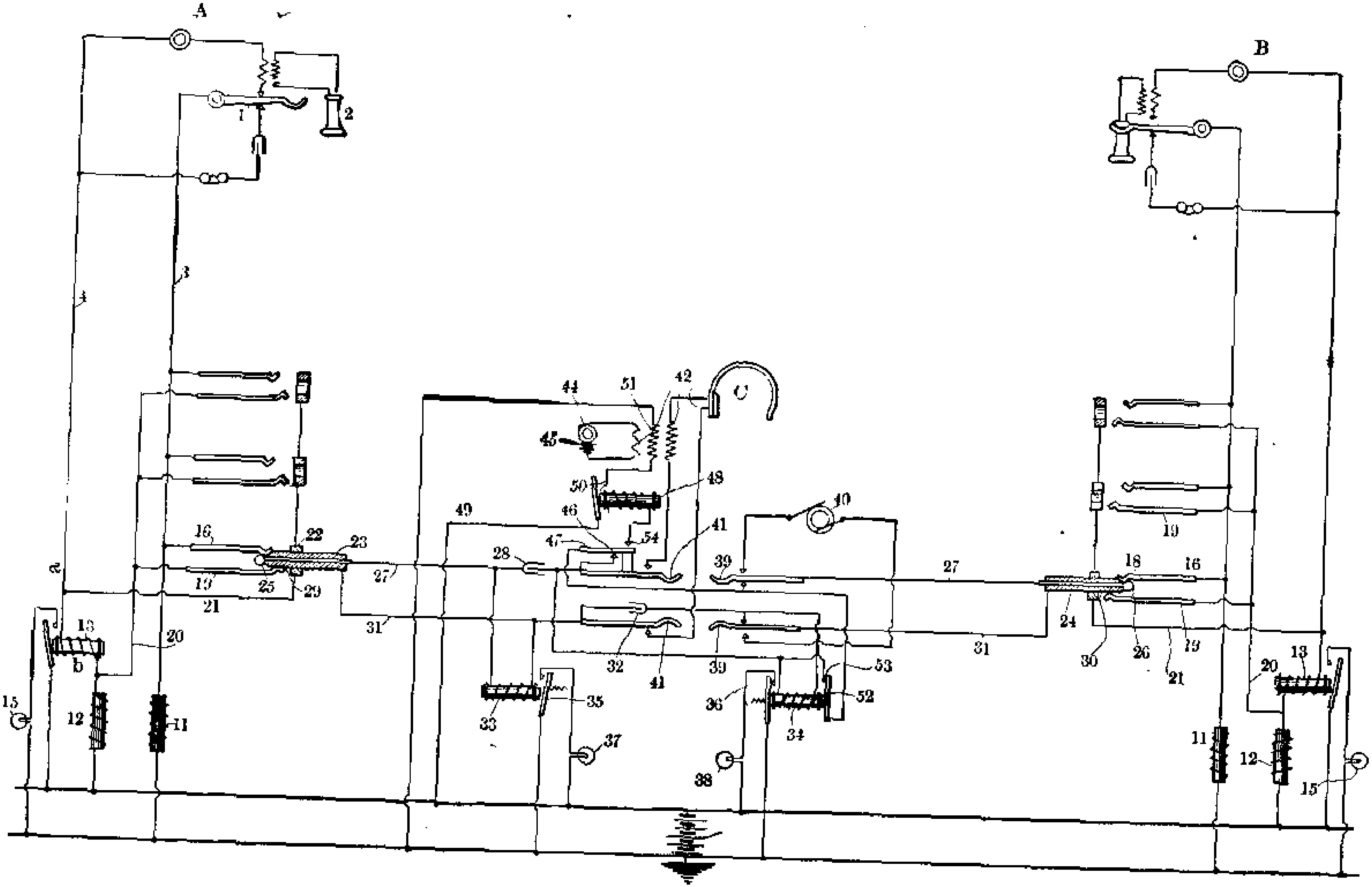


Fig. 94. — Stromberg-Carlson Circuit No. 3.

displays the corresponding disconnect signal in the usual manner.

A circuit typical of a later practice is Fig. 94. The substations "A" and "B" are connected with the office by conductors 3 and 4. Conductor 4 extends through relay 13, retardation coil 12 to the negative side of the battery. A wire is branched from conductor 4 to the rings 22 of all the jacks of the line. From point *b* conductor 20 extends to the sleeve springs. Conductor 3 is attached in multiple to all the tip springs, and thence through retardation coil 11 to the positive pole of the battery. When the subscriber removes his receiver, current flows from positive pole of battery through retardation coil 11, conductor 3, the substation, conductor 4, relay 13, and retardation coil 12 to the negative pole of the battery. Relay 13 is excited, its armature completes a circuit through signal lamp 15 which is illumined. The operator inserts answering plug 23; the sleeve 29 connects sleeve spring 19 with the ring 22. Then relay 13 is short-circuited, its contact opens, and the line signal extinguished. Current now passes from the positive pole through retardation coil 11, conductor 3, the substation, conductor 4, conductor 21, ring 22, sleeve of plug 23, the sleeve spring 19 of the jack, conductor 20, retardation coil 12 to the negative pole. The cord circuit consists of the tip conductor 27, to which conductor 28 is connected, and sleeve conductor 31, in which is condenser 32. On the answering side of the condensers, supervisory relay 33 forms a bridge between conductors 27 and 31. On the connecting side relay 34 is bridged. Armatures 35 and 36 control the circuits of supervisory lamps 37 and 38.

Listening key 41 enables the operator to bridge her receiver *C* across the cord circuit. The talking set comprises an induction coil 42, transmitter 44, local battery 45 in series with the primary 51. The listening key 41 includes a contact point 46 and spring 47 in the tip conductor. When the listening key is thrown, contact 46 and spring 47 are separated, and interrupt the continuity of the cord circuit. This key also connects one terminal of the high resistance test relay 48 with tip strand 47 to the tip 26 of the connecting plug. The other terminal of the test relay runs through conductor 49 to the negative pole of the battery. The armature 50 of the test relay controls a local circuit through induction coil winding 51.

After the answering plug is inserted there are two parallel circuits; one has already been traced. The other is from positive pole of the battery through impedance coil 11, tip spring 16, tip contact 25, tip conductor 27, supervisory relay 33, sleeve strand 31, sleeve contact 29, sleeve spring 19, conductor 20, impedance coil 12 to the battery. The substation forms a shunt about this path, so that relay 33 may be so wound and adjusted that so long as the receiver is off the hook, the shunt due to the substation circuit will allow too little current to traverse relay 33 to cause its armature to be attracted; but when the receiver is replaced and the line circuit opened, sufficient current will traverse relay 33 to attract its armature and display the disconnect lamp 37. The operator takes the order in the ordinary manner and tests. If the line is busy the following test circuit may be traced: From the negative pole of the battery, conductor 49, test relay 48, contact 54, contact spring 47, tip strand 27, the tip of the plug, test ring 22 (assuming the connecting plug of another line to be inserted in the multiple jack), through the sleeve strand corresponding to 31, the supervisory relay corresponding to 34, the tip conductor corresponding to 27, tip contact corresponding to 26, tip spring 16, and impedance coil 11 to the positive pole of the battery. When this circuit is completed by touching the tip 26 to any ring of a busy line, the test relay is excited, its armature 50 closed, and a click produced in the receiver. If no other plug has been inserted in the called line, but if the subscriber has removed his receiver, the test circuit is as follows: From the negative pole of the battery, test relay 48, contact 54, spring 47, tip conductor 27, tip contact 26, test thimble 22, conductor 21, line 4, the substation set, conductor 3, retardation coil 11, to the positive pole of the battery. If the line is not in use and the receiver is on its hook no test click is given because the plug tip and jack rings go to the same side of the battery; the operator inserts the connecting plug and rings with 39 in the usual manner. The insertion of the connecting plug completes the following circuit: Positive pole of battery, impedance coil 11, tip spring 16, tip contact 26, tip strand 27, supervisory relay 34, sleeve conductor 31, sleeve contact 30, sleeve spring 19, and impedance coil 12 to the battery. Both armatures 36 and 52 of supervisory relay 36 will be attracted; armature 36 completes the circuit of supervisory lamp 38, which is illumined, indicating that the subscriber has not answered. Armature 52 places a shunt about contacts 46 and 47, and thereafter the listening key can be manipulated without interrupting the continuity of the tip conductor. When the subscriber removes his receiver the disconnect signal 38 is extinguished, as has already been described for 37.

The signal system of a reversed call circuit trunk should perform the following operations in the following order: First — having nominated the trunk line the "B" operator must receive a signal indicating that the "A" operator has inserted the connecting plug in the proper jack; second, a signal must notify the "A" operator when the called subscriber removes his receiver; third, the "A" operator must be signaled when each subscriber removes his receiver, and these signals must reappear as a disconnect as soon as the receivers are replaced; fourth, a disconnect signal must appear before the "B" operator when the "A" operator removes the connecting plug, and not till then. The Stromberg-Carlson Company accomplishes these functions in an ingenious manner, as shown in Fig. 95. The operation is as follows: The "A" operator having received from the "B" operator the number of the trunk over the order wire in the usual manner, inserts the connecting plug P' into the trunk line jack L; current from the negative pole of the battery B' in the "A" office passes over conductor 2, relay R_2 to tip side of A cord to the tip spring of trunk line jack, conductor 1 and relay K to the battery. This excites the A supervisory relay R_2 on the connecting side of the cord and illuminates the disconnect lamp s'; relay K is also excited, which closes contact a. Current can then pass from battery B', via conductor 4, relay Z to the center of repeating coil r in the "A" office, over both sides of the trunk line to the

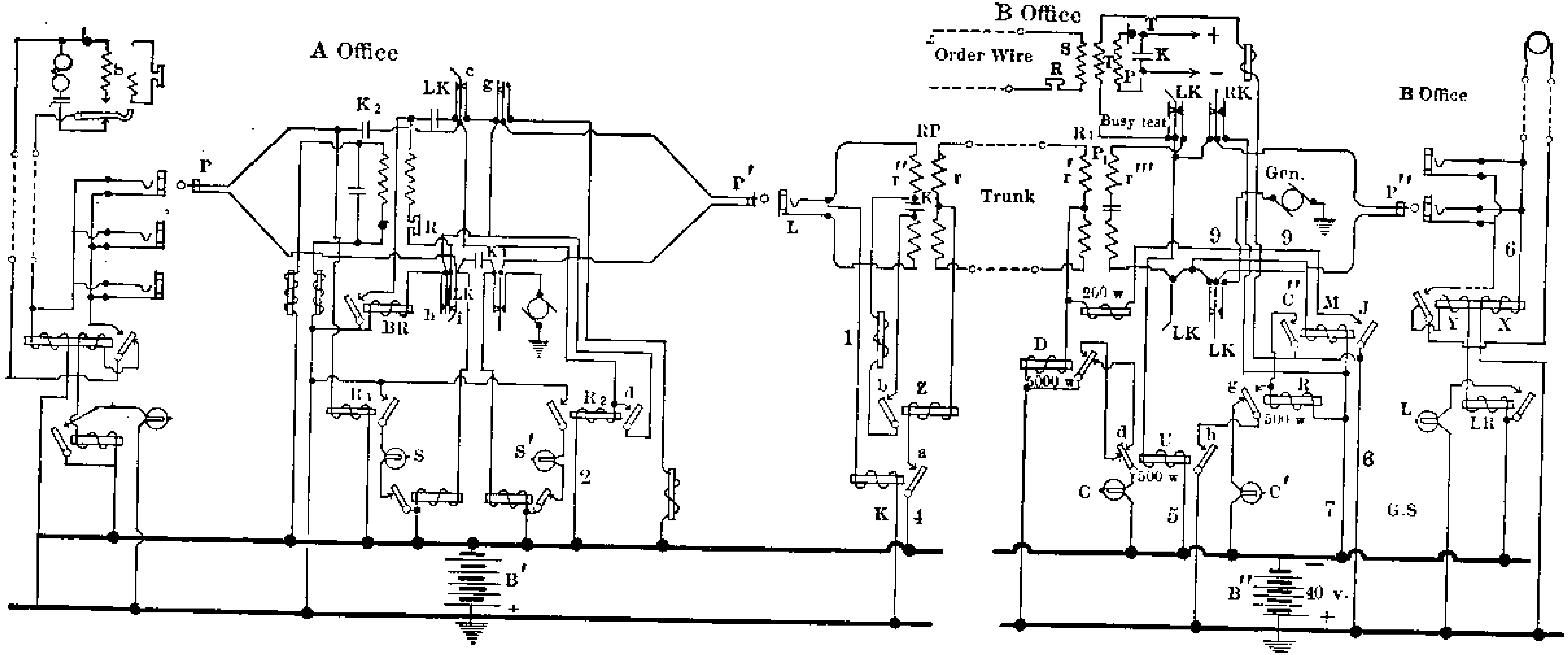


Fig. 95. — Stromberg-Carlson Trunk Circuit.

center of the coil r' in the "B" office, and relay *D* to the battery. Relay *D*, wound to about 5000 ohms, is excited and closes its contact, but its resistance is so great that relay *Z* does not operate. Contact of relay *D* illuminates lamp *C*, which informs the "B" operator that the "A" operator has plugged the proper trunk line, the "B" operator tests the called line, and if idle inserts the connecting plug P''. The insertion of this plug permits current to pass over conductor 5, relay *U*, tip side of line, conductor 6, and winding *X* of the cut-off relay to the battery. The line lamp *L* is prevented from lighting, relay *U* closes contacts *h* and *d*, lamp C' is illumined, indicating that the subscriber has not answered, and lamp *C* extinguished. The "B" operator rings in the usual manner. So long as the "B" subscriber's receiver remains on its hook, relay *M* is inert, because the sleeve side of the line is opened by the condenser at the substation. When the receiver is removed, relay *M* is excited, and closes contacts C'' and *J*. There is then circuit over conductor 7, relay *R*, contact C'', and conductor 6 to the battery, then *R* is excited and lamp C' extinguished. The closure of contact *J* completes a 200-ohm shunt via conductor 6, contact *J*, and conductor 9 about relay *D*. This increases the current over the trunk line sufficiently to excite relay *Z*, which closes contact *b*. This bridges the condenser *K* at the center of repeating coil r', and permits the battery from the "A" office to flow over the tip through both windings of coil r'', and back through the sleeve, and extinguishing the disconnect signal S' of the "A" operator, notifies her that the "B" subscriber has answered. When the parties replace their receivers the disconnect signals light

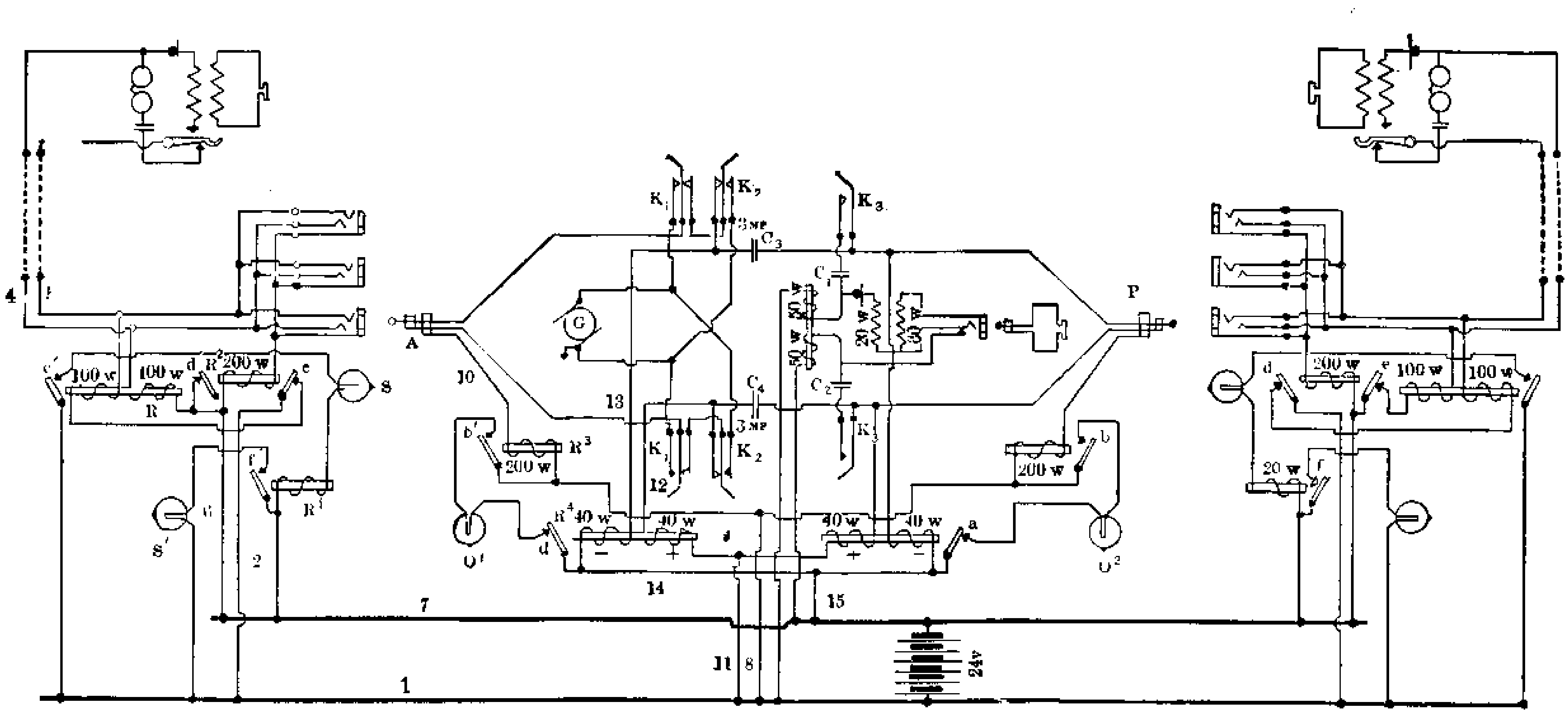


Fig. 96.—Century Common Battery Circuit.

in front of the "A" operator, who removes the trunk line plug, thus causing the disconnect signal in front of the "B" operator to illumine.

Few manufacturing companies, excepting the Western Electric, the Kellogg Switchboard and Supply Company, and the Stromberg-Carlson Manufacturing Company, have installed extensive trunking systems, but a number of others have devised ingenious common battery circuits; the following drawings show a few typical designs.

A circuit advocated by the Century Telephone Company is in Fig. 96. The office battery has a potential of 24 volts and is not grounded. When the subscriber removes his receiver, there is a circuit from the battery by conductor 1, conductor 2, contact *e*, line relay *R*, conductor 5, the substation, conductor 4, the line relay, contact *d′*, conductor 6 and 7 to the battery. Relay *R* is excited, contact *c′* closed, lighting signal *S*, exciting pilot relay *R′* and lamp *S′*. When the operator inserts answering plug *A* there is a circuit via conductors 8 and 9, relay R^3, conductor 10 to the ring of the jack, and thence through the cut-off relay R^2, to the battery. Relay R^2 operates deënergizing relay *R* and extinguishing signal *S*. As the receiver is off the hook there is also a circuit via conductor 11 to relay R^4, conductor 12, to the sleeve of the cord, thence to the substation, and return by the tip to conductor 13, through relay R^4 and conductors 14 and 15 to the battery. Relay R^4 is excited, lamp *O′* extinguished. When the receiver is replaced, R^4 is deënergized, and disconnect lamp *O′* glows. Normally the jack rings and plug tip are connected to the negative side of the battery, but when a line is in use, the positive battery is put on the *rings by the sleeve of the plug A. The ringing and listening* circuits are easily traced.

A circuit devised by Mr. Fowler is shown in Fig. 97. There are two line relays. The removal of the receiver permits current to flow from the positive pole of battery *B* over conductor 1 through coil A', and conductor

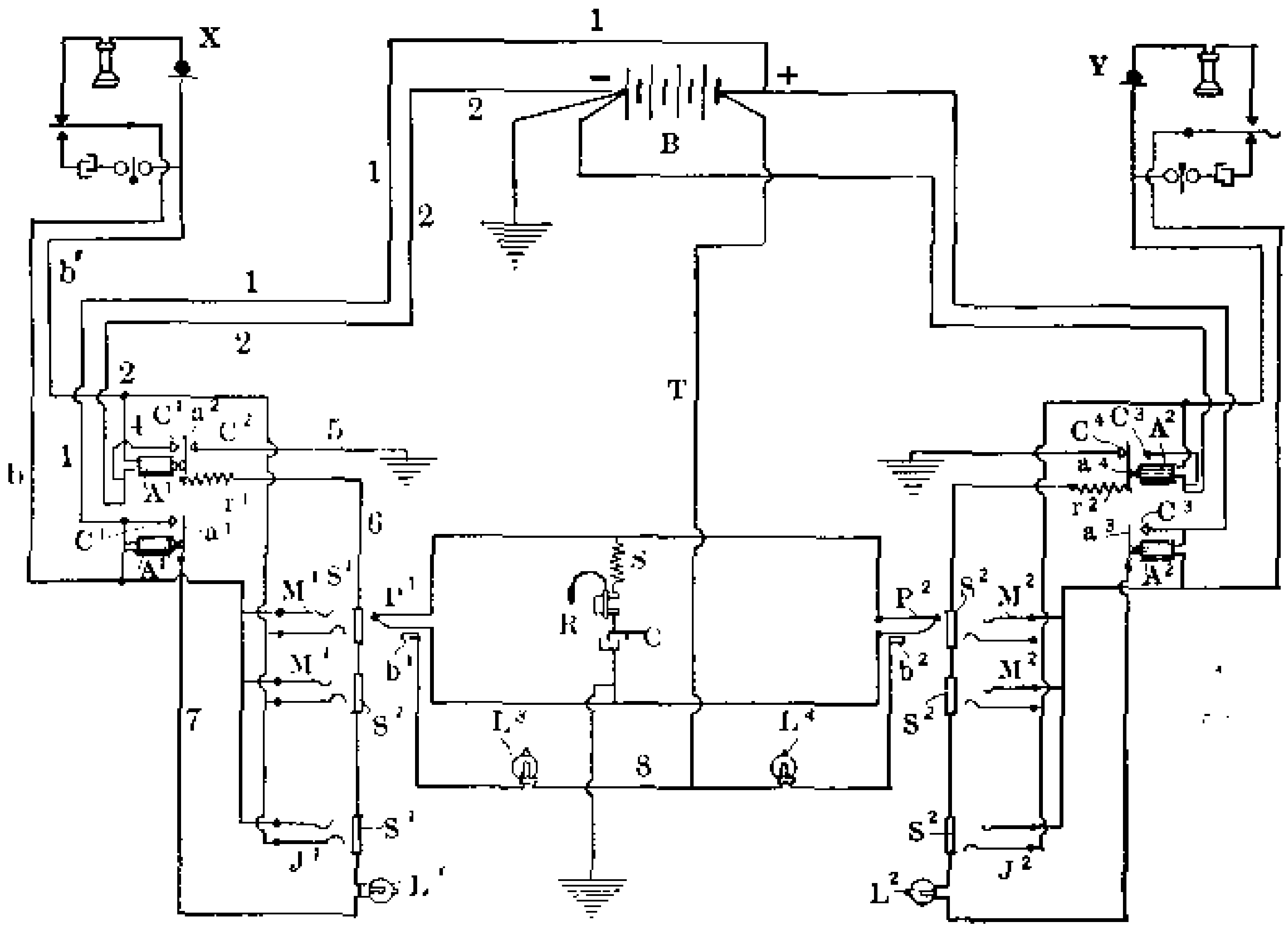


Fig. 97. — Fowler Circuit.

b to the substation, returning by conductor b', coil A'', and thence by conductor 2 to the battery. The relays are excited and the contacts C'' and C^2 closed. There is then circuit from the battery over conductor 1, contact C' through conductor 7, line lamp L', jack rings S', conductor 6 to contact C'', and conductor 2 to the battery. The line lamp L' is illumined. When the operator inserts the connecting plug P' a circuit is provided over conductor *T* to conductor 8, sleeve of the plug, conductor 6, resistance r', contact C'', and conductor 2 to the battery. Line lamp L' and supervisory lamp L^3 are in parallel, and the resistance r' does not permit sufficient current to flow to illumine both, hence both are extinguished. The operator tests in the usual manner. So long as the line is disengaged, the rings of the jacks are earthed by contact C^2 and conductor 5, and no busy signal is given. As soon as a subscriber removes a receiver, the jack rings are connected to the

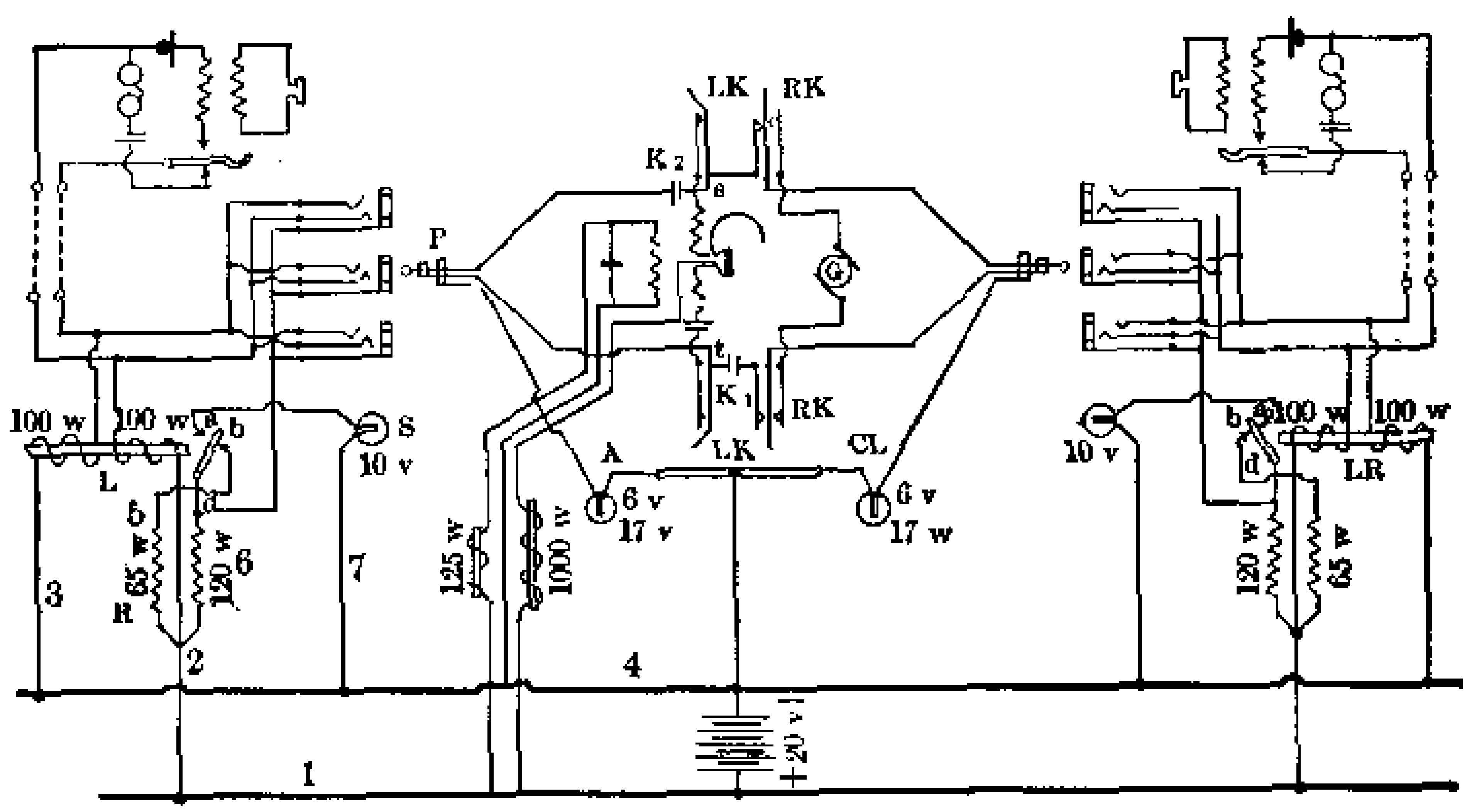


Fig. 98. — Stirling Circuit.

positive pole of the battery, hence, in this circuit, the test does not depend upon the insertion of an answering plug, but only on the position of the subscriber's receiver. As soon as the subscribers replace their receivers the line relays are deënergized, and then the disconnect lamps are lighted by current through conductor T, conductor 8, conductor 6, contact C^2, conductor 5 to battery.

A circuit used by the Stirling Company is shown in Fig. 98, which in some respects resembles the Fowler, but employs but one relay. When the subscriber removes his receiver, battery flows through conductor 1, conductor 2, line relay *L* to the substation, and returns through the line relay, conductor 3, and conductor 4 to the battery. The line relay is energized, its armature attracted, contact *a* closed, and signal lamp *S* illumined by the circuit through conductor 4, conductor 7, line lamp *S*, and conductor 6, containing 120 ohms resistance. The operator inserts the connecting plug *P*, this puts the disconnect lamp *A* as a shunt around signal lamp *S*, both being in series with the 120 ohms resistance, and hence both lamps are extinguished. When the subscriber replaces the receiver, the line relay is deënergized, contact *b* is closed, circuit of signal lamp *S* is broken, and the two resistances 65 and 120 ohms put in parallel and in series with the rings of the jack, the third wire of the cord and the disconnect lamp *A*, which is illumined. Ringing and testing are accomplished in the ordinary manner. Normally all the jack rings are connected to the positive side of the battery, and the tip of the plug similarly joined. When the line is busy the negative pole of the battery is connected to the jack thimbles.

Lattig and Goodrum have devised circuits noteworthy as using a 40-volt battery, split into two parts, arranged so that the supervisory relays are controlled by the difference in potential of the two parts of the battery. These circuits are shown in Figs. 99 and 100. In Fig. 99 the removal of the receiver permits current from main battery to pass over buss bar 39, wire 27, coil 8, wire 28, line wire 1, through substation, line wire 2, wire 15, relay 9, coil 7, and wire 30, buss bar 38, to battery, putting 40 volts

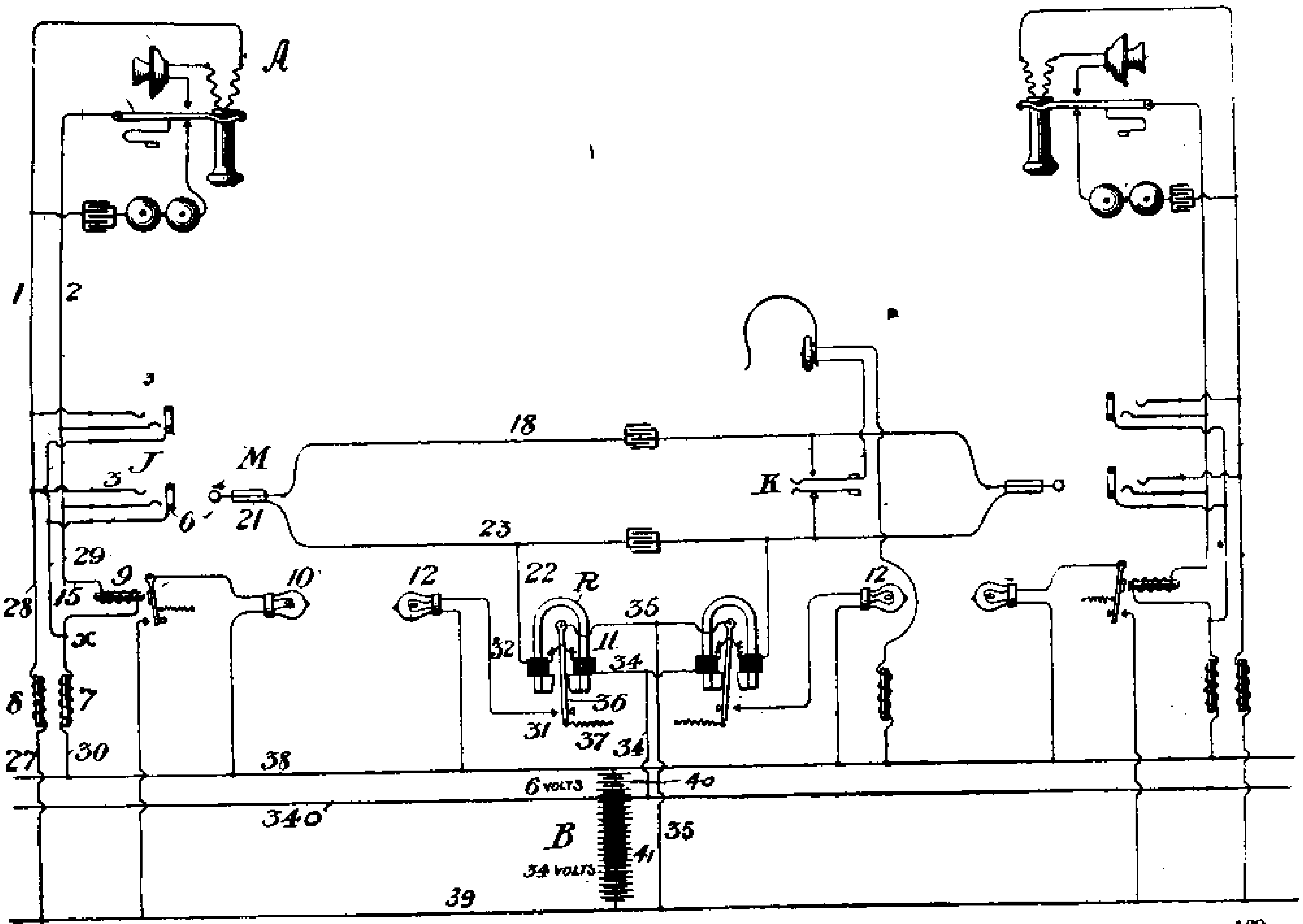


Fig. 99. — Lattig and Goodrum Circuit No. 1.

on the subscriber's line. This energizes relay 9, and illumines signal lamp 10. When the operator inserts the answering plug *M*, three results follow: The cord conductors are connected to the line wires, relay 9 is shunted by wire 29, jack ring 6, sleeve 21 of plug, and spring 4. Signal lamp 10 is extinguished. There is a circuit through conductor 34, supervisory relay *R*, wire 22, conductor 23, sleeve 21, ring 6, wire 29, coil 7, wire 30, and buss bar 38 to the upper division of the battery. The current from this part of the battery passing through the relay coils, if unopposed, would close contact 31, and light supervisory signal 12, but there is an opposing current through buss bar 39, wire 27, coil 8, wire 28, line wire 1, the substation, wire 2, spring 4, sleeve 21, wire 23, wire 22, windings of relay *R*, wire 34, and to buss bar 340; thus the battery is divided, so that there are opposing electromotive forces acting on relay *R*, and the resulting current is in such a direction (because the relay is polarized) as to aid spring 37 and not to oppose it, hence the supervisory lamp does not light so long as the receiver is off the hook. Normally all the jack thimbles are connected to one pole of the battery, and the tip of the plug similarly connected when the operator uses listening key *K*. A busy line has the other pole of the 6-volt battery placed upon the rings, hence the busy test — the called subscriber is rung in the usual manner. In Fig. 100, a similar arrangement of battery is shown, but the line is provided with a polarized line relay *L*, and the supervisory signals are controlled by means of relay L^4, whose armature shunts relay L^2 so long as the receiver is off the hook. This circuit is so readily traced, in connection with the description of the previous circuit, as to need no further explanation.

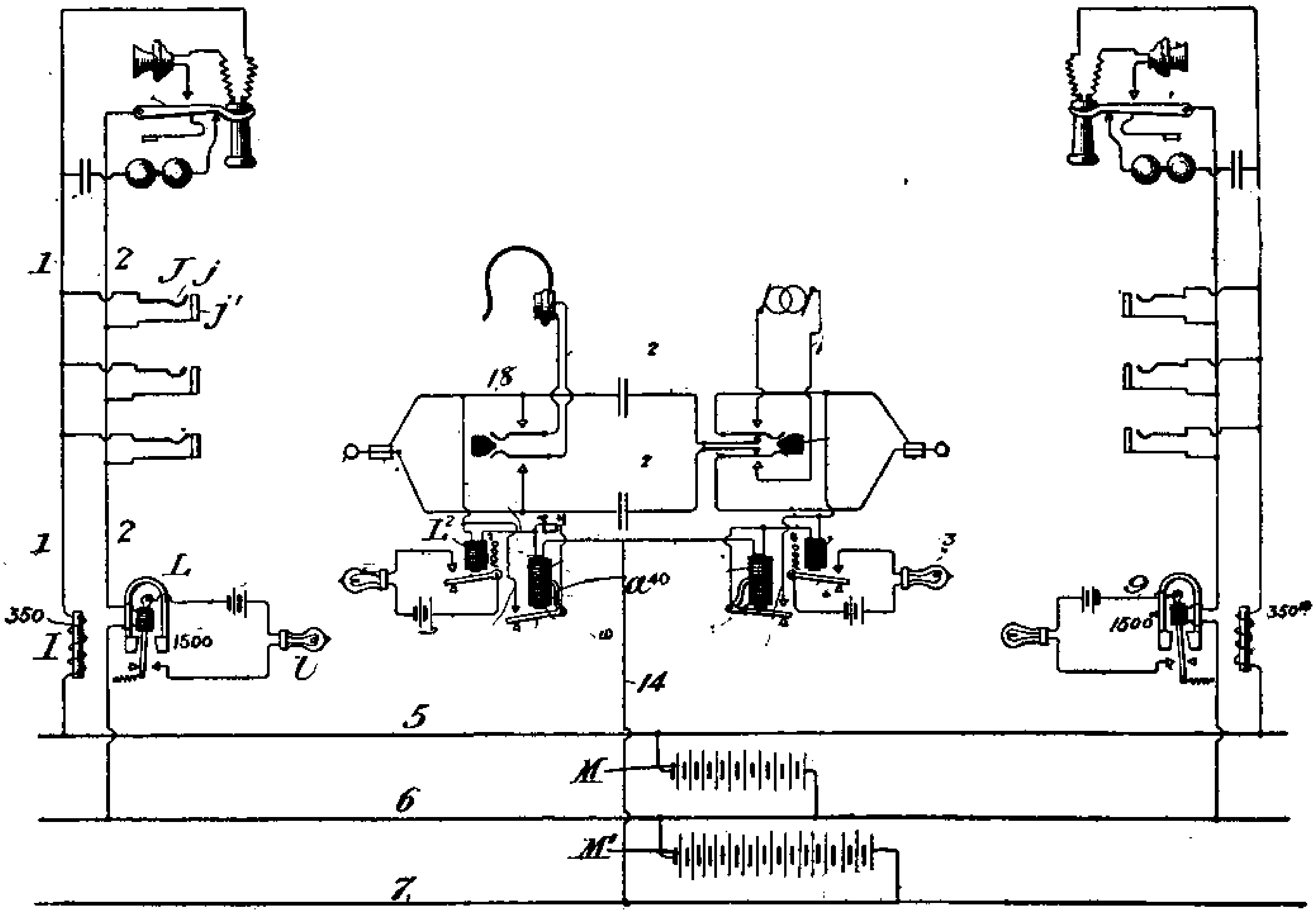


Fig. 100. — Lattig and Goodrum Circuit No. 2.

A circuit used by the International Telephone Company is shown in Fig. 101. The terminal is equipped with two relays. The adjustment of these relays is such that when the receiver is removed current will flow through buss bar and the cut-off relay, to one side of the line, thence through the substation and return through the line relay to the buss bar and the battery. These relays are so wound and adjusted that under the line conditions the line relay is excited, closes its contact, and illumines the line lamp, while the cut-off relay does not attract its armature. When the operator inserts the answering plug, there is a circuit through the buss bar, the cut-off relay, the sleeve of the jack, sleeve strand, and the relay *C* to the battery. This circuit decreases the resistance sufficiently to excite the cut-off relay, which extinguishes line lamp. A circuit may also be traced from one buss bar through the cut-off relay, the line, the tip spring of the jack, the tip of the plug, tip conductor of the cord circuit, the relay *A*, to the battery. Hence both relays are excited, and their contacts closed. The contact of the relay *C* connects the supervisory lamp lead with the battery, the contact at the relay *A* controls the answering lamp which is extinguished. When the subscriber replaces the receiver, the substation circuit is opened, the relay *A* is deënergized, the contact closed, and the answering lamp illumined; the relay *C* is not deënergized after it is once excited, on account of the circuit previously traced through the cut-off relay, hence the supervisory lamp is illumined. Testing and ringing are performed in the usual manner.

A circuit employed by the North Electric Company is

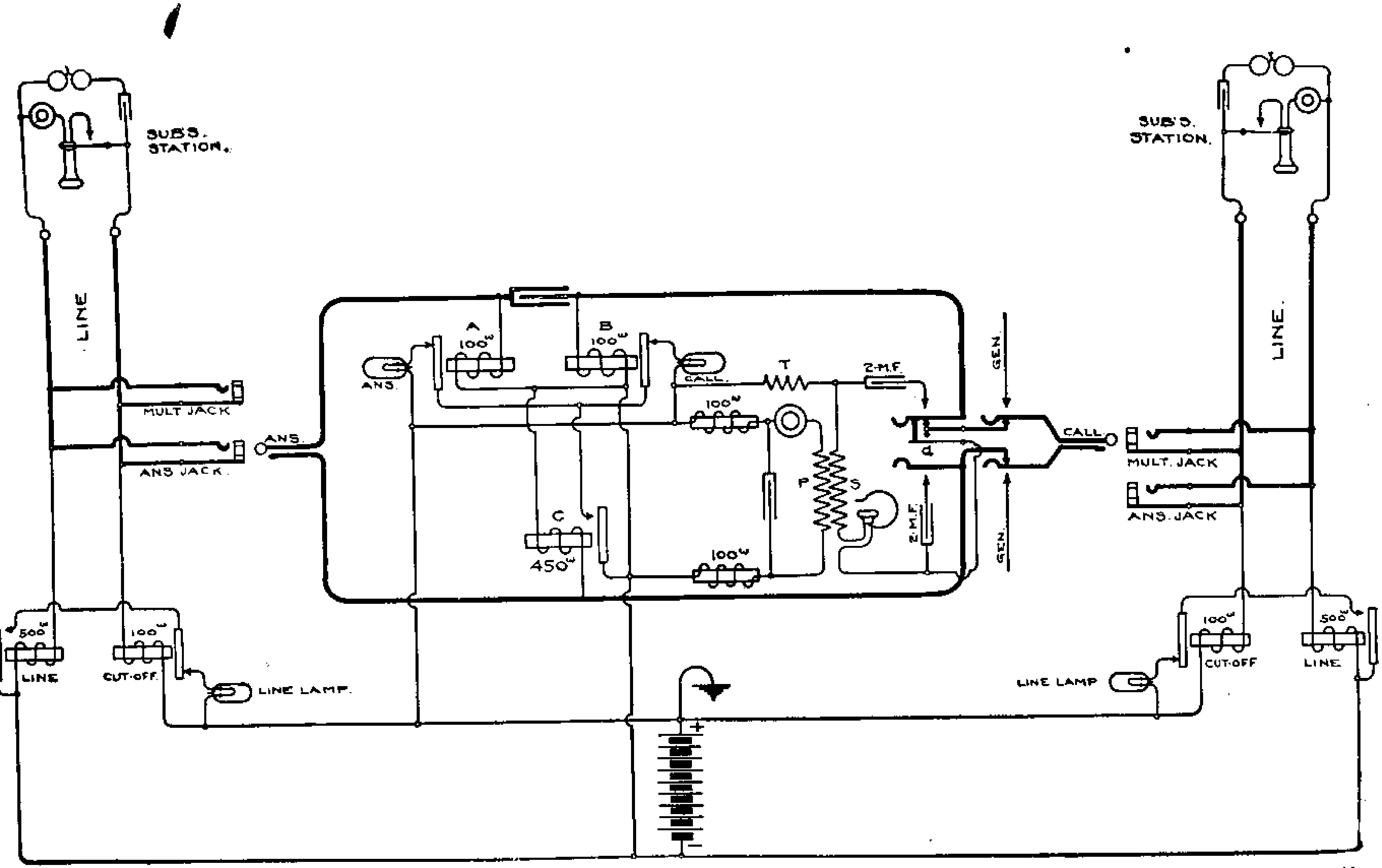


Fig. 101. — Circuit of International Telephone Co.

shown in Fig. 102. There are two 24-volt batteries, *B* and *A*. The removal of the receiver energizes line relay, its contact is closed and signal lamp lights. The insertion of the answering plug gives circuit from the battery through the cut-off relay to the ring of the jack. The cut-off relay is energized, its contact opened and the line lamp extinguished. As the subscriber's receiver is removed from the hook, there is a circuit through one winding of the disconnect relay *R*, the sleeve of the jack to the substation, tip of the plug, the other winding of the disconnect relay *R*, and to the battery. Disconnect relay *R* is energized, its back contact opened, and its front contact closed, hence the supervisory lamp is short-circuited and extinguished. Ringing and testing are accomplished in the usual manner, because normally the rings of the jacks are all connected to the positive pole of the battery, and the plug tip is similarly connected while testing by means of the listening key.

An ingenious circuit invented by Mr. Claussen is shown in Fig. 103. On the removal of the receiver, current flows from battery *B*, buss bar 1, conductor 2, retardation coil *A*, conductor *a*, the substation, conductors *a′*, 6, and 3, line relay *L*, to conductor 4, conductor 5, retardation coil *B*, and buss bar 10 to the battery, the line relay is excited and illumines line lamp *S*. The insertion of the answering plug *P* places the supervisory relay *A* as a shunt around the line relay *L*, which is sufficiently deënergized to extinguish line signal *S*. Also relay *A* is excited by the current which it withdraws from relay *L*, hence contact *a* is opened and disconnect lamp *D* is extinguished. When the receiver is replaced the line circuit is opened,

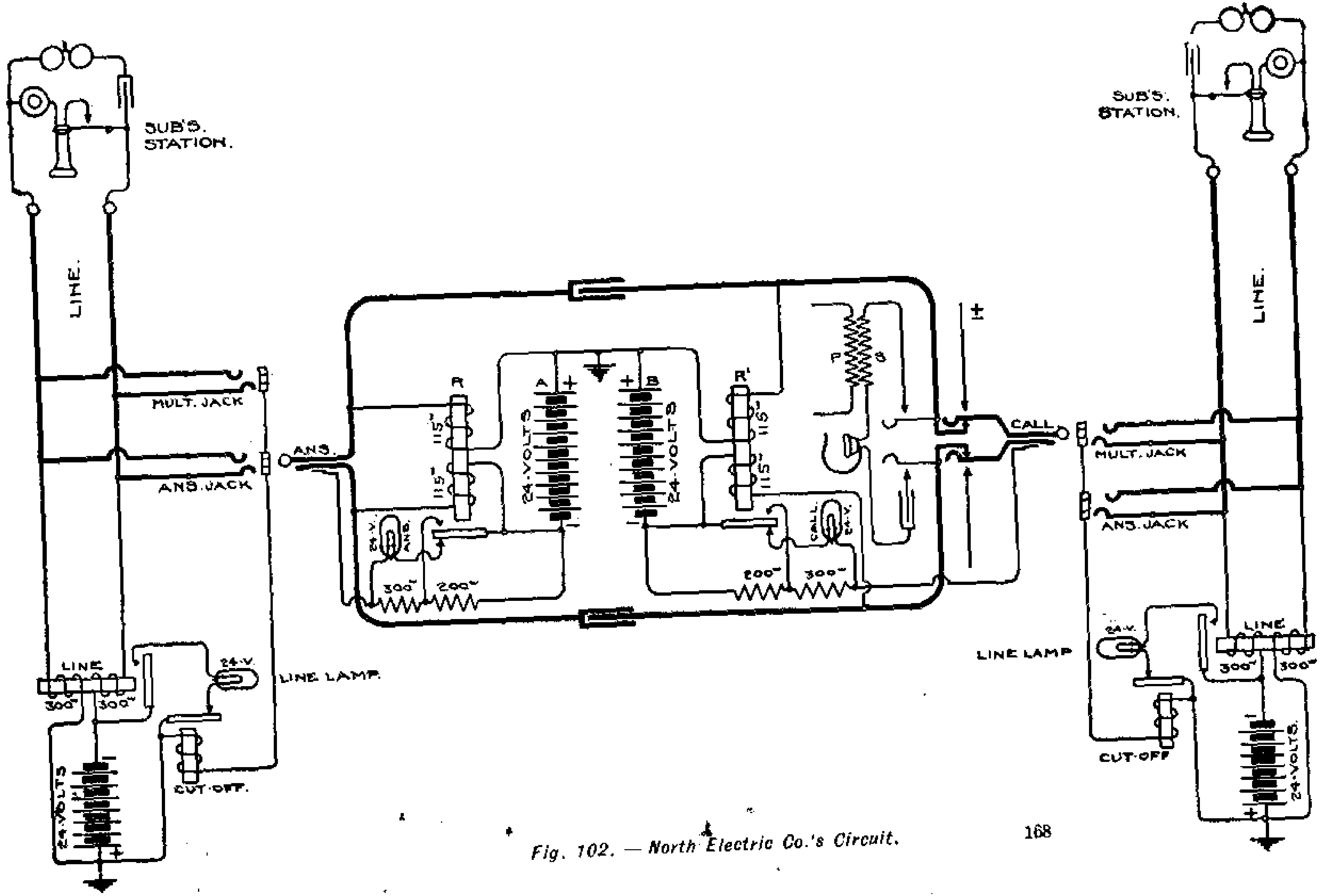


Fig. 102. — North Electric Co.'s Circuit.

relays *L* and *A* deënergized and contact *a* closed, then there is circuit from buss bar 10, through conductor 6, relay *R*, conductors 7 and 8, the ring of the jack, conductor 9, coil *A*, conductor 2, to buss bar 1, lighting lamp *D*. Ringing and testing are done in the usual manner.

Enough has been said to indicate that the relay and lamp are the most important pieces of apparatus in the modern switchboard. Various types of relays have already

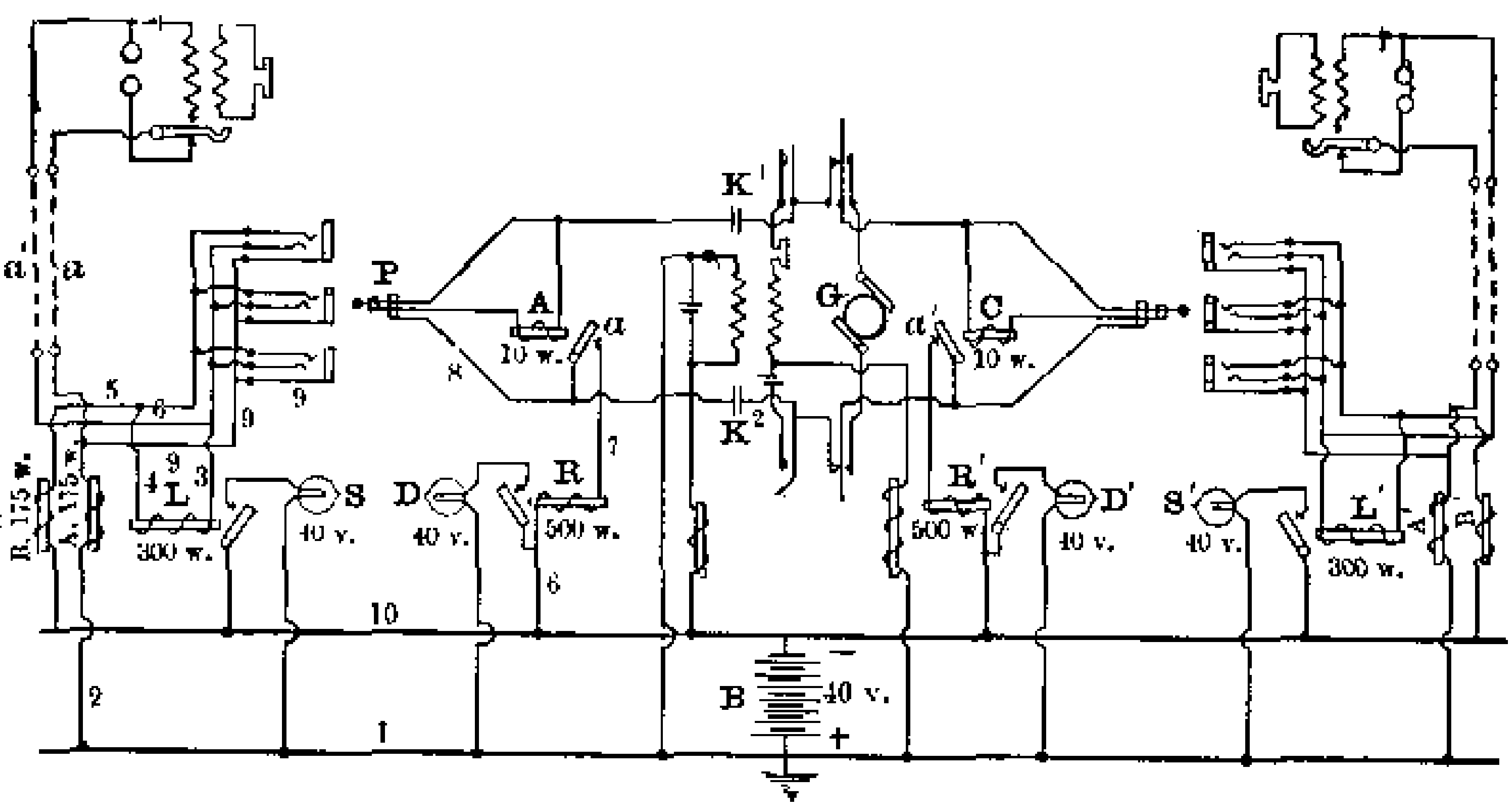


Fig. 103. — Claussen's Circuit.

been illustrated, but the circuits described show that lines and cord circuits require several relays, and hence, as offices of say 5000 lines must house from 15,000 to 25,000 relays, including those used upon trunking circuits, it becomes a matter of much importance to design relays to be as substantial and as reliable as possible, and to so arrange them that they may be compactly placed in a manner to permit of easy inspection. Figs. 104 and 105 show modern designs that have been successful. The relays may be mounted in strips of ten or twenty, and placed upon an iron rack, resembling a distributing board.

Lamp signals have passed through a similar process of evolution until now they are compactly arranged in strips, the same space as the jacks, and so may be conveniently associated with them. Fig. 106 is a modern bank of lamp signals. The apparatus of a modern switchboard is assembled in a frame which is merely the natural evolution of the single position switchboard into one accomodating a number of operators. At a convenient height above the floor, a key shelf is placed, upon which the plugs stand and into which the listening and ringing keys are fixed.

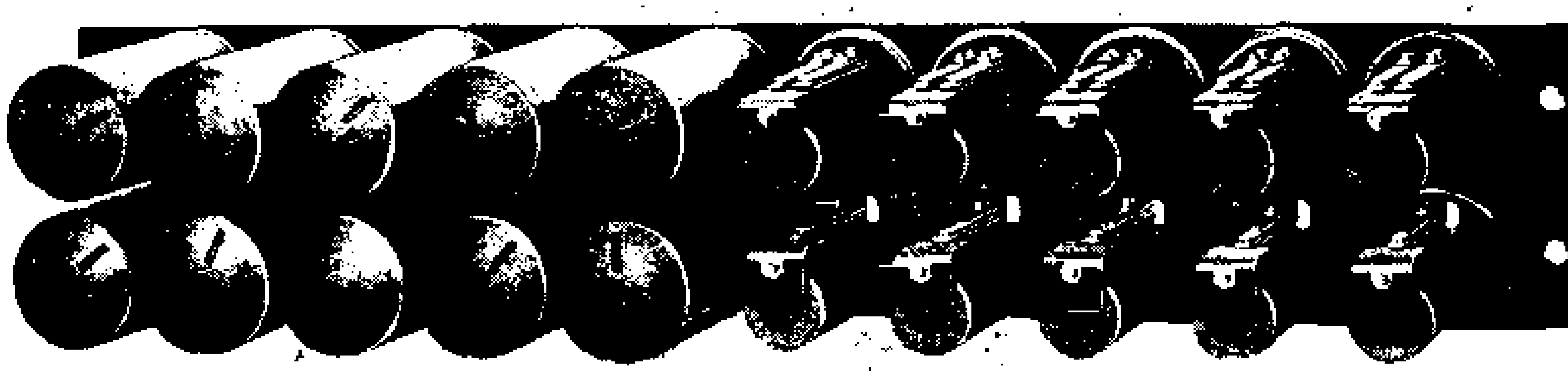


Fig. 104. — Tubular Relays.

In front of the operator rises a series of panels, the lower portions being occupied by the line lamps and answering jacks, the upper ones by the multiple jacks. Fig. 107 is an elevation and an enlarged view of the switchboard panels.

The increasing tendency to adopt measured service modifies the switchboard circuit in order that a record of calls may be secured. Measured service is handled in

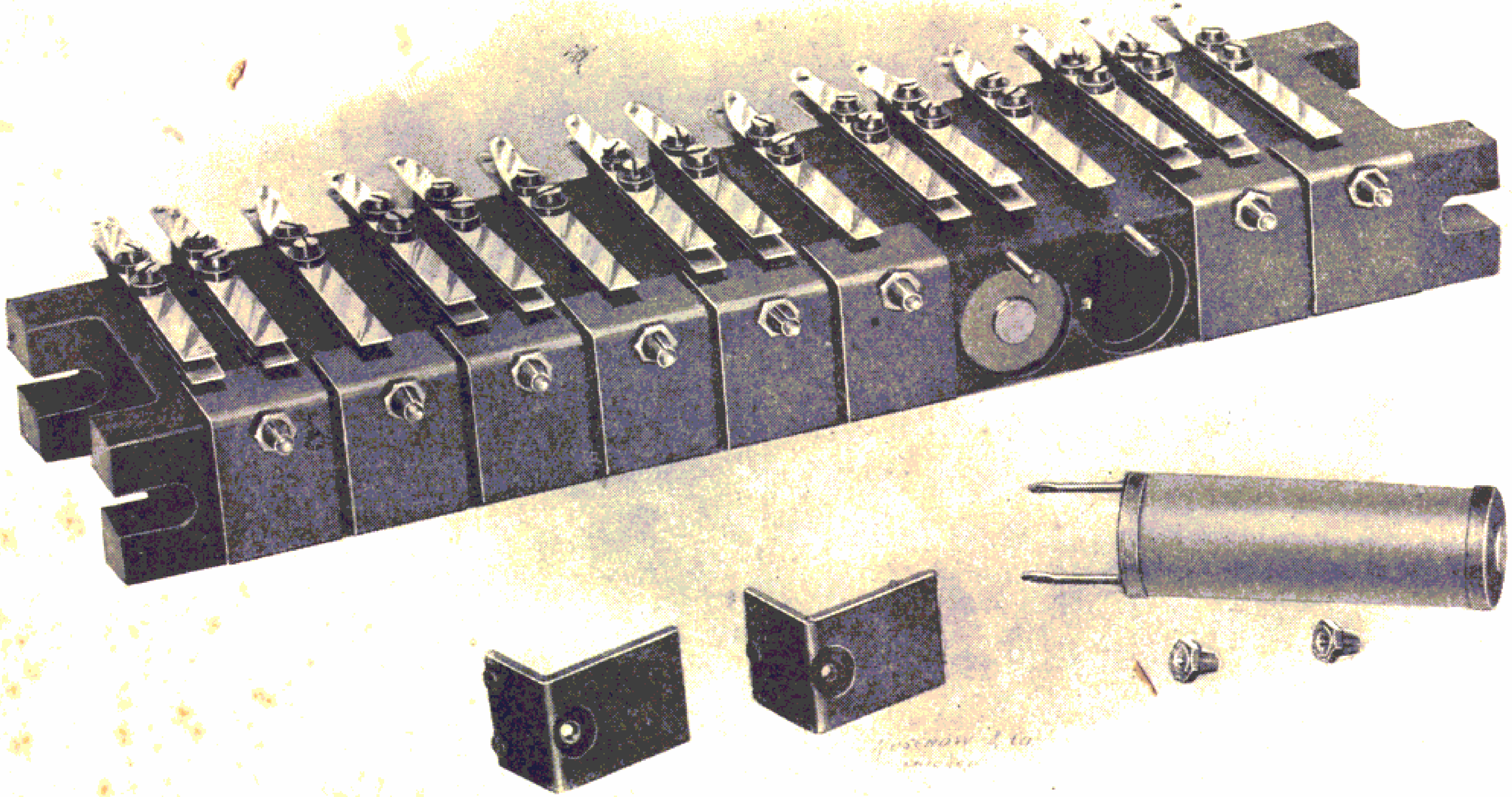


Fig. 105. — Relays Mounted on a Strip.

three ways. First, the record plan — the operator makes a pencil memorandum, or ticket, showing the number of the calling line and other desirable details; second, the prepayment plan — the substation is provided with a coin box into which the message fee is deposited, and each message is prepaid; third, the message meter — a counter being placed upon the subscriber's line, which more or less automatically records the number of messages transmitted. As it has been difficult to secure an entirely satisfactory method of prepaying messages or a perfect call register, measured service has in the past, and still is sometimes handled by the ticket method. Nevertheless, automatic appliances are rapidly being improved and their use extended. For pay-stations the coin-box is the only expedient. Two different methods are in use — an appropriate receptacle is provided, which contains chutes of such sizes as will accept coins of particular denominations. Each chute is arranged so that a coin falls on a gong, the impact producing a sound which is delivered to the operator by means of the transmitter. After the operator has secured the desired correspondent, she notifies the calling party to drop the necessary coins into the chutes, and refuses to give connection unless she hears such sounds as indicate that the proper sum has been deposited. This is the principle of the well-known Gray paystation and its congenors. The other method exclusively adopted by the so-called "nickel-in-the-slot" machines requires the calling party to deposit a coin of given size before the circuit is completed, in such a manner as to secure the attention of the operator. Many devices of this kind have been developed by Scribner, McBerty and Bullard. A recently

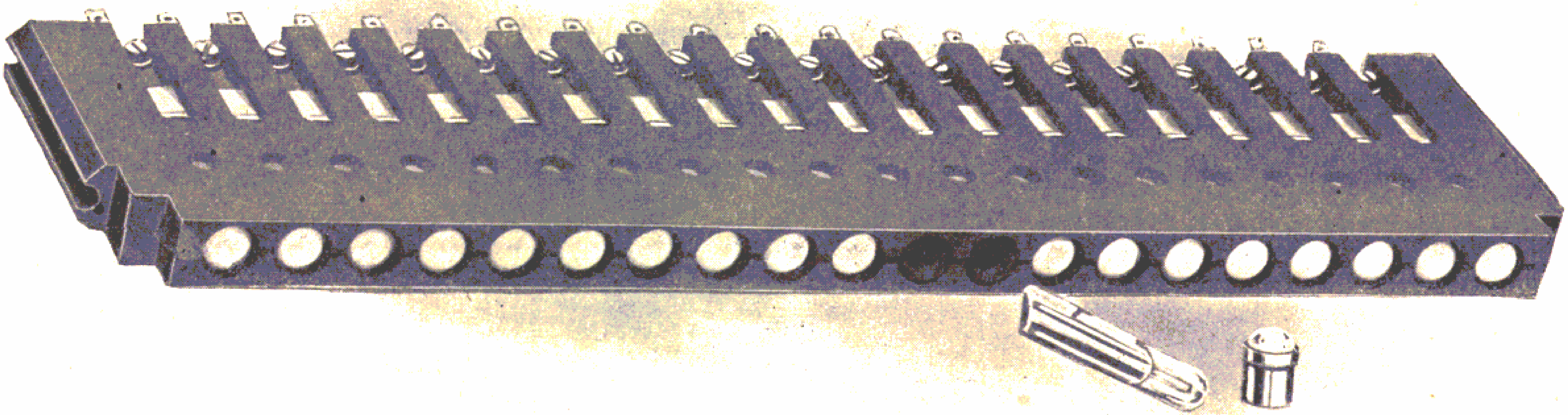


Fig. 106. — Line Lamp Signals.

improved form is shown in Fig. 108. The control of the coin is accomplished by the peculiar contour of the coin slot, and by three pins, e^2, e^4 and e^5, mounted upon the tilting armature of a polarized electro magnet (outline dotted) and projecting into the coin slot. The various circles marked c', c^2, etc., show different positions which a coin may assume. The coin c', just deposited rolls down the slot until it strikes the pin e^5. If this is in its normal position the coin will be deflected to the left as at c^2, c^4, c^5, and be returned to the depositor at b. This route corresponds to some abnormal condition of the apparatus, such as failure to remove the receiver — the operator cannot be signaled. Suppose everything is in working order. Then the pin e^5 will be in the position y', the armature to which it is fastened having tilted under the influence of a circuit closed by the rising switch hook. The coin will then fall to the position c^3, where it closes a circuit between pins e^3 and e^2, shunting a high resistance in the signal circuit, and permitting sufficient current to actuate the line signal. When the operator responds the circuit changes permit the armature of the collector magnet to return to mid-position. This brings pin e^4 in the middle of the slot, obstructing the slot entirely, and at the same time causes pin e^2 to release the coin, which falls to position c^6. The operator is now in communication with the caller. If she succeeds in completing the desired connection, a key on the switchboard enables her to actuate the electro magnet and move pin e^4 to throw the coin in the cash-box. If, on the other hand, the call fails, a reversal of the current enables the coin to be returned at b.

For the regular subscriber the ideal measured service

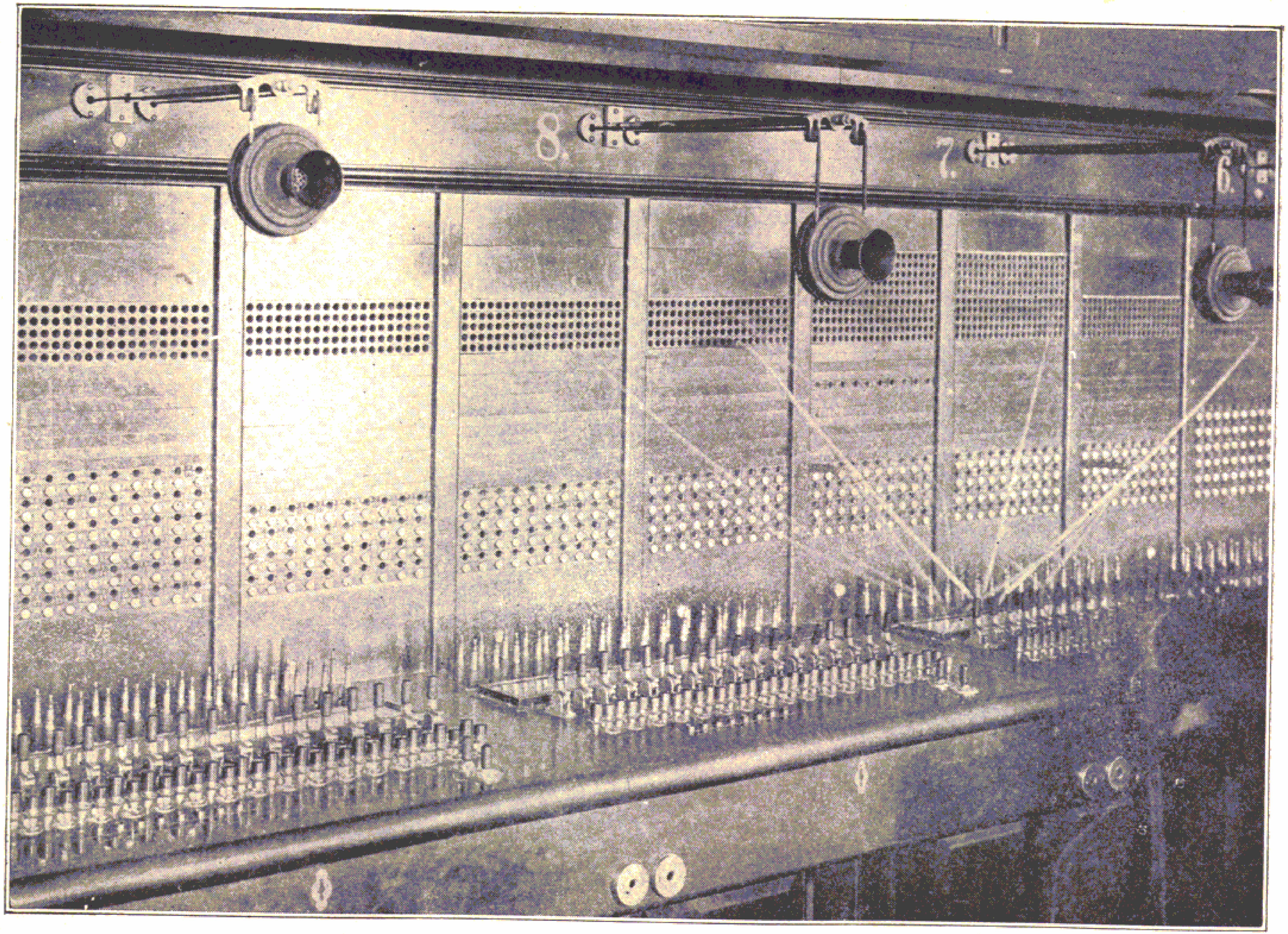


Fig. 107.—Elevation of Lamp Signal Switchboard.

method is to provide a register which will count the number of calls, but it has been difficult to devise machinery which should meet all requirements imposed by telephone managers. It is held that a proper service meter should record originating calls only, and should fail to record when the subscriber does not obtain the party called.

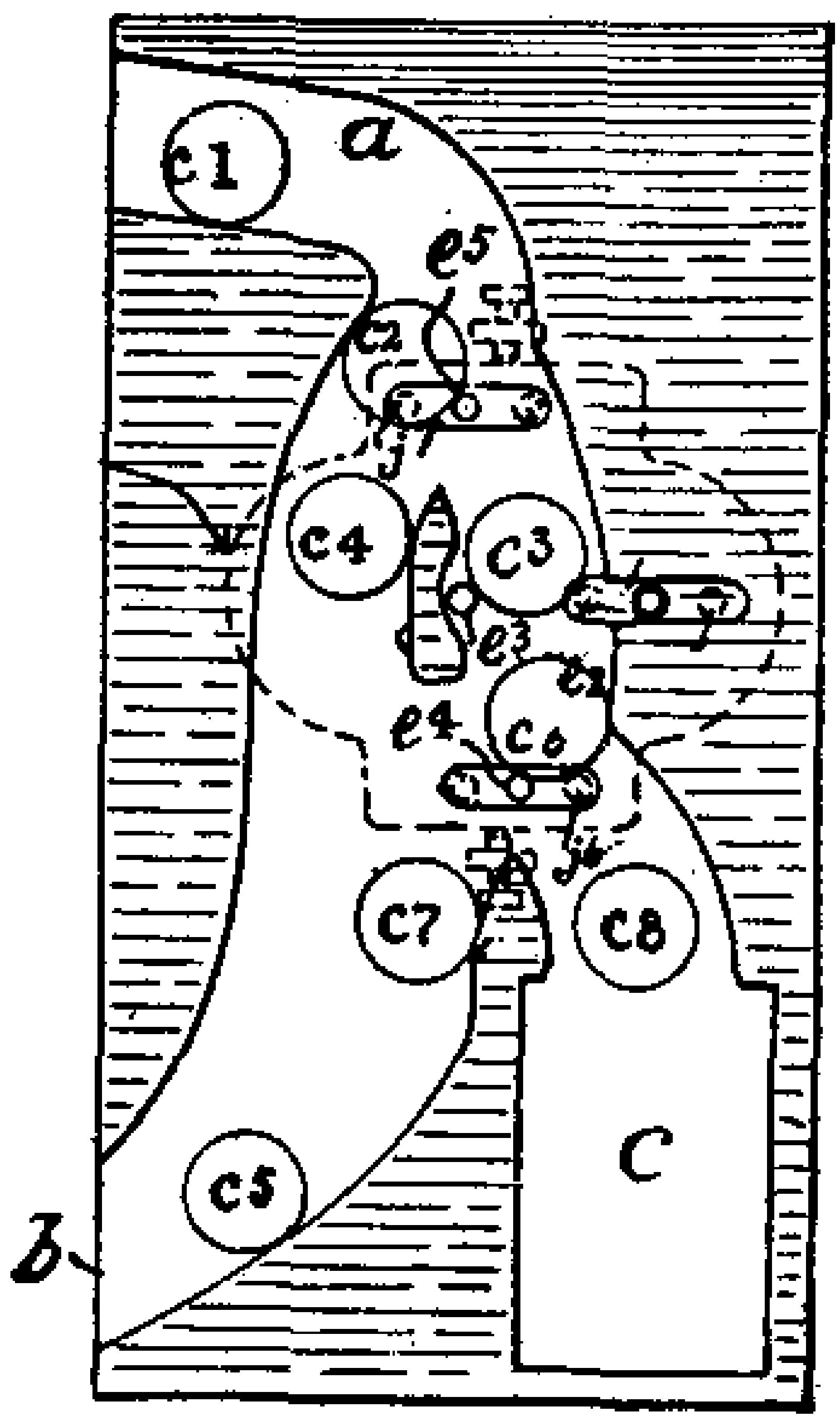


Fig. 108.—Coin Box Device.

Some believe that the meter should be installed at the subscriber's premises in order that he may have the satisfaction of seeing that his call is properly recorded; others, that it is none of the subscriber's business to watch the meter, and that *for the convenience of* the company it should be placed at the central office and form a perpetual peg count. There is reason in all these views, but impossible to construct a machine that shall fulfil all. A typical central office meter is the McBerty circuit of Fig. 109. The substation and subscriber's terminal is as previously described, excepting that an additional electro magnet *A* is in the circuit of the cut-off relay. This magnet actuates the counting mechanism of the message recorder. The winding of the cut-off relay *c*, and the relay *A*, are so proportioned that it requires a much greater current to operate relay *A* than relay *c*. Into conductor 6 two resistance coils *i* (100 ohms) and *k* (30 ohms) are inserted. From the ring of the connecting plug *e'*, conductor 7 extends through supervisory lamp *h'*, resistance *l*, and lever m^3 which is connected to conductor 11; conductor 8 forms with armature *m'* a shunt about resistance *i*. When

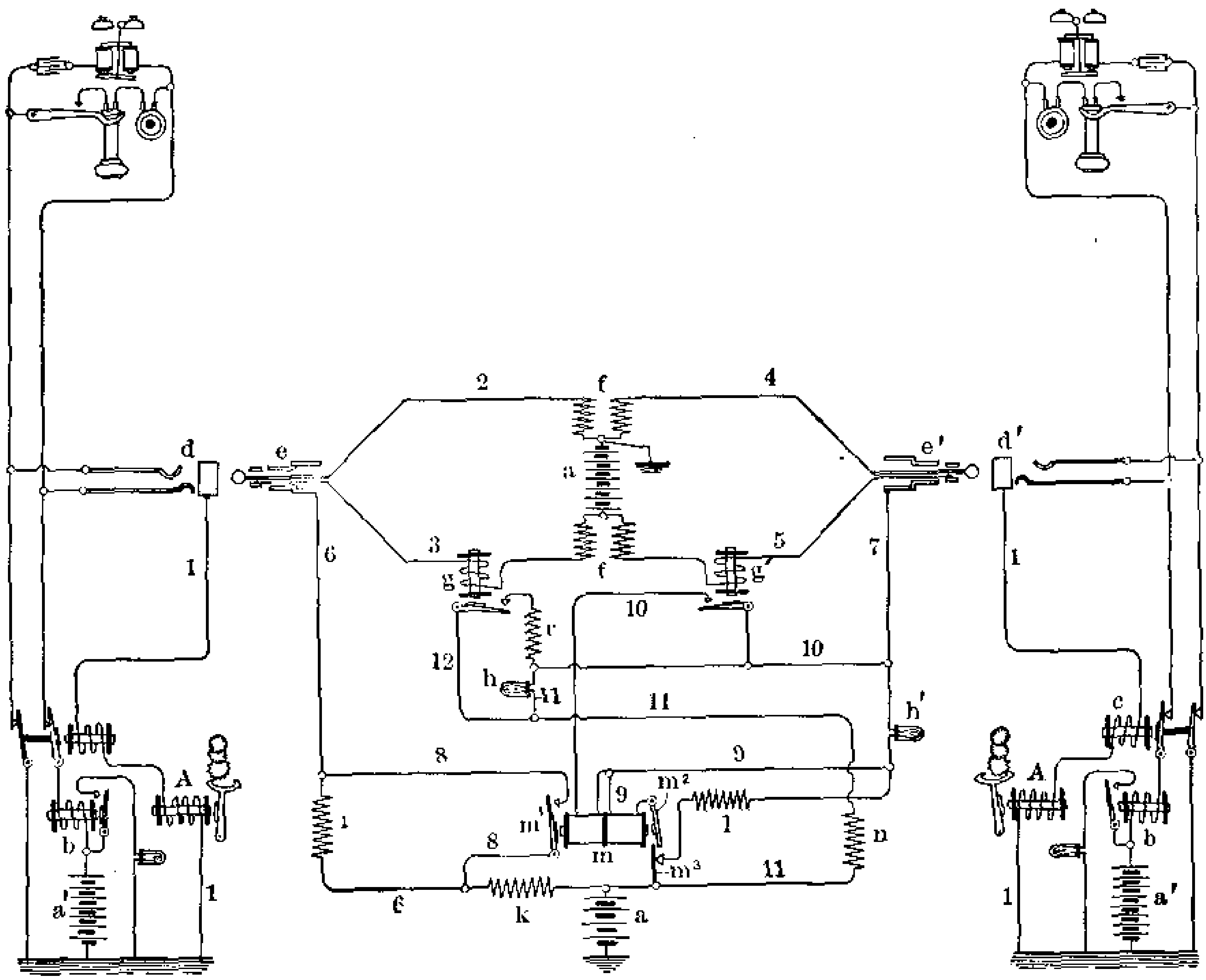


Fig. 109.—Meter Circuit Meter at Central Office.

the calling subscriber removes the receiver, relay *b* is excited. The insertion of the answering plug *e* closes a circuit from the battery through resistances *k* and *i*, conductor 6, conductor 1, relay *c* and relay *A* to the ground. Relay *c* operates, but *A* does not, because resistances *s* and *i* prevent enough current from traversing the circuit to excite it. Likewise when the connecting plug e' is inserted into the jack of the called line, there is a circuit through conductor 11, resistance n and l and lamp h', then conductor 12 and

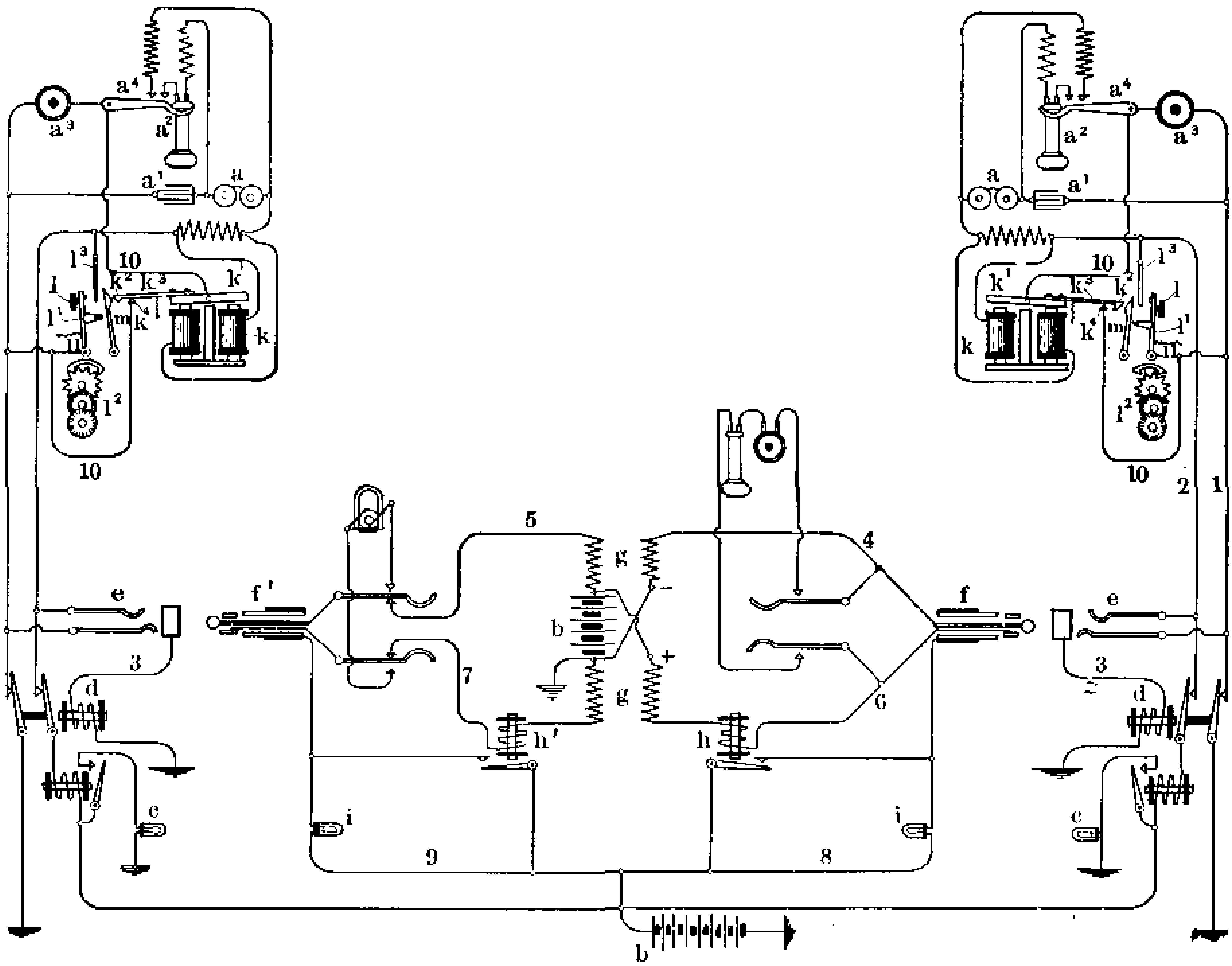


Fig. 110.—Meter Circuit Meter at Substation.

resistance r in parallel with lamp h, conductor 10, conductor 7, relay c and relay A; relay c is excited, but owing to the resistances $1n$ and r, A does not operate. Lamp h' is illumined because relay g' is unexcited. When the receiver of the called line is removed relay g' is excited, attracts its armature and there is circuit from battery *a* through armature m^3, resistance 1, conductor 9, winding of relay *m*, conductor 10, conductor 7, conductor 1, and to ground, shunting out lamp *h*. Relay *m* is excited, its armatures attracted; armature m^2 breaks the circuit through lamp *h'* and completes a new circuit through the other winding, locking the armatures in their places, subject only to the circuit through conductors 9, 7, and 1; the local contacts of the calling plug and the spring jack of the called line; armature *m'* shunts the resistance *i*, and then sufficient current will traverse conductors 6 and 1 to operate relay *A* and record a message. Relay *A* of the called line will not be actuated because of the resistance of relay *m*.

The circuit in Fig. 110 shows a circuit for a meter located at the substation. The telephone set is provided with a polarized magnet *k* having a pivoted armature *k'*, so connected as to form with conductor 10 a shunt around the transmitter. There is a push button 1 which actuates the message counter 1^2. Under normal conditions the apparatus is in the position shown, and hence the transmitter is shunted out of service. If the operator obtains the called party she notifies the subscriber to press the button 1. This forces the lever *m* underneath the catch *k*, lifts the lever and opens contact k^4, thus breaking the shunt around the transmitter; the parties can then talk. It will be noticed that the poles of the office battery *b* to the connecting side of the cord circuit are reversed. When the operator inserts the connecting plug *f*, the direction of the current through the called subscriber's line is reversed, magnet *k* is excited, its arma-

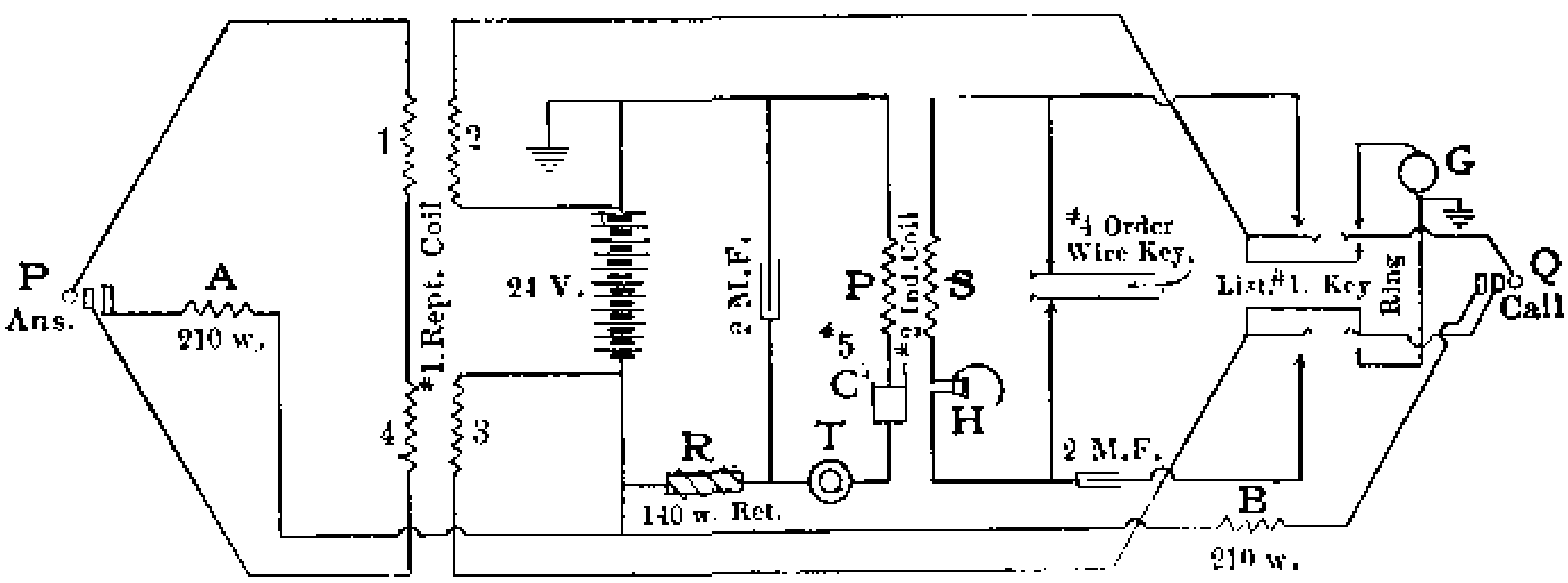


Fig. 111.—Chief Operator's Cord Circuit.

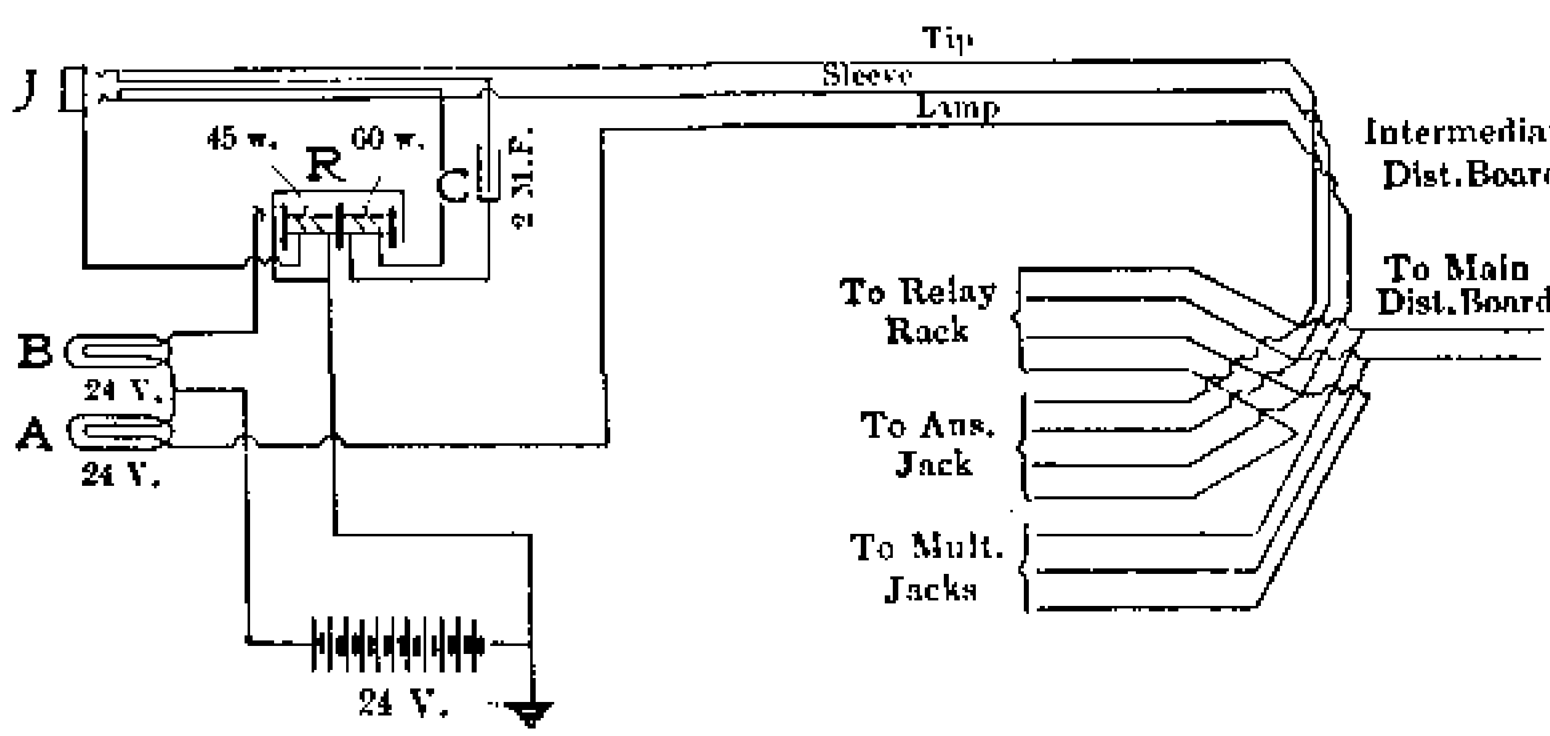


Fig. 112.—Observation Lines.

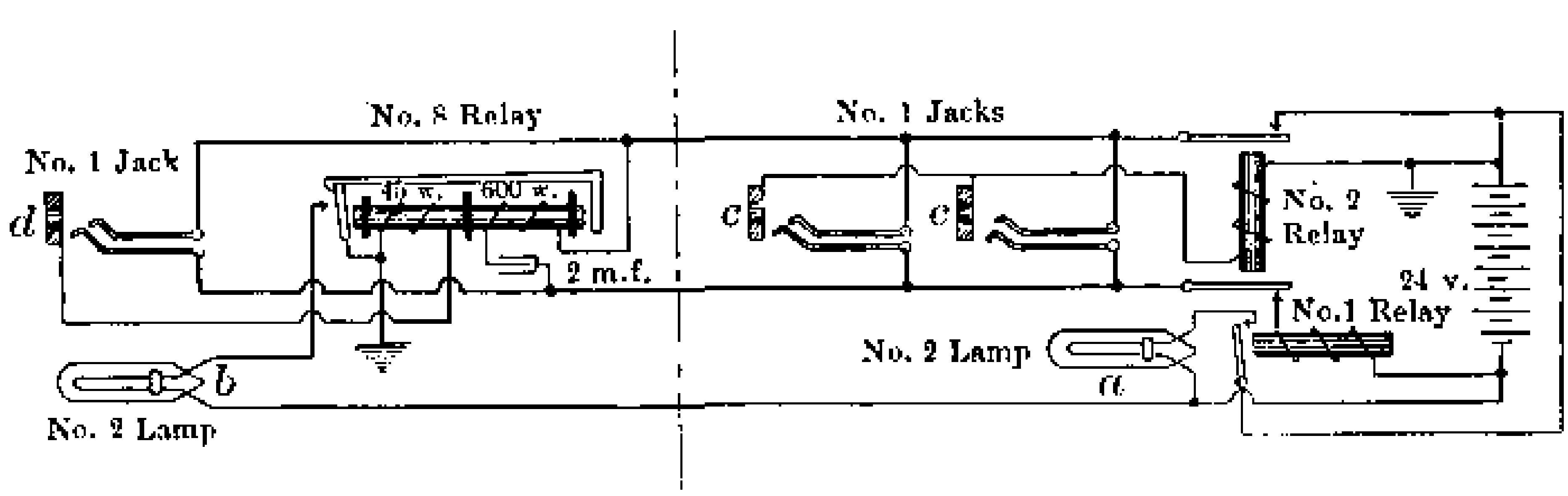


Fig. 113.—Lines to Multiple Board.

ture k' attracted, the shunt around the transmitter of the called party automatically removed, and no record made. The object of shunt 11, which is controlled by contacts 1^3 and $1'$, is to prevent the user from pressing and holding the button 1 in order to avoid registering a second call in case one is desired, for such an act would maintain a short circuit about the line and interfere with the transmission of signals to obtain the attention of the operator.

To enable the chief operator to transact business, certain special circuits are necessary, they are as follows:

1. Cord Circuit.
2. Observation Lines.
3. Lines to Multiple Board.
4. Test Lines to "B" operator.
5. Listening and pilot circuits.
6. Local Trunks to other officials.
7. Trunks for calling subscribers.

1. *"A" Operator's Cord Circuit.* — The "A" operator's cord circuit is shown in Fig. 111. It is divided by a repeating coil into two parts, that on the right-hand side resembling one-half of the ordinary "A" operator's cord circuit, while the left-hand side has no battery.

2. *Observation Lines.* — It is frequently necessary for the chief operator to supervise a subscriber's line in order that all the business transacted over it may pass under her notice. For this purpose a circuit shown in Fig. 112 is provided, which runs to terminals upon the intermediate distributing board. At any time the chief operator may order jumpers run to connect an observation line with that of the subscriber's whose traffic is to be studied. Should

the subscriber remove his receiver, lamp *A* will light simultaneously with the regular signal as it is in parallel therewith. Observing this signal the chief will insert plug *P* (Fig. 111) in jack *J* (Fig. 112), and can listen unsuspected. This circuit also informs the chief how long the "A" operator occupies in answering. The 60-ohm winding of relay *R* is bridged across the line in series with the condenser *c*, which prevents current from flowing through the relay and lighting the subscriber's signal. When any operator calls the subscriber, ringing current will excite relay *R* and light lamp *B*, thus the chief operator is informed whenever the line under test makes or receives a call.

3. *Lines to the Multiple Board.* — Fig. 113 shows the circuit between the chief desk and the switchboard. The apparatus on the right hand of the dotted line is similar to a regular subscriber's terminal and string of multiple jacks. If an operator wishes to talk to the chief she inserts the connecting plug into jack *e*. The insertion of the plug operates the cut-off relay in the usual manner; then ringing current traverses the 2 *m.f.* condenser and the 600-ohm winding of the relay on the left-hand side of the dotted line. The armature falls, and lamp *b* illumines. When the chief inserts plug *P*, Fig. 112, into jack *d*, Fig. 113, the relay is restored and lamp *b* extinguished. When conversation is completed the chief operator removes her plug. The disconnect lamp at the switchboard then lights in the usual manner, the operator, obeying this signal, removes the plugs. The chief operator can call the multiple board over this circuit by inserting plug *P*, Fig. 111, in jack *d*, Fig. 113. The circuit of plug *P* operates in a

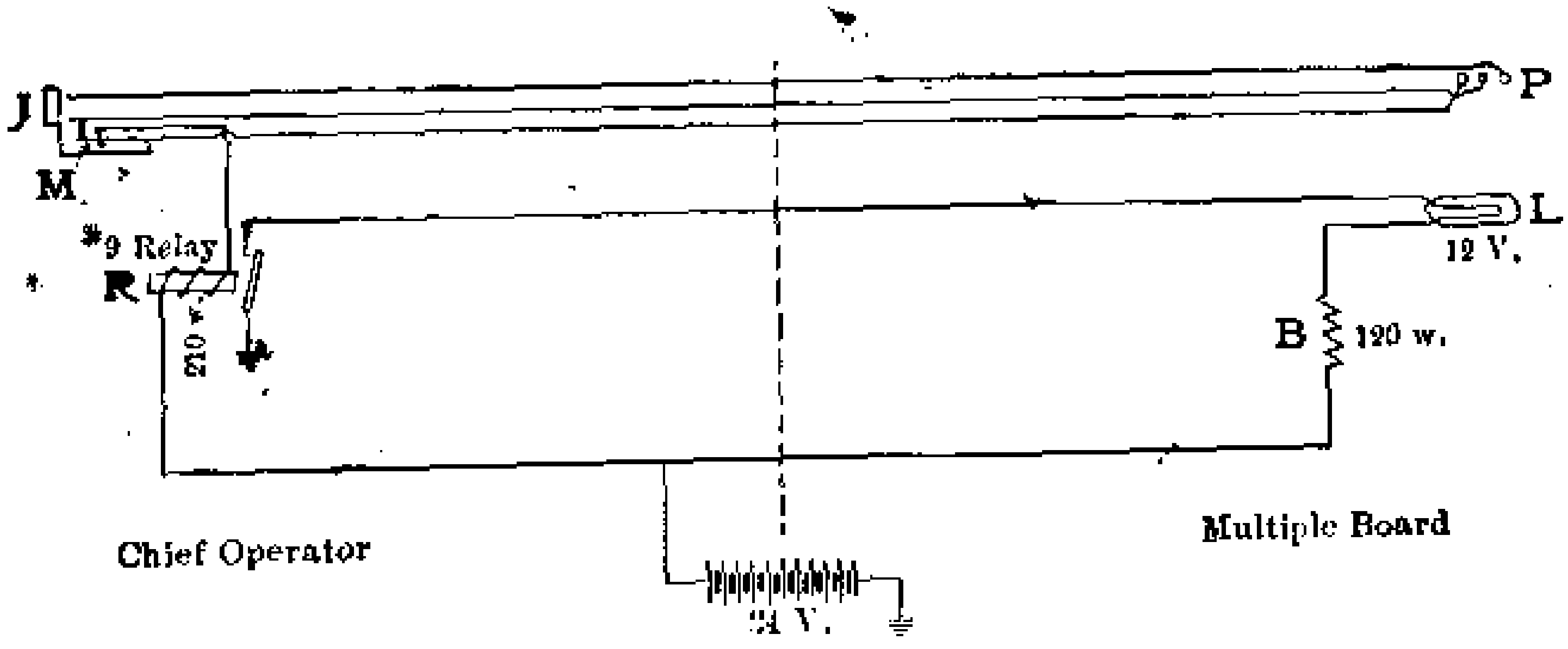


Fig. 114. — Testing Line to B Operator.

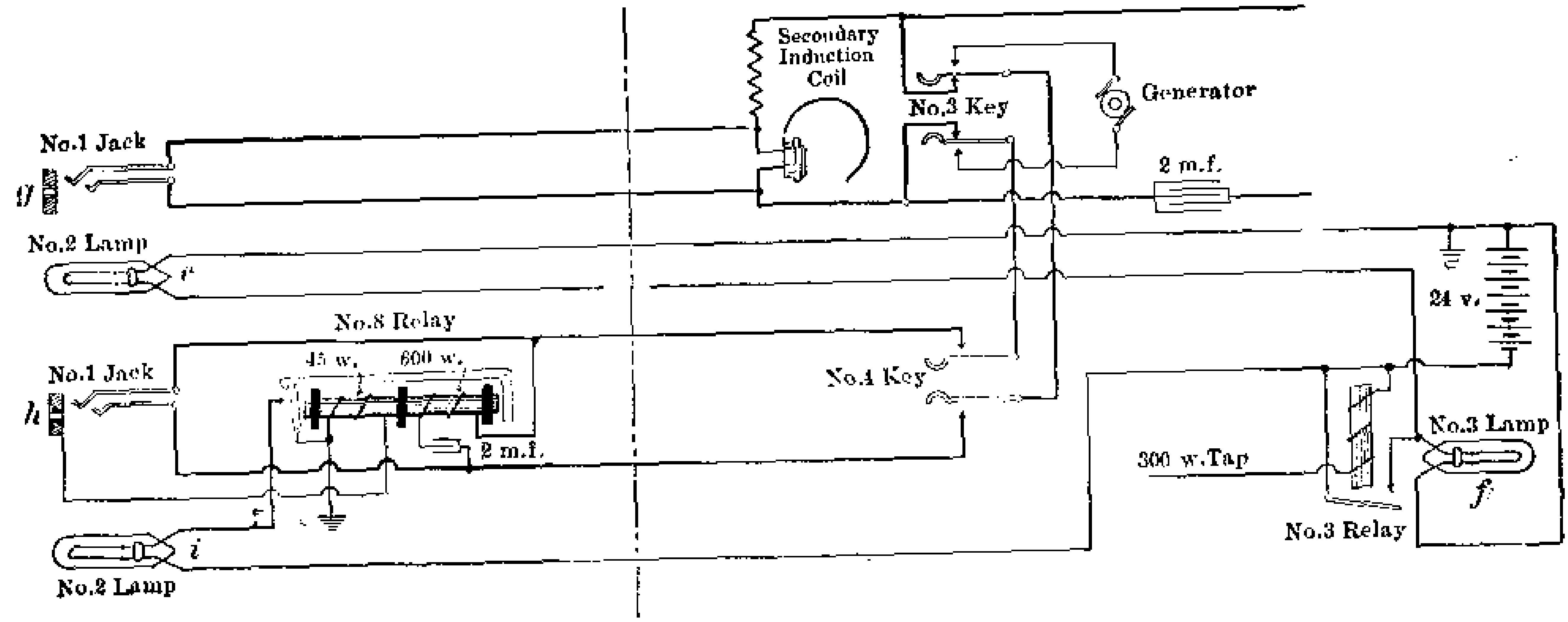


Fig. 115. — Listening and Pilot Circuits.

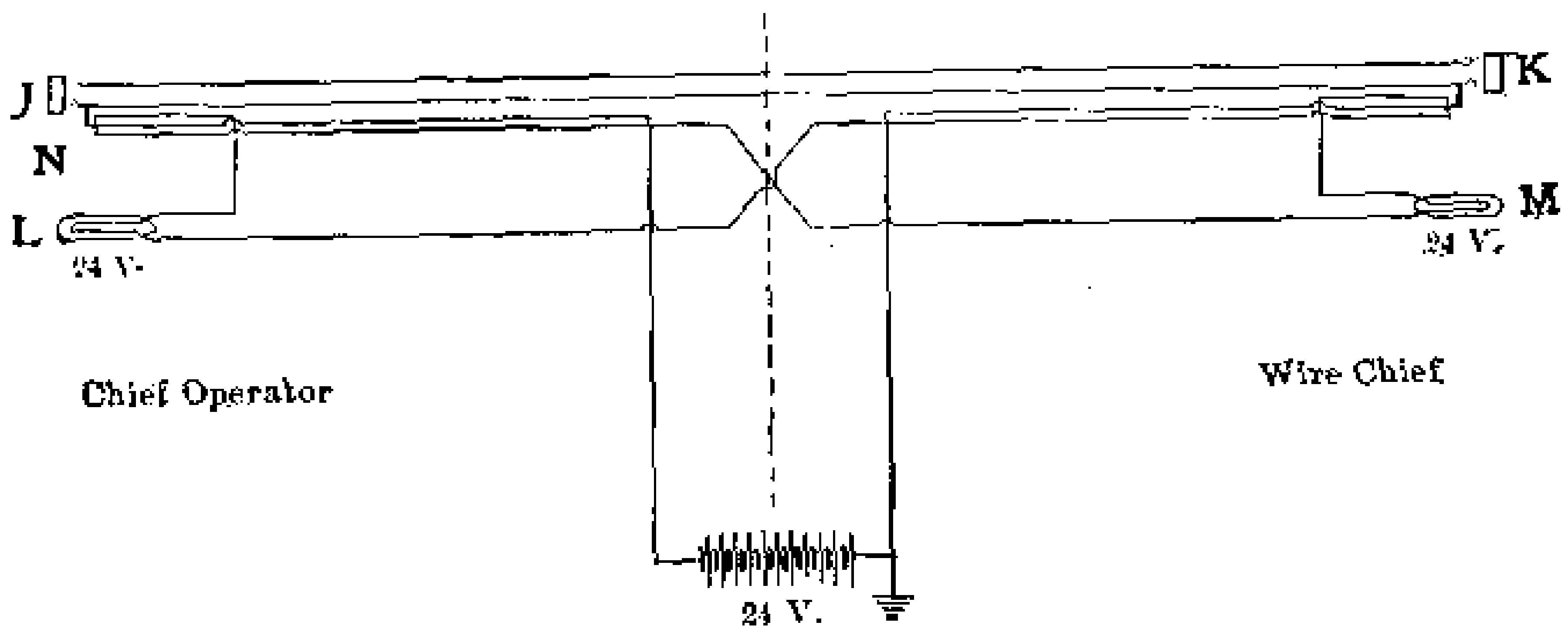


Fig. 116. — Local Trunks.

manner similar to the removal of the receiver at a substation, and hence the line signal lamp will illumine and operator answer as usual.

4. *Testing Lines to the "B" Operator.* — The chief must frequently make service tests to ascertain the speed of "A" operators. The circuit of Fig. 114 is provided for this purpose. Plug *P* and lamp *L* are located upon a "B" operator's plug shelf, and jack *J* at the chief's desk. By means of an order wire the chief speaks to the "B" operator, requesting her to insert plug *P* into a multiple jack of the line to be tested. Then the chief inserts plug *P*, Fig. 111, into jack *J*, Fig. 114 — the subscriber's line signal lights in the usual manner, but the "A" operator is unaware that the chief is calling. When the inspection is completed the chief removes plug *P*; the "A" operator receives the disconnect signal, and clears out. Current will then flow through the 210-ohm relay *R*, Fig. 114, through contact of jack *J*, tip of plug *P*, and to ground through the multiple board circuit; relay *R* is excited, illumines lamp *L*, giving a disconnect signal to the "B" operator, who removes plug *P*.

5. *Listening and Pilot Circuits.* — Fig. 115 exhibits three circuits. The upper one is called the listening circuit, a jack *g* is provided for each multiple-board operator and wired in parallel to the secondary of her talking set. By inserting plug *P*, Fig. 111, into jack *g*, Fig. 115, and opening the transmitter circuit by key *c*, Fig. 111, the chief operator can listen unsuspected. The next circuit is termed the pilot circuit. A lamp *e* is provided for each local operator, wired in multiple with the pilot lamp of the position. Whenever a call arrives, the position pilot lamp

lights, lamp *e*, Fig. 115, is also illumined, and, so long as a call is unanswered at a local position, lamp *e* will notify the chief operator thereof, serving as a check to inform her whether the subscribers are answered promptly. The third circuit is used by "B" operators to call the chief operator. The apparatus on the right of the dotted line is located in the "B" operator's position, and that on the left at the chief operator. By means of key 4 and key 3 the "B" operator can ring through the 600-ohm winding of the relay, lighting lamp *i*. The chief inserts plug *P*, Fig. 111. As soon as the plug is in jack *h*, the relay is restored and lamp *i* extinguished. As long as the "B" operator presses key 4, leaving key 3 normal, she can talk to the chief operator.

6. *Local Trunks to Other Officials.* — For the transmission of business between the local officers of the company, the chief is provided with the circuit in Fig. 116, which closely resembles the transfer circuit in Chapter III. At the chief's desk the jack *J* and lamp *L* are provided, and on the desk of any other official there is a similar jack *K* and lamp *M*. Inserting a plug into either jack lights both lamps; when both plugs are inserted, both lamps are extinguished, and when either plug is removed a disconnect is given by the lighting of both lamps.

7. *Trunks for Calling Subscribers.* — The chief frequently desires to call a subscriber unsuspected by the answering operator. The circuit of Fig. 117 is for this purpose. The plug *P* and lamp *L* are located upon any cord shelf. By an order wire the chief instructs the operator before whom the plug and lamp appear, to insert the plug into the multiple jack of the subscriber desired. Then the chief

inserts plug *Q*, Fig. 111, into jack *J*, Fig. 117, and rings the subscriber in the usual manner. The insertion of the plug opens jack *J*, then current will flow through the 210-ohm resistance *B*, Fig. 111, ring of jack *J*, Fig. 117, to cut-off relay to ground, thus actuating the subscriber's terminal apparatus in the usual manner and preventing a false call upon the multiple-board. The conversation completed, the chief removes the plug, current passes through the 210-ohm relay *R* to the subscriber's terminal apparatus. This maintains the cut-off relay excited, and operates relay *R*. There is then current through the 210-ohm resistance *B*, lamp *L* to the ground illuminating lamp *L* and giving a disconnect signal to the regular operator who removes plug *P*.

CHAPTER VI.

TOLL BOARDS.

THE switchboards previously described are those adapted to the work of the local exchange. There is another and rapidly extending telephonic field — the toll or long distance business — that demands a different treatment. The investment in toll lines is large, service over them is necessarily much slower than between ordinary exchange stations; each message is charged by time and distance; hence it is important to keep the lines as fully occupied as possible; the operators must pursue entirely different methods, and use different circuits and apparatus. In ordinary exchanges where the toll lines are few, short, and carry little business, they may be terminated in the subscriber's position, and handled in much the same fashion as an ordinary subscriber. As the toll lines increase in magnitude and number, the business grows in complexity, until finally a separate office with a fully equipped operating room, switchboard, and collateral paraphernalia are needed. When it comes to considering the full-fledged toll office, its apparatus and methods appear clumsy, and all that can be said in their defense is that they have been proved in the fire of experience and found good. Unquestionably improvements will come, because the toll practice of to-day differs with every company, so it is impossible to present anything but a few typical examples of

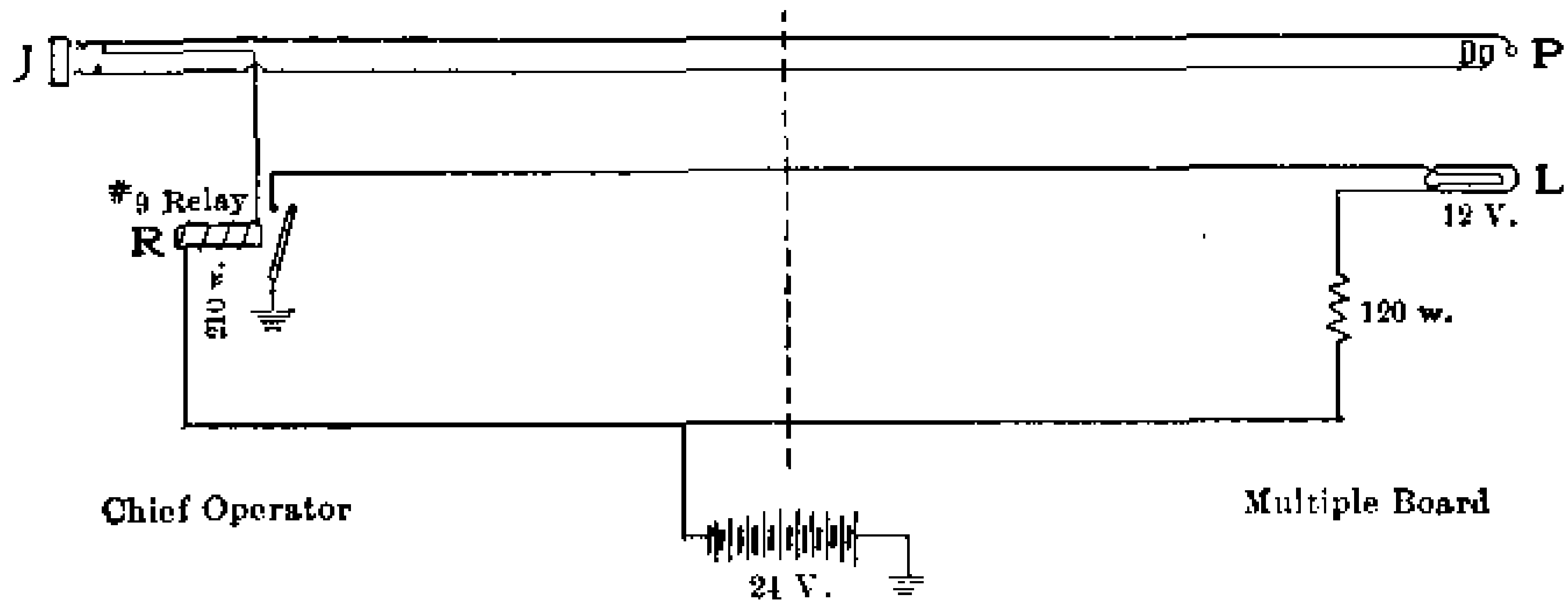


Fig. 117. — Trunks for Calling Subscribers.

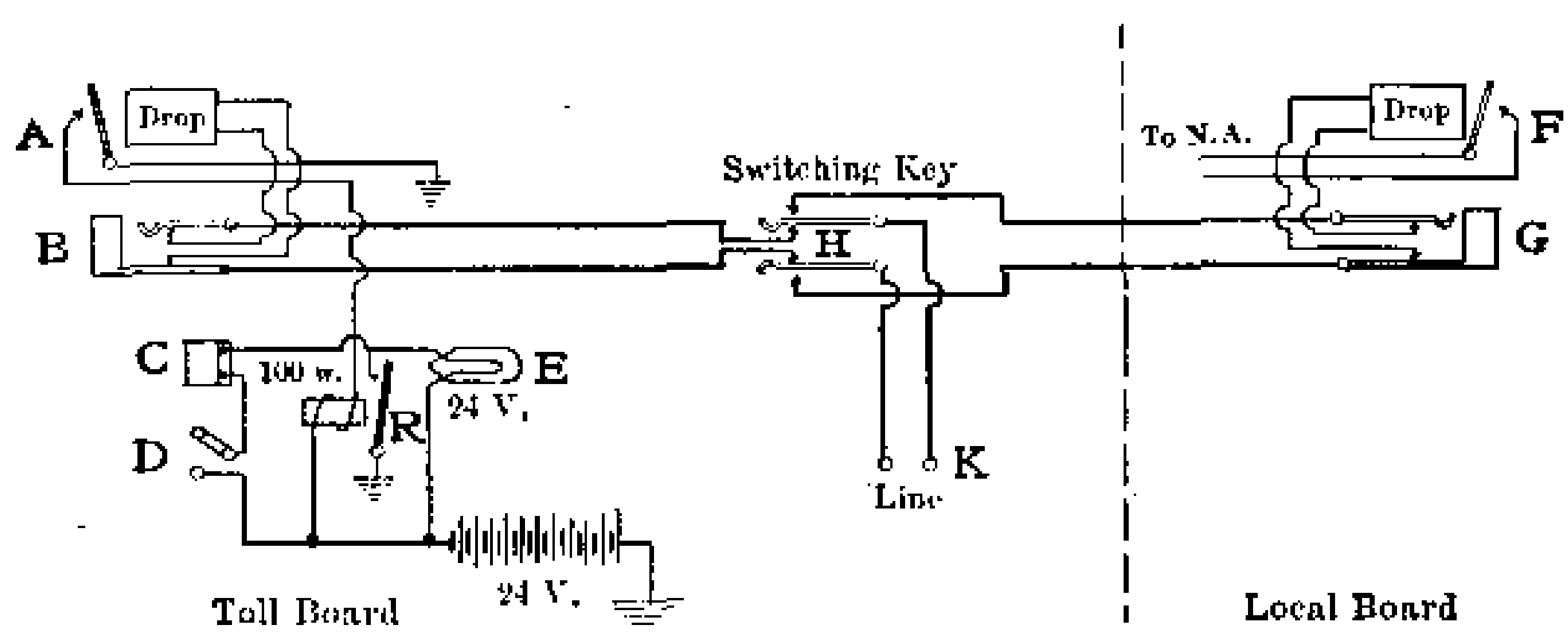


Fig. 118. — Circuit Toll Board to Local Board.

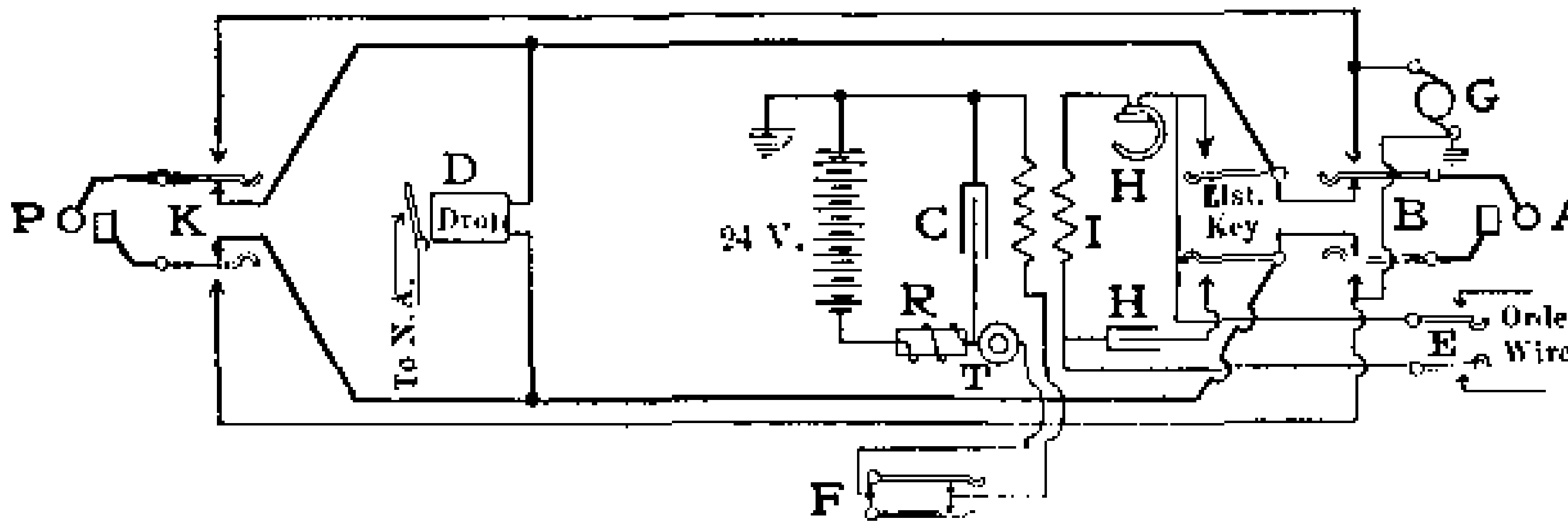


Fig. 119. — Toll Cord Circuit.

the methods most widely adopted. So commencing with small boards, Fig. 118 is a circuit to connect a toll board with a local board. At the toll board the toll line ends in a drop, the shutter being so wired that when it falls it closes a local circuit and illumines a signal lamp. A switching key *H* is provided which, when thrown, connects the toll line with a drop and jack placed before an operator at the local board, so either a toll or local operator may take calls depending on the position of *H*.

Fig. 119 shows a cord circuit often employed on toll position. It closely resembles the cord circuit of a magneto board, but has a transmitter key *F*. When this key is thrown, the operator can listen on the toll line unsuspected, because the key opens the transmitter circuit, preventing it from picking up and delivering to the line any local noise. Fig. 120 is a cord circuit for connecting a toll line with the subscriber's line of an automatic common battery switchboard. The right-hand half of this cord is similar to the answering cord of a common battery circuit, while the left-hand half resembles the toll line cord of Fig. 119. Fig. 121 is a two-way toll trunk line between a toll and a local board. When used from the toll to the local board, the toll operator inserts plug *P*, Fig. 120, in the jack *B*, Fig. 118, and puts connecting plug *A* of Fig. 120 in jack *J*, Fig. 121, and at the same time transmits the order over the call wire ending at the ear of the operator in front of plug *P*, Fig. 121. When plug *A* is inserted in trunk jack *J*, supervisory lamp *N*, Fig. 120, will light through the 30-ohm winding of relay *A*, Fig. 121. Relay *A* is excited and will shunt out lamp *L*, the local operator inserts plug *P*, Fig. 121, in the called subscriber's multiple jack. If the subscriber is not busy the supervisory lamp *N* in front of the toll line operator is illumined, and the operator then rings with key *B*, Fig. 120. The removal of the receiver extinguishes the supervisory lamp *N*. As soon as the receiver at the common

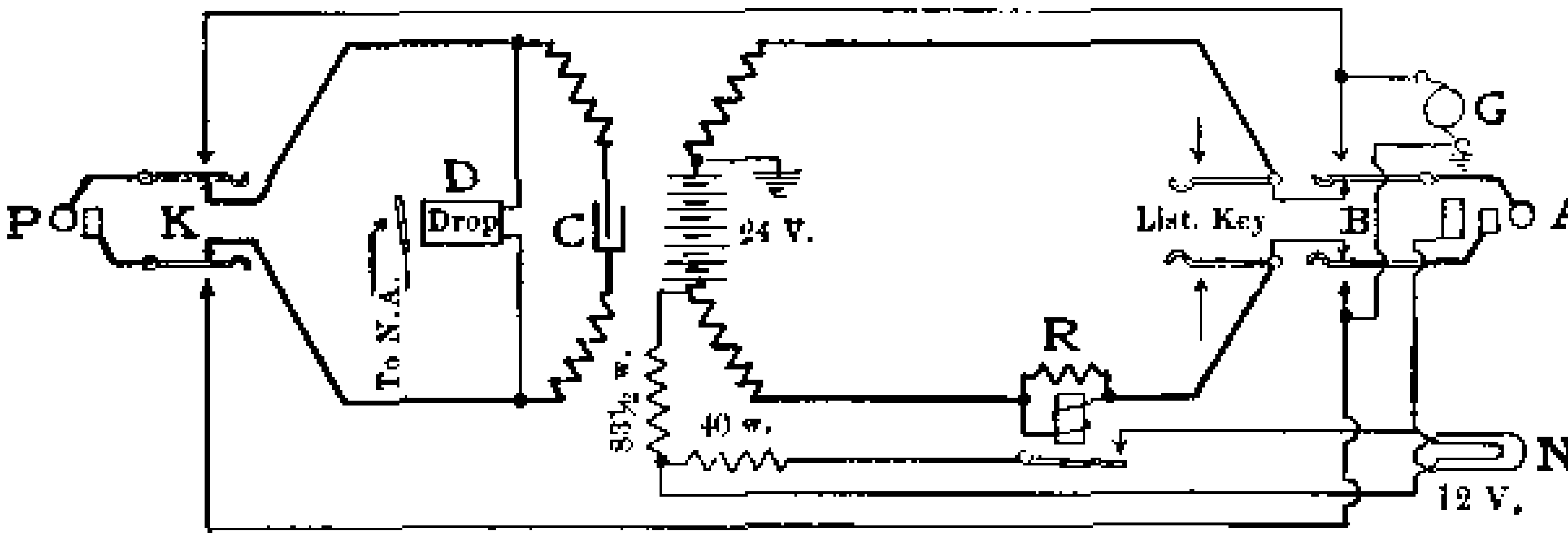


Fig. 120.—Cord Circuit Toll Line to Common Battery Board.

battery station is replaced, relay *R*, Fig. 120, will be deenergized, and the supervisory lamp *N* will light; when the toll line subscriber rings, the clearing-out drop falls, and the toll operator pulls down both plugs. When the plug is removed from jack *J*, Fig. 121, relay *A* will re-

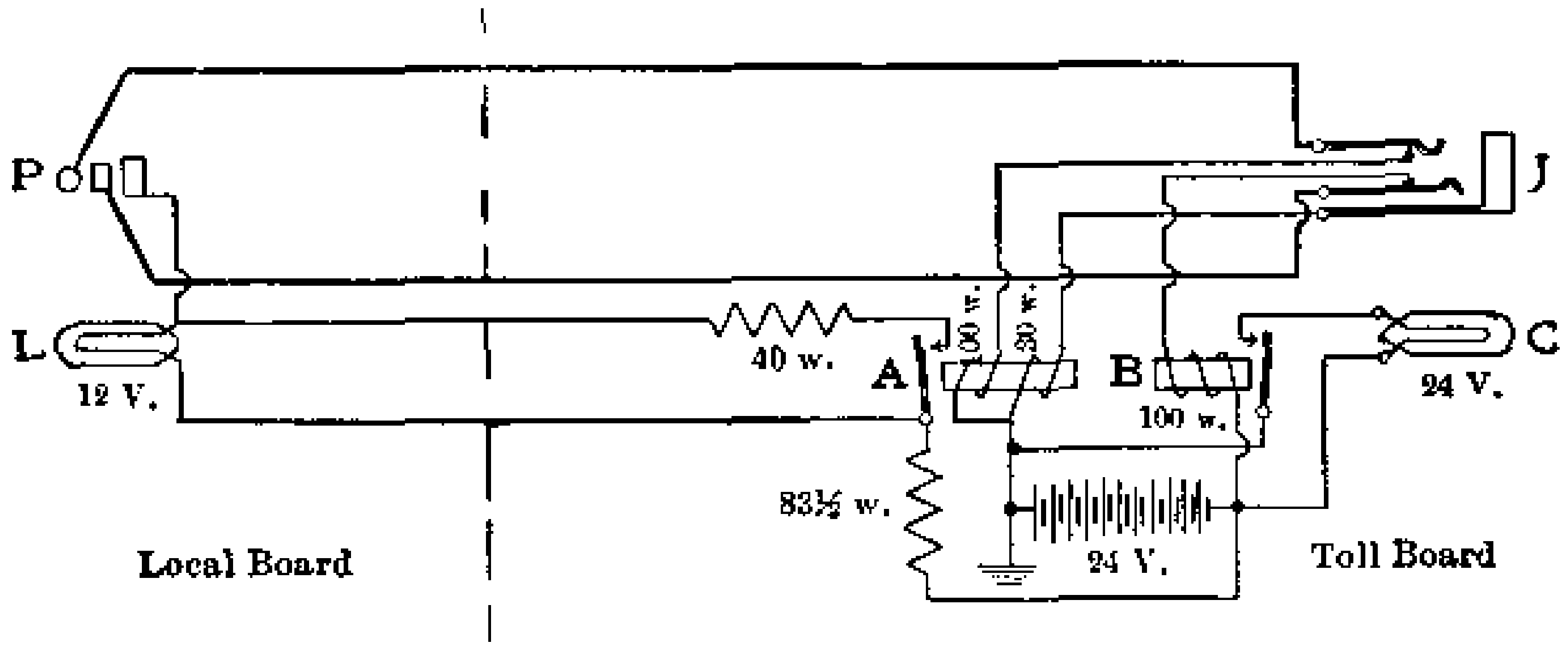


Fig. 121.—Two-way Toll Trunk.

move the shunt, lighting the supervisory lamp *L* at the local operator's position, who will then pull down the plug.

If a common battery subscriber desires a toll connection, he calls the local operator, who inserts plug *P*, Fig. 121, into the calling subscriber's jack. Since the subscriber's receiver is off the hook, current will flow from battery through relay *B*, Fig. 121, over the sleeve and back over the tip side of the line, through the 100-ohm winding of relay *A*, Fig. 121. Both relays *A* and *B* will operate; lamp *L* will not light, but line lamp *C* will, through contact of the armature of relay *B*. When the toll operator sees the lamp *C* lighted, she inserts plug *A*, Fig. 120, into jack *J*, Fig. 121, and takes the order. The toll operator then tells the local party to replace the receiver. She next pulls down her plug, giving the signal to the local operator to pull down plug *P*, Fig. 121, and then inserts plug *P*, Fig. 120, in jack *B*, Fig. 118, and rings the toll station by key *K*. When the called party arrives, the local subscriber is called and the connection completed as described.

In large offices to which many toll lines converge, a more intricate system has been found advisable. The toll board is entirely distinct from the local board, but connected to it by trunk lines. The coöperation of two operators is needed for every incoming toll message and four for every outgoing one. The toll lines end in answering positions on the toll board, each line ending in a terminal consisting of a drop and jack, but it is also equipped with multiple jacks, and appears in several other positions. The operators before whom the toll lines appear are called toll line operators. In addition to the toll lines each toll position has trunk lines extending to a *B* position at the local board where these trunks end in plugs, and are handled by a "B" operator, just as if the toll board was a branch office in the exchange. This "B" operator is called a toll switching operator. There is a set of operators called recording operators, who have trunk lines to the "A" operator at the local board, and trunk lines to the toll line operators. It is the business of the toll operator to handle the toll lines exclusively, and to connect them with the trunk lines to the toll switching operator. The toll switching operator connects the toll trunk line with the local subscribers, nothing more. The recording operators deal with the calling subscribers, make the charge tickets, and pass the message to the proper toll line operator. The general course of business is as follows:

Incoming Toll Calls. — Toll line drop falls. Toll operator inserts answering plug of a pair of cords. The calling party asks for a local subscriber. Toll operator speaks to the toll switching operator over the order wire, giving the number of the called subscriber. The toll switching operator nominates the trunk line, inserts its plug into the jack of the called subscriber; meanwhile the toll line operator has inserted the connecting plug into the jack of the trunk line nominated. When the parties have completed their conversation they disconnect signals, instruct the operators in succession to remove the cords.

Outgoing Toll Calls. — The local subscriber calls. The "A" operator answers and the subscriber asks for toll. "A" operator inserts the connecting plug into the jack of a trunk line to a recording operator. The signal lamp lights before the recording operator, who inserts an answering plug into the jack of the trunk line signaled. The recording operator takes the subscriber's order, makes a ticket, sends the same to the toll line operator, who gets the toll party called to the telephone. The toll line operator then calls the toll switching operator by order wire receives trunk line number, and the connection as above is completed.

The recording operators are seated in a gallery from which a carrier proceeds to the various toll operators. By means of this carrier, the recording operators are enabled to transmit rapidly and economically the tickets to the various toll operators as fast as they are made out.

The independent telephone companies have not as yet developed the toll circuits to the point of standardization, and the best practice of the day is represented by that devised by the engineers of the Western Electric Company, one of their circuits, which is widely used, shown in Fig. 122. At the extreme left of the drawing the usual common battery substation circuit and the subscriber's terminal, including pilot lamp and other terminal apparatus, is shown. Next on the left of the dotted line appears the cord circuit of the toll switching operator. On the right of the dotted line is the trunk line, between the toll switching operator and the toll operator. Then comes the cord circuit of the toll operator, and finally, at the extreme right of the toll line, a toll line and terminal. The operation of the circuit in all cases commences with the toll switching operator, who nominates the trunk line to the toll operator in response to a request over the order wire. Hence, the first thing which happens is the insertion of the plug into the jack of the subscriber, who has either called for toll through the recording operator, or is to be

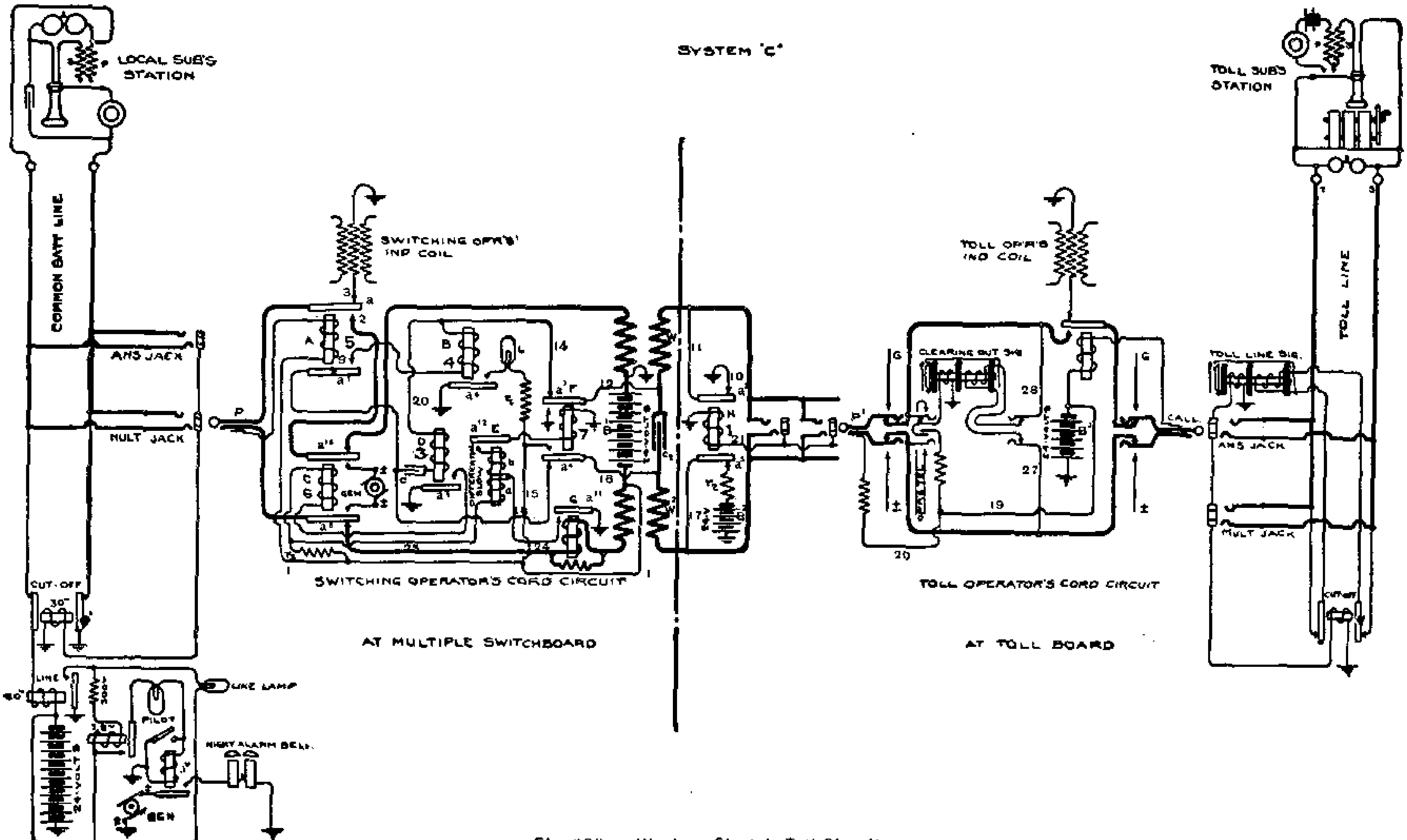


Fig. 122.—Western Electric Toll Circuit.

called by the toll switching operator to talk with a party waiting at a toll station. When the plug is inserted into the multiple jack of the local subscriber, there is a circuit from the battery through relay *A* to the ring of the jack. This operates the subscriber's terminal apparatus in the usual manner. Relay *A* is excited and closes its armatures. One armature opens a contact, which disconnects the test circuit and closes a contact, which completes the continuity of the tip side of the trunk line. The other armature closes a contact, then there is circuit from the battery in the toll office to the lower armature of relay *H*, the winding of the repeating coil, the lower armature of relay 7, the lower armature of relay *A*, relay *B*, the armature *F* of relay 7, the winding of the repeating coil to the other side of the battery. Relay *B* is excited, attracts its armature, lighting the signal lamp *L*. Simultaneously the toll line operator inserts her plug into the jack of the toll line nominated by the toll switching operator. There is then current from battery to the ring of the trunk line plug, to relay *H*, and back to the battery. Relay *H* is excited and closes its armatures, removing the battery from the trunk line, and thus deënergizing relay *B* and extinguishing signal. The toll operator rings the called subscriber in the following manner: By pressing key *K*, generator current is placed upon the sleeve side of the trunk line, passing through the winding of the repeating coil to the condenser *C*, thence, through relay *D*, the armature *F* of the relay 7, the winding of the repeating coil to the tip side of trunk line and thence back to ringing generator. By this means relay *D* is excited, attracts its armature, thus completing a circuit from the battery through resistance r_3, relay C, and to the battery. Relay C attracts its armatures which connect the tip and sleeve of the plug with the ringing generator at the multiple board, thus ringing the subscriber. When the called subscriber removes the receiver there is a circuit through relay G (which corresponds to the ordinary supervisory relay), over the sleeve side of the cord, back to battery by the tip side. Relay G is excited and attracts its armature, then there is a circuit from battery through resistance r_3, winding a of relay E to the battery. This excites relay E which attracts its armature, providing another path for the battery through winding b of relay E and relay 7 to the battery. Relay E is peculiar in having two differential windings, a and b. It is also arranged mechanically to be slow acting, so that an appreciable time will elapse between the make and the break of its circuits and the corresponding response of its armature. From the middle point a conductor passes to the armature of relay G; this, it will be seen, short-circuits the winding b and relay 7 so long as relay G is excited and its armature closed. Owing to the differential winding of relay E when current flows through both coils, relay 7 and to ground, relay E will not be excited, as relay 7 is quick acting it can attract its armatures before the armature of relay E is retracted. When relay 7 closes its armatures, there is a circuit from the battery, the sleeve side of the trunk line, the exciting coil of the clearing-out drop in the toll line cord, the tip side of the trunk line, to the battery. So, during the instant that relay 7 is excited, an impulse of current is transmitted back to the clearing-out drop of the toll line which is actuated, and indicates to the toll line operator that the local subscriber has replaced his receiver. The toll line operator removes the plug, then lamp lights as already described, giving to the toll switching operator the necessary disconnect signal. A consideration of this circuit shows that its entire control is placed in the hands of the toll line operator, and that all the work required of the toll switching operator is that of nominating the trunk line, testing the jack of the subscriber to be called, inserting the line plug, and disconnecting when the proper signal arrives. It is also noticeable that the toll operator may receive a disconnect signal from the toll line subscriber who can ring off, actuating the clearing-out drop in the usual manner. While at first sight this circuit seems to be somewhat atavistic, as there is only one supervisory signal, yet experience has so far demonstrated its superiority over other plans previously proposed.

The assemblage of toll line apparatus does not differ materially over the methods employed for magneto or multiple boards, and the frames used for toll work closely resemble the designs for other forms of switchboard, excepting that the space allotted to jacks and signals is proportioned to the apparatus to be used, and the cord shelf is made considerably larger, in order that the operator may have a chance to handle the tickets and perform other duties which are necessary to a different method of operating. Further it is usual to supply a number of pigeon holes, so that the operator may have abundant space in which to keep the communication records, and to add to the cord shelf a calculograph or other mechanical device, whereby the operator can stamp or otherwise record upon the ticket the length of time which the subscriber's have occupied in conversation, so that the proper charge may be made.

As toll line business is rapidly growing, it is likely that more radical departures will be made in apparatus, and methods are likely to be expected in this division of telephony.

CHAPTER VII.

POWER PLANTS AND THE WIRE CHIEF'S EQUIPMENT.

THE common battery switchboard requires suitable collateral apparatus which is commonly installed in a room by itself, and placed under the charge of the wire chief. The principal components are:

1. Cable entrance.
2. Main distributing board.
3. Intermediate distributing board.
4. Relay racks.
5. Coil racks.
6. Battery.
7. Charging outfit.
8. Ringing machinery.
9. Switchboard.
10. Wire chief's desk and testing outfit.

The cable entrance, main and intermediate distributing boards have already been discussed.

Relay and Coil Racks. — The relay and coil racks consist of iron frameworks, somewhat similar in general design to the main and intermediate distributing boards, but used solely for supporting the relays, resistance and retardation coils, which the previous diagrams have shown to be important parts of all common battery circuits. The coils and relays are mounted upon strips, in such a manner as to correspond with the line terminals and the cord circuits; each strip is numbered and each coil or relay designated, so that it may be readily found. The angle iron racks stand between the floor and the ceiling, in such a manner that ready access may be had to the various coils and relays which are supported thereon.

Fig. 123 shows the general arrangement of the racks and the distributing board. It is customary to construct the coil and relay racks of angle iron in order to provide a fireproof structure sufficiently substantial to sustain the weight of this apparatus. Racks must necessarily be designed to fit the circuits and type of apparatus which is employed, but their construction is so simple that little other consideration is needed but to build them in a manner adapted to the building and the apparatus.

Battery. — The most important piece of apparatus under the charge of the wire chief is the storage battery, upon which the exchange depends for the necessary energy to operate it. The chief function of the battery is to provide a supply of electricity that is absolutely reliable. It would be easy to build a dynamo machine, wound to the proper voltage, and constructed with sufficient care so that an entire office might be operated directly from the machine. This method avoids the expense of the battery installation and the difficulties which attend its maintenance, and is also somewhat more economical in current supply, as it obviates the necessary losses which occur in the battery. Could a dynamo machine be depended upon to run with absolute uniformity and uninterruptedly, this plan would present many attractions, but bearings will get hot, brushes may break, and many other accidents may occur to interfere for a longer or shorter period with the operation of such a piece of machinery. In this event,

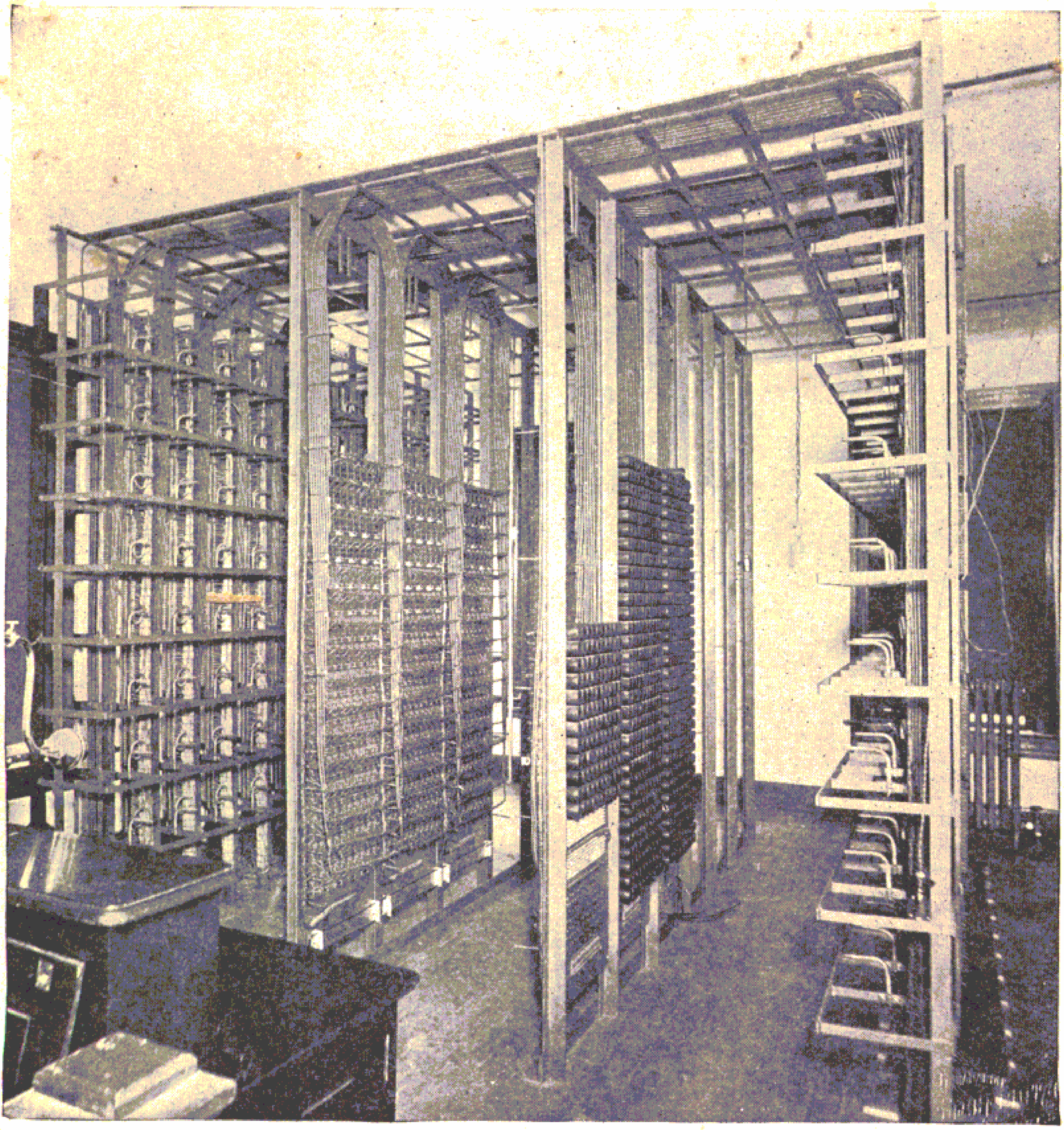


Fig. 123.—General Arrangement of Distributing Boards, Coil and Relay Racks.

the exchange during the time that that machine was still, would be absolutely paralyzed. The storage battery can unfailingly be depended upon, if properly charged and reasonably cared for. A full account of the storage battery would far transcend the limits of present space, so the reader is referred to many excellent treatises for all information that does not strictly pertain to the relation of the battery and the telephone exchange.

The battery installation should be adapted in size of cells and in voltage to the switchboard which it is to operate. The circuits described in a previous chapter are those commonly used and employ 24, 36, and 40 volts. As each cell gives an average potential of 2 volts, central office batteries must consist of 12, 18, and 20 cells. While the battery is charging, its potential rises to about 2½ volts per cell, and when safely discharged falls to about 1.85 volts.

It is, therefore, desirable either to use two batteries in the exchange, one of which may be charged while the other is discharged, or else if a single battery is used, to arrange what is called an *end cell*, that is one or more cells which may be disconnected from the switchboard during the period of charging and reconnected during the period of discharge. This is advisable in order that the switchboard lamps and other apparatus may not be subjected to too wide fluctuations in potential. The size of the cell to be employed will depend upon the number of subscribers and the traffic rate. It is advisable to provide a battery of sufficient size so that it may carry the switchboard for at least 48 hours without recharging, and also advisable to remember that after the exchange is installed, the capacity of the battery gradually decreases with age while the demand thereon will increase with a growing number of subscribers. So in the installation of a new office a large excess of battery capacity should be provided. Knowing the number of subscribers and the probable traffic rate it is easy to calculate the amount of electricity which will be required. The following table shows an estimate of the number of ampere hours required by the common battery circuits, shown in Chapter IV.

TABLE SHOWING AMPERE HOURS PER MESSAGE.

Subscribers' Lines.

		Ampere hours per call.
To call central	.126 ampere for 5 seconds	.000175
To light line lamp	.100 ampere for 5 seconds	.000139
To light calling auxiliary lamp	.200 ampere for 5 seconds	.000278
To light disconnect auxiliary lamp	.200 ampere for 5 seconds	.000278
To serve two subscribers' lines	.184 ampere for 1.75 minute	.005370
To serve two supervisory signals	.228 ampere for 1.75 minute	.006666
To serve operators' transmitter	.100 ampere for .01 hour	.001000
Ampere hours per call		0.013906

Total ampere hours per day is equal to the number of subscribers' lines times the number of calls per line per day, divided by 72.

Incoming Trunk Lines.

To serve one local subscribers' line	.092 ampere for 1.75 minute	.002680
To serve two supervisory signals	.228 ampere for 1.75 minute	.006666
To serve one disconnect auxiliary lamp	.200 ampere for 5 seconds	.000278
To serve operators' transmitters	.100 ampere for .005 hour	.005000
Ampere hours per call		.010124

Total ampere hours per day is equal to the number of incoming trunk lines times the number of calls per line per day, divided by 100.

Toll Lines.

Toll line to subscribers' line, or subscribers' line to toll line including switching operator.

To light line lamp	.100 ampere for 5 seconds	.000139
To light auxiliary lamp	.200 ampere for 5 seconds	.000278
To serve subscribers' line	.092 ampere for 7.5 minute	.011500
To serve subscribers' supervisory signal	.114 ampere for 10 minutes	.019000
To serve toll line drop	.0937 ampere for 10 minutes	.015610
To serve supervisory drop	.106 ampere for 5 seconds	.000147
To serve toll disconnect signal	.104 ampere for 5 seconds	.000144
To serve toll operators' transmitter	.100 ampere for .024 hour	.002400
Ampere hours per call		.049218

Total ampere hours per day is equal to the number of toll lines times the number of calls per line per day, divided by 20.

Toll Lines.

Toll line to toll line.

To light line lamp	.100 ampere for 5 seconds	.000139
To light line auxiliary lamps	.200 ampere for 5 seconds	.000278
To serve calling toll line drop	.106 ampere for 8 minutes	.014150
To serve called toll line drop	.0937 ampere for 8 minutes	.012490
To serve supervisory toll cord drop	.106 ampere for 5 seconds	.000147
To serve supervisory toll disconnect signal	.126 ampere for 5 seconds	.000175
To serve operators' transmitters	.100 ampere for .024 hour	.002400
Ampere hours per call		.029779

Total ampere hours per day is equal to the number of toll lines times the number of calls per line per day, divided by 33.

The capacity of a battery is not only limited by the total ampere hours which it is able to deliver, but also by the greatest discharge rates which can be drawn from the battery without subjecting it to injury. In Chapter VIII, it will be shown that the load line of a telephone exchange reaches a maximum between 8 and 10 A.M.; so in selecting a battery it is necessary not only to proportion it to deliver the total electricity which will be daily demanded, but secure cells sufficiently large so that the maximum demand during the peak of the load may not exceed a proper discharge rate. The accompanying table contains statistical information relating to the cells of the Electric Storage Battery Company, a representative maker of storage batteries.

TABLE OF STORAGE BATTERY DATA.

Elements of Type "E."

Size of Plates, 7¾ inches by 7¾ inches.

"CHLORIDE ACCUMULATOR."

	Number of Plates.					
	5	7	9	11	13	15
Discharge in amperes:						
For 8 hours	10	15	20	25	30	35
For 5 hours	14	21	28	35	42	49
For 3 hours	20	30	40	50	60	70
For 1 hour	40	60	80	100	120	140
Normal charge rate	10	15	20	25	30	35
Outside measurement of glass jar, in inches:						
Length	5½	6¾	8	8⅝	11	11
Width	9¼	9¼	9¼	9¼	9¼	9¼
Height	11⅜	11⅜	11⅜	11⅜	11⅜	11⅜
Weight of cell complete, with acid, in pounds:						
In glass	49	60	74	86½	104	112
Price, element only	$8.25	11.75	15.25	18.75	22.25	25.75
Price, glass jar, extra	1.20	1.35	1.50	1.75	2.55	2.55

Elements of Type "F."

Size of Plates, 11 inches by 10½ inches.

	Number of Plates.									
	9	11	13	15	17	19	21	23	25	27
Discharge in amperes:										
For 8 hours	40	50	60	70	80	90	100	110	120	130
For 5 hours	56	70	84	98	112	126	140	154	168	182
For 3 hours	80	100	120	140	160	180	200	220	240	260
For 1 hour	160	200	240	280	320	360	400	440	480	520
Normal charge rate	40	50	60	70	80	90	100	110	120	130
Outside measurements of all metal tanks, in inches:										
Length	13⅛	14⅞	16½	18⅛	19¾	21½	23⅛	24¾	26⅜	28⅛
Width	15	15	15	15	15	15	15	15	15	15
Height	15⅛	15⅛	15⅛	15⅛	15⅛	15⅛	15⅛	15⅛	15⅛	15⅛
(Clearance between metal tanks, 2 inches.)										
Weight of cell complete with acid, in pounds:										
In all metal tanks	256	297	337	377	416	457	497	537	577	618
In wood tanks	250	292	332	372	411	452	492	532	573	615
Price, element only	$30.00	37.50	45.00	52.50	60.00	67.50	75.00	82.50	90.00	97.50
Price, all metal tank, extra	13.50	14.50	15.50	16.50	17.50	18.50	19.50	20.50	21.50	22.50
Price, lead-lined wood tank, extract	11.25	12.00	12.75	13.50	14.25	15.00	15.75	16.50	17.25	18.00

ELEMENTS OF TYPE "G."

Size of Plates, $15\frac{5}{16}$ inches by $15\frac{5}{16}$ inches. Clearance between tanks, 2 inches.

"CHLORIDE ACCUMULATOR."

	Number of Plates.															
	11	**13**	**15**	**17**	**19**	**21**	**23**	**25**	**27**	**29**	**31**	**33**	**35**	**37**	**39**	**41**
Discharge in amperes:																
For 8 hours	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
For 5 hours	140	168	196	224	252	280	308	336	364	392	420	448	476	504	532	560
For 3 hours	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800
For 1 hour	400	480	560	640	720	800	880	960	1040	1120	1200	1280	1360	1440	1520	1600
Normal charge rate	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
Outside measurement of tank in inches:																
Length	15⅛	16¾	18⅜	20	22⅜	24⅜	26	27⅝	29⅝	31	32⅝	34¼	36	37⅝	39¼	40⅞
Width	19¾	19¾	19¾	19¾	20¾	20¾	20¾	20¾	20¾	20¾	20¾	20¾	20¾	20¾	20¾	20¾
Height	26	26	26	26	26½	26½	26½	26½	26½	26½	26½	26½	26½	26½	26½	27½
Weight of cell, complete, with acid, in lead-lined wood tank in pounds:	561	638	716	795	917	997	1076	1156	1236	1316	1396	1476	1557	1639	1718	1810
Height of cell from floor to top of buss-bar, for double insulation, in inches	$39\frac{3}{16}$	$39\frac{3}{16}$	$39\frac{3}{16}$	$39\frac{3}{16}$	40¼	40¼	40¼	40¼	40¼	40¼	40¼	40¼	40¼	40¼	40¼	41¼
Price, element only	$75 00	90 00	105 00	120 00	135 00	150 00	165 00	180 00	195 00	210 00	225 00	240 00	255 00	270 00	285 00	300 00
Price, lead-lined wood tank, extra	$16 25	17 00	17 75	18 50	20 75	21 75	22 75	23 75	24 75	25 75	26 75	27 75	28 75	29 75	30 75	31 75

ELEMENTS OF TYPE "G." (*Continued.*)

	Number of Plates.																
	43	**45**	**47**	**49**	**51**	**53**	**55**	**57**	**59**	**61**	**63**	**65**	**67**	**69**	**71**	**73**	**75**
Discharge in amperes:																	
For 8 hours	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720	740
For 5 hours	588	616	644	672	700	728	756	784	812	840	868	896	924	952	980	1008	1036
For 3 hours	840	880	920	960	1000	1040	1080	1120	1160	1200	1240	1280	1320	1360	1400	1440	1480
For 1 hour	1680	1760	1840	1920	2000	2080	2160	2240	2320	2400	2480	2560	2640	2720	2800	2880	2960
Normal charge rate	420	440	460	480	500	520	540	560	580	600	620	640	66	680	700	720	740
Outside measurement of tank in inches:																	
Length	42⅝	44¼	45⅞	47½	49¼	51⅝	53¼	54⅞	56⅝	58¼	59⅞	61½	63¼	64⅞	66½	68⅛	69⅞
Width	20¾	20¾	20¾	20¾	20⅝	21⅛	21⅛	21⅛	21⅛	21⅛	21⅛	21⅛	21⅛	21⅛	21⅛	21⅛	21⅛
Height	27½	27½	27½	27½	27½	27⅝	27⅝	27⅝	27⅝	27⅝	27⅝	27⅝	27⅝	27⅝	27⅝	27⅝	27⅝
Weight of cell, complete, with acid, in lead-lined wood tank, in pounds	1890	1972	2053	2135	2216	2354	2434	2516	2598	2682	2764	2847	2930	3013	3096	3177	3260
Height of cell from floor to top of buss-bar, for double insulation, in inches	41¼	41¼	41¼	41¼	41¼	41⅝	41⅝	41⅝	41⅝	41⅝	41⅝	41⅝	41⅝	41⅝	41⅝	41⅝	41⅝
Price, element only	$315 00	330 00	345 00	360 00	375 00	390 00	405 00	420 00	435 00	450 00	465 00	480 00	495 00	510 00	525 00	540 00	555 00
Price, lead-lined wood tank, extra	$32 75	33 75	34 75	35 75	38 75	39 75	40 75	41 75	42 75	43 75	44 75	45 75	46 75	47 75	48 75	49 75	50 75

Every purchaser of batteries is supplied by the vending company with full instructions as to setting up, maintaining and operating the cells, so that a general discussion of storage battery maintenance appears superfluous.

Towards the close of each charge the cells liberate considerable gas and the battery is said to boil. The gas bubbles, as they rise through the electrolyte, carry into the air a fine spray, which, as it consists partly of sulphuric acid, is extremely irritating to the lungs, and injurious to apparatus. So it is necessary to carefully house the battery in such a manner that the fumes therefrom may not be objectionable. Two methods are in use. Where plenty of space is available it is customary to provide a battery room as is shown in Fig. 124. This is separated by a tight partition from the rest of the office, provided with ample windows, and a ventilating fan or other form of draught so arranged as to supply a constant current of air that shall expel all objectionable fumes.

Batteries of large size are usually contained in lead-lined oak tanks, which should be mounted upon porcelain insulators in such a manner as to thoroughly insulate each cell from all its surroundings. Smaller cells are placed in glass jars which may be set upon insulators, supported upon an iron rack furnished with slate shelves. When a separate battery room is not easily secured, it is practical to build an acid-proof case, formed of angle iron and rough glass plates, in which the battery may be so enclosed as to be air tight. If this case be connected with a chimney, or other flue, and proper air inlet provided, the battery may be placed in the wire chief's room, but so thoroughly protected as to produce no injurious results. This effects considerable saving of space.

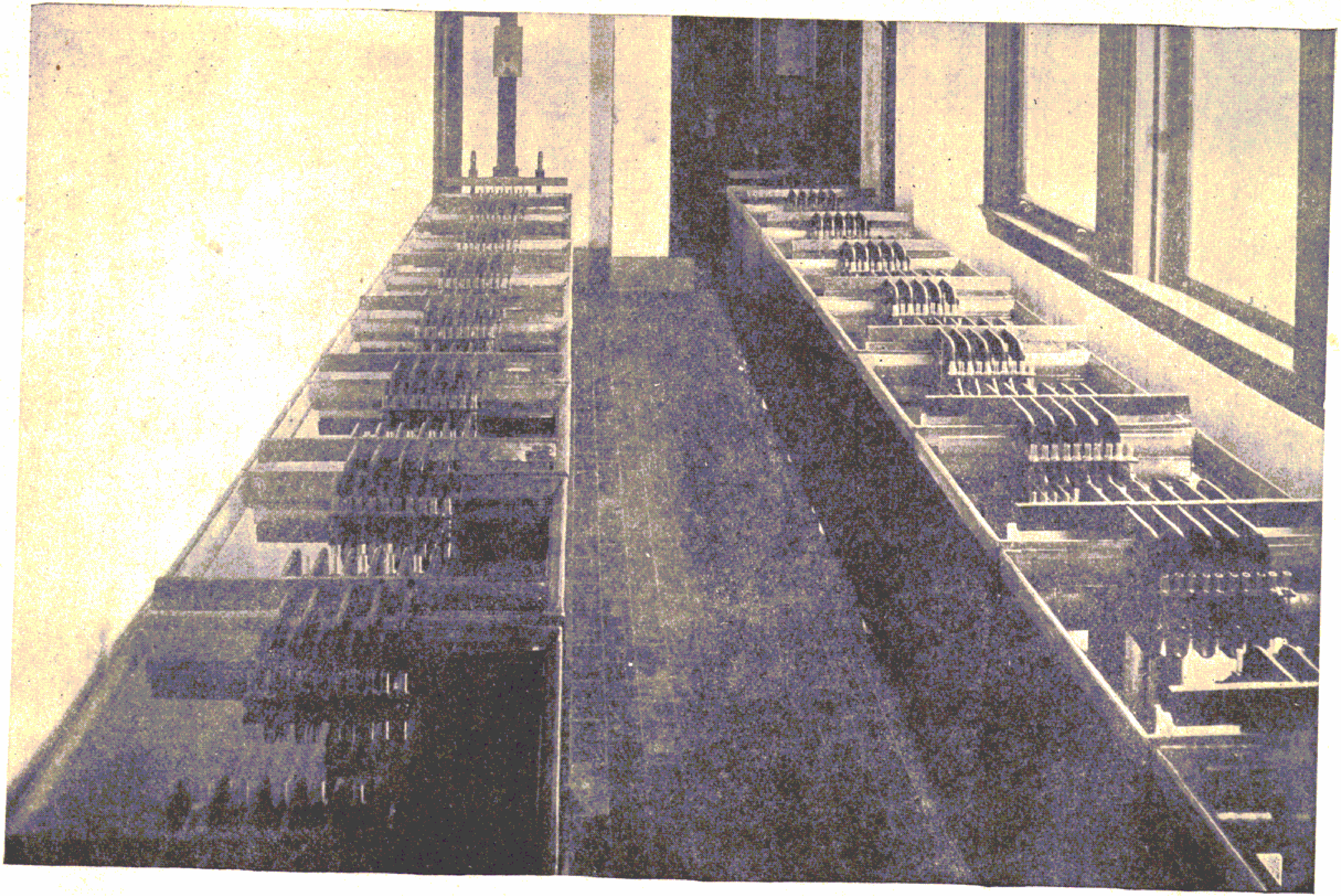


Fig. 124.—Battery Room.

The storage battery must be frequently charged and no matter what capacity is provided, it is best to pursue a regular recurrent daily cycle of charge and discharge, save on Sundays or holidays when there is less demand. Wherever there is a commercial electrical circuit, the charging outfit may consist of a motor, driven from the electric mains and directly connected or belted to a dynamo of the proper voltage and capacity. When alternating current or 500 volts direct current are the only sources of supply, the motor generator set is preferable to the double commutator motor, or the rotary converter, on account of the possibility of a short circuit in the armature, which may allow the high potential circuit to become crossed with the battery when both windings are on the same armature. For low potential direct current mains, the motor with two windings upon the same core, forms a simpler and correspondingly preferable type. The charging outfit is usually mounted upon a bed plate as shown in Fig. 125. In case no commercial circuit is available, it is necessary to have recourse to some other form of prime mover, usually a gas or oil engine as less complicated and more easily maintained than a steam engine. Sometimes it is possible to economically operate a water motor driven from the city mains, but whatever form of prime mover is secured it is belted to the dynamo, which is then driven in the same manner as if actuated by an electric motor. Dynamos for charging the storage batteries of telephone exchanges have one peculiarity. If the battery is to be charged at the same time that it is discharged, it is necessary to secure a machine which shall produce as little noise as possible, in order that the charging may nor interfere with conversation. To this end it is desirable to have a commutator built with a large number of segments, so that the brushes may overlap two or three segments at one time, to have the machine more carefully designed, so that it may be both magnetically and electrically in the best possible balance. If these details are secured it is possible to find the telephone circuits perfectly quiet, even

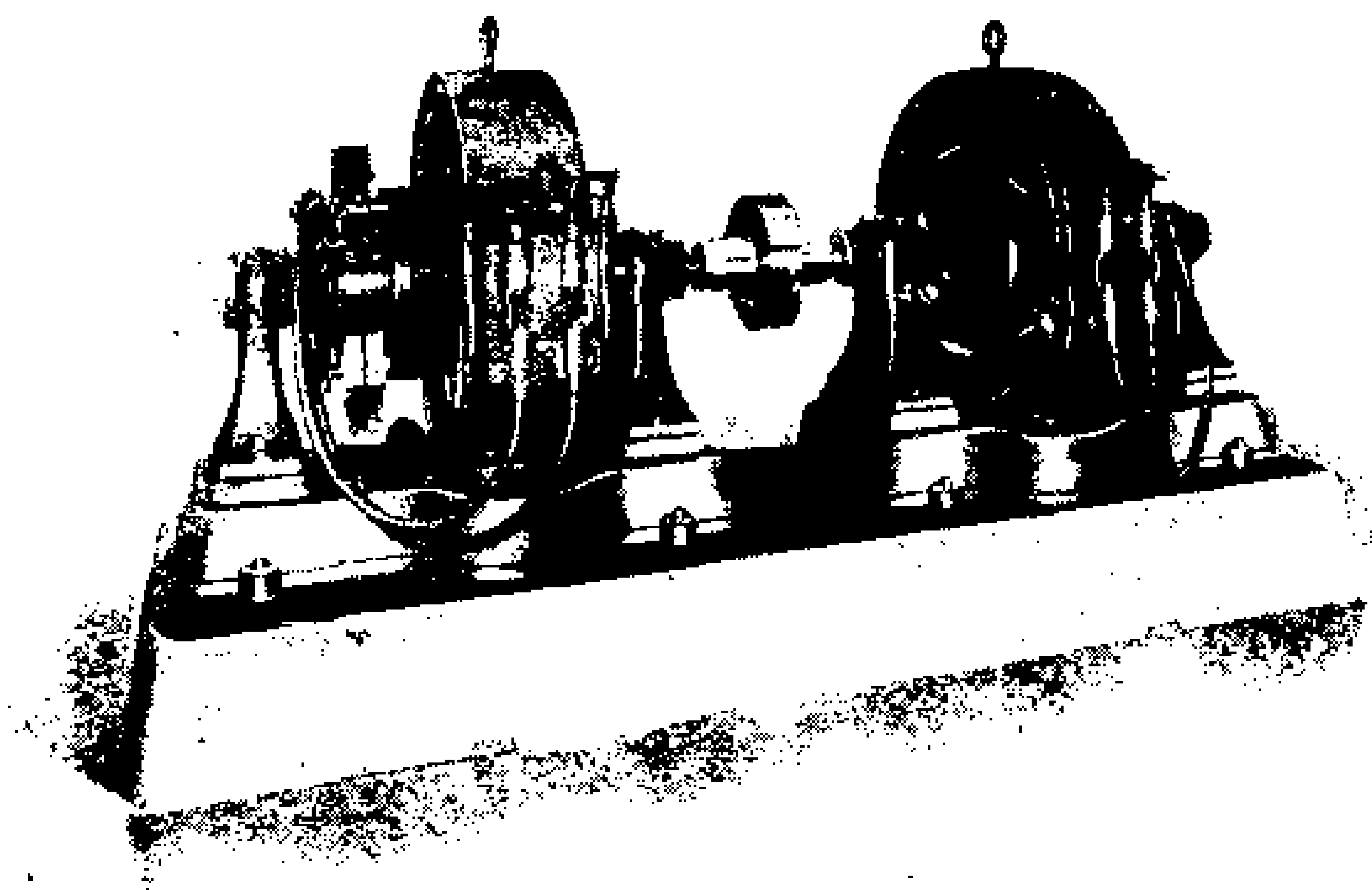


Fig. 125. — Charging Set.

though the battery be under charge. In case the charging machine produces any noise, it is usually possible to quiet it by interposing in the dynamo leads a properly proportioned retardation coil, and bridging the leads by several condensers. This expedient involves the extra expense due to the losses in the coil, but if it be properly designed these are insignificant.

To enable operators to call subscribers, it is necessary to provide an adequate supply of ringing current. For offices which do not exceed 100 or 200 subscribers, it is customary to mount a hand generator in some convenient position upon the switchboard, which is manipulated by the operator whenever she wishes to signal, but as the exchange grows, this method becomes too burdensome.

The first step is to attach a pulley to an ordinary ringing generator and drive it by means of a small prime mover. Where electric current is available a small motor

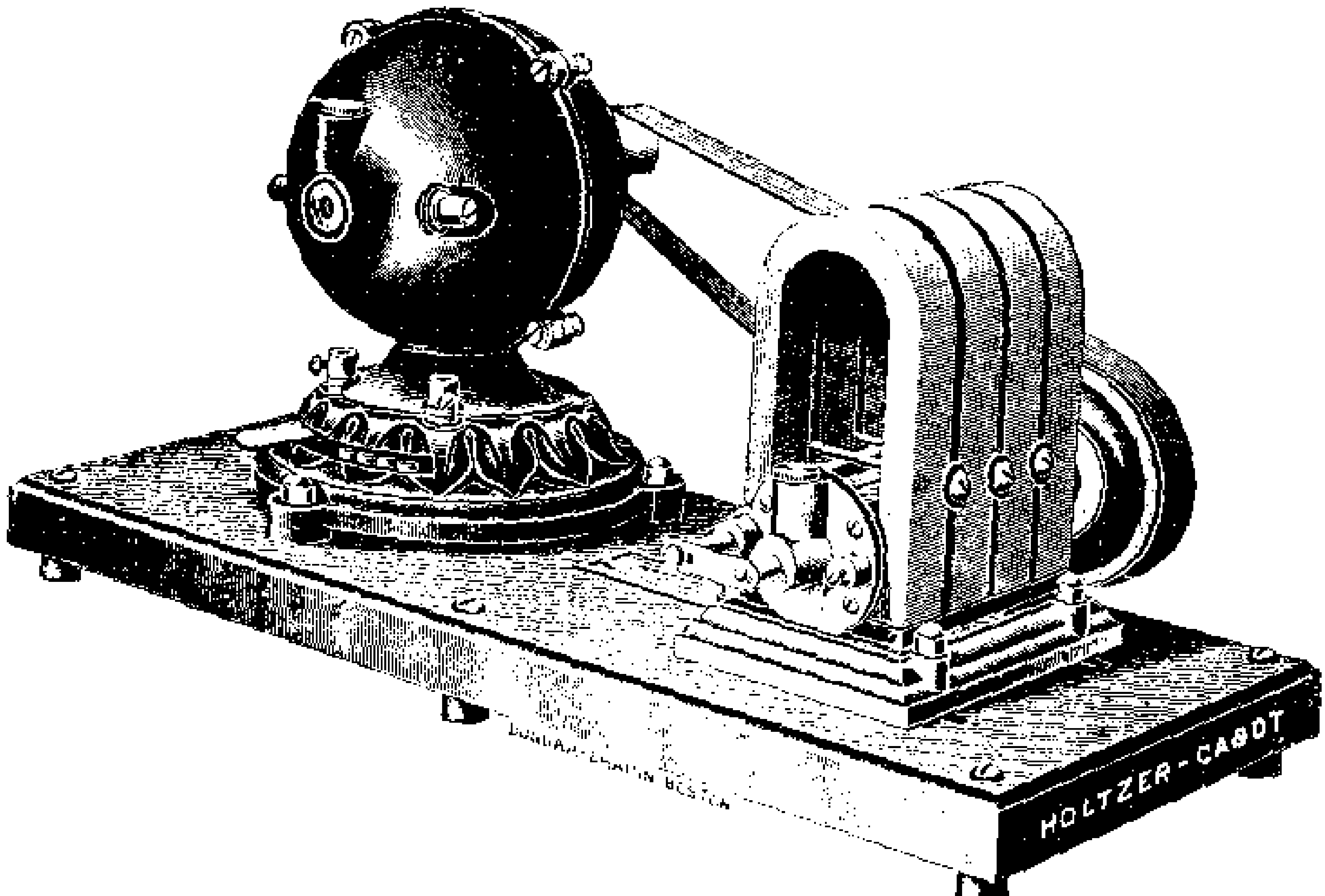


Fig. 126.—Ringing Machine for Small Offices.

is the best, this combination being shown in Fig. 126. The device at A consists of a small alternating current motor, belted to a ringing generator, the two machines being placed upon an appropriate base board. There are few small towns having telephone exchanges of sufficient size to need a mechanically operated generator which do not possess an alternating system of electric lighting, so that this combination is popular and meets the wants of a large number of offices. Where direct current is obtainable, the same design may be used by substituting a direct current motor. As central offices increase in size, ringing generators must be built of larger and larger capacity, and additional appliances adapted to a more complicated service are needed. Where party line service is offered, ringing generators must be designed for the ordinary alternating ringing current and supply positive and negative pulsating current. Where selective signaling depends upon differences in frequency, the generator must be arranged to supply such different frequencies as the polystation lines require.

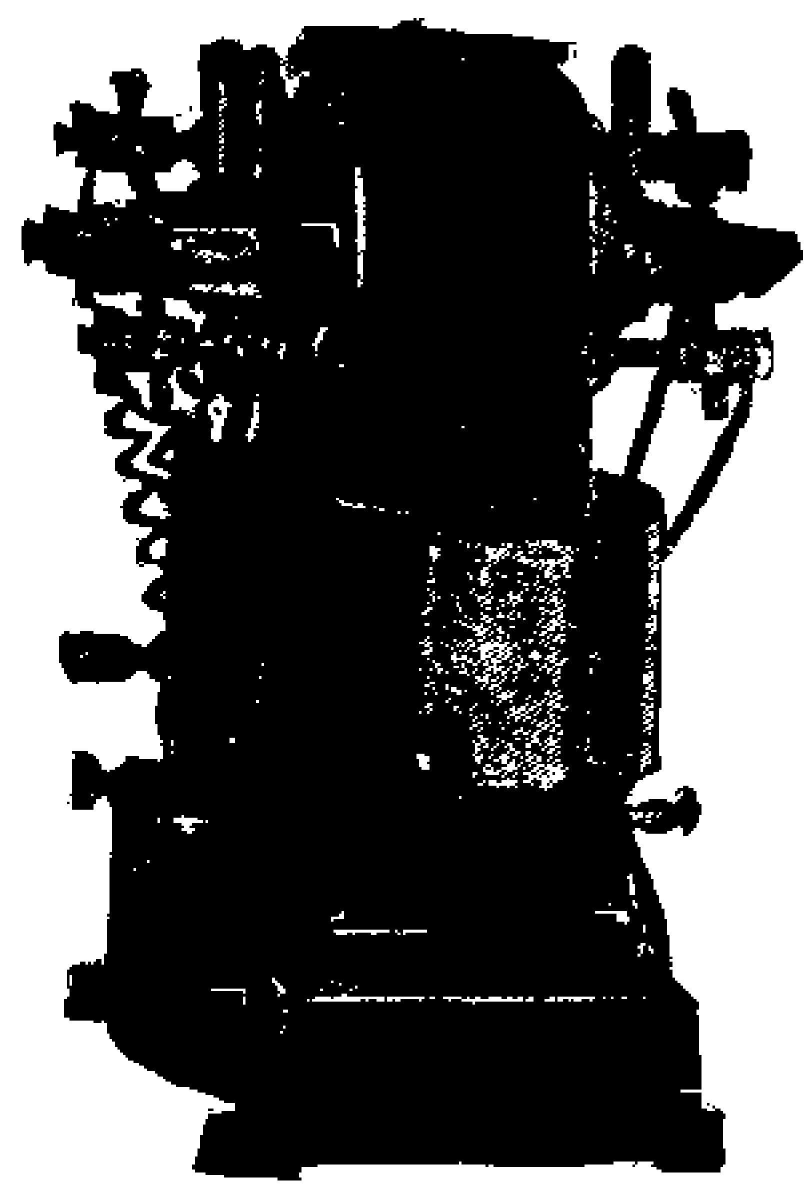


Fig. 127. - Central Office Ringer.

To relieve the operator from telling subscribers that a party called is busy, the ringing generator is sometimes supplied with a peculiar form of interrupter arranged to produce a *buzzing* tone, that subscribers quickly learn to recognize as the *busy back signal.* Subscribers often fail to place the receiver upon the hook, then the sub-station cannot be called as it is impossible to actuate the ringer. To draw attention, the practice has arisen of arranging the ringing generator to produce such an alternating current as shall set the diaphragm of the receiver into active vibration, and cause it to emit a long drawn and exceedingly disagreeable note. This attachment is termed a *howler*, and so the large modern central office requires an exceedingly elaborate motor dynamo. Typical styles of central office ringing generators are shown in Figs. 126, 127, and 128. Fig. 127 is a well designed and compact pattern, arranged to give normal alternating ringing current. It is an inverted rotary converter designed to be driven as a motor by a direct current, at either 110 or 120 volts, and to deliver alternating current at about 16 cycles per second and 80 to 100 volts. Fig. 128 shows a central office ringer with howler. Where it is necessary to drive

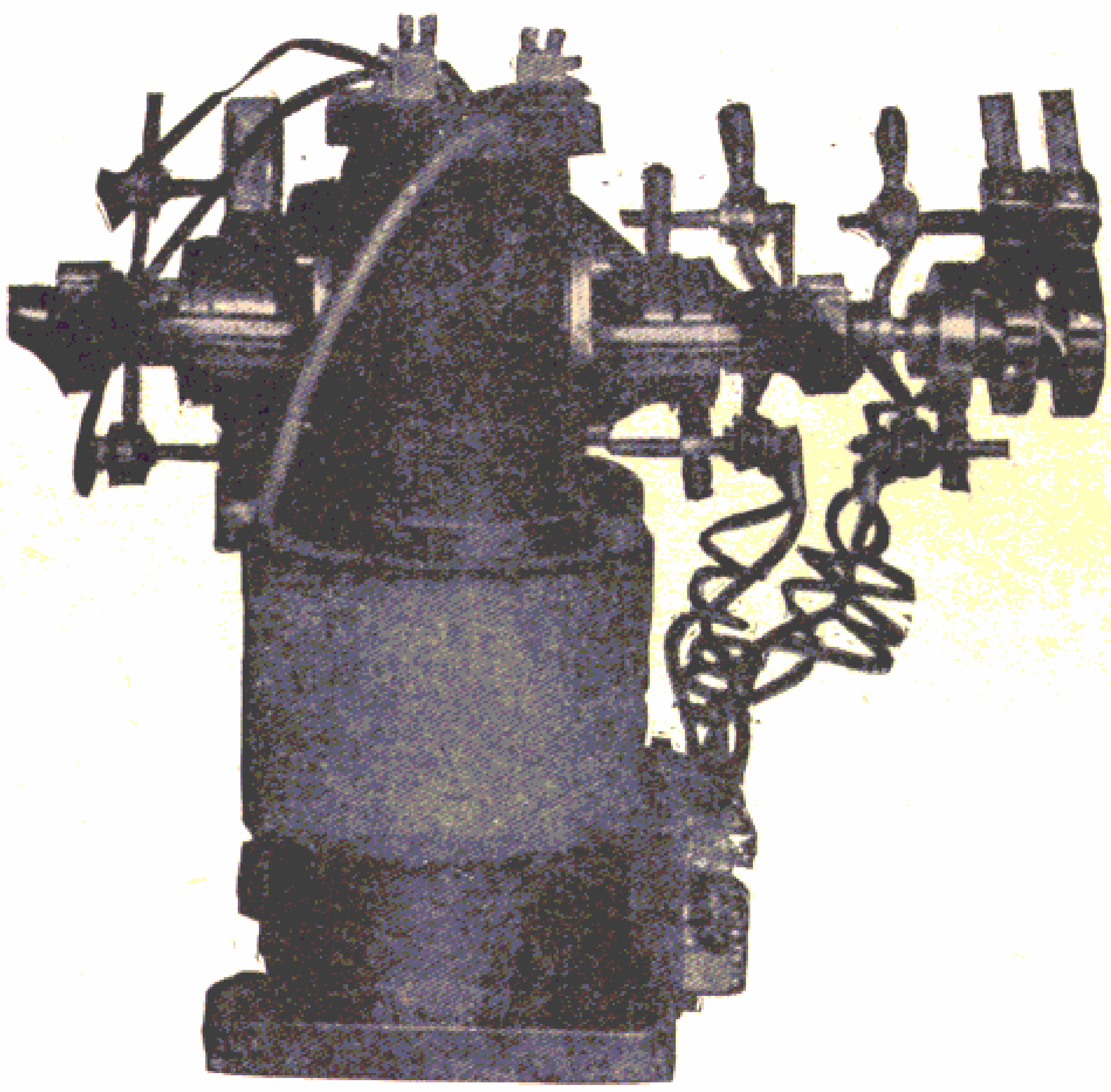


Fig. 128.—Central Office Ringer with Howler.

the ringing generator by means of alternating current, as it is inexpedient to connect the alternating current mains to the same armature that supplies ringing current, the alternating current selective ringing machine, consisting of an alternating current motor which drives an alternating current generator, arranged with three circuits, from one of which alternating ringing current may be obtained, while the other two give respectively positive and negative pulsating currents. Figs. 130 and 131 are two views of a ringing machine sufficient for an exchange of 6000 or 7000 subscribers, completely equipped with circuits for regular alternating current, positive and negative pulsating current, howler and busy back. This machine is arranged to give an interrupted ring, which is useful

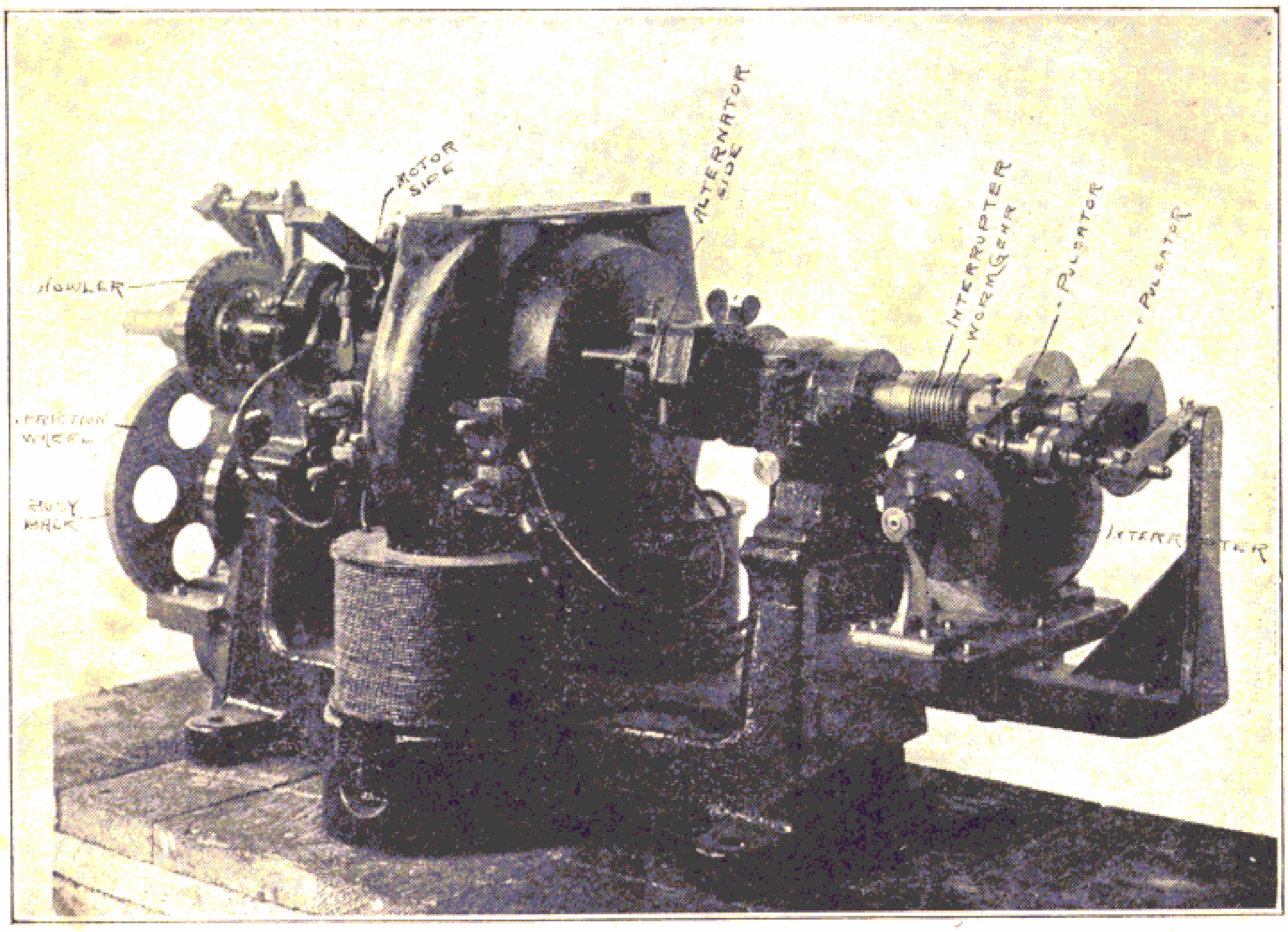


Fig. 130.—Complete Ringing Machine. Pulsating End.

where the operator's key shelf is supplied with automatic ringing keys. The circuits of the pulsating current and interrupter, the howler and busy back, are given in Figs. 132, 133, 134, and 135. A machine of this description is usually rated at about 1 H.P. and is wound to take current from either a 24-volt, 110-volt, or a 220-volt circuit as may be desired. At full load the motor side should not absorb more than 35 amperes on a 24-volt circuit, 6 amperes upon a 110-volt circuit, or 4 amperes upon a 220-volt circuit. The ringing current should have an electromotive force from 100 to 120 volts and a strength of 4 amperes. The pulsator consists of two commutators rigidly attached to the main shaft. Each commutator consists of

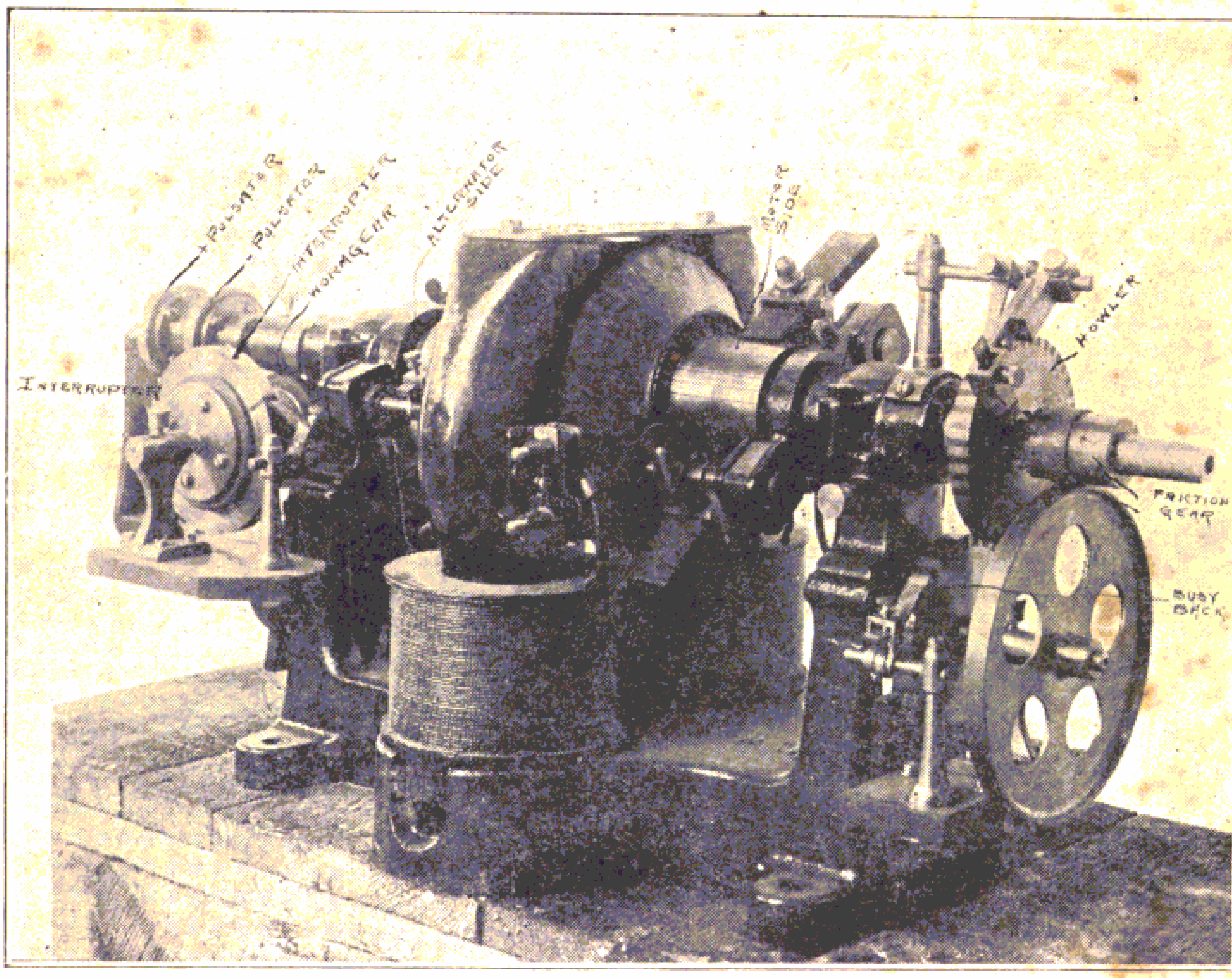


Fig. 131.—Complete Ringing Machine. Howler End.

a brass wheel divided into two parts insulated from each other by mica. One commutator is so attached to the armature winding as to deliver positive waves and the other negative ones. This is accomplished by connecting the commutators to the collector rings so that one side of one is without current, while the opposite of the other carries current, hence one commutator will have its active half connected during the positive half of the wave, and the other its active half during the negative half. Thus the pulsator will give as many positive and negative impulses as there are cycles. This is shown in Fig. 132. The interrupter consists of a brass disk, separated into two parts, insulated by mica and driven by worm searing. The interrupter is arranged so that it will supply ringing current to the line for two seconds and then interrupt it for three seconds, thus it will deliver 12 rings of two seconds each per minute and 12 intermissions. Fig. 133 shows the circuit. The howler, a brass wheel $4\frac{1}{2}$ inches in diameter, the circumference of which is supplied with 40 notches each $\frac{5}{32}$ inches wide and $\frac{7}{32}$ inches deep filled with mica insulation. As the speed of the machine is 1000 revolutions per minute, this wheel will give 40,000 interruptions per minute, which is sufficient to produce a sound in the receiver that will under all ordinary circumstances attract subscriber's attention. The arrangement of connection is given in Fig. 134.

To notify the calling subscriber that the connection desired is engaged, the ringing machine is arranged to deliver an interrupted buzz. There is a commutator wheel which is driven from the main shaft by means of a friction wheel. This commutator wheel is $4\frac{1}{2}$ inches in diameter, and contains on its circumference 23 slots comprised in an angle of 270 degrees of the same size as for the howler, filled with mica in the same manner, and a vacant space of 90 degrees. The friction gearing between the shaft and this wheel is in the proportion of 13 to 57, and consequently, this commutator revolves 228 times a minute. As $\frac{1}{4}$ of the commutator is unoccupied by slots, the period of silence is .0658 seconds and the period of "singing" .1974 seconds. As there are 23 slots in the circumference, the note emitted is at the rate of 116 vibrations per second. The circuits are given in Fig. 135.

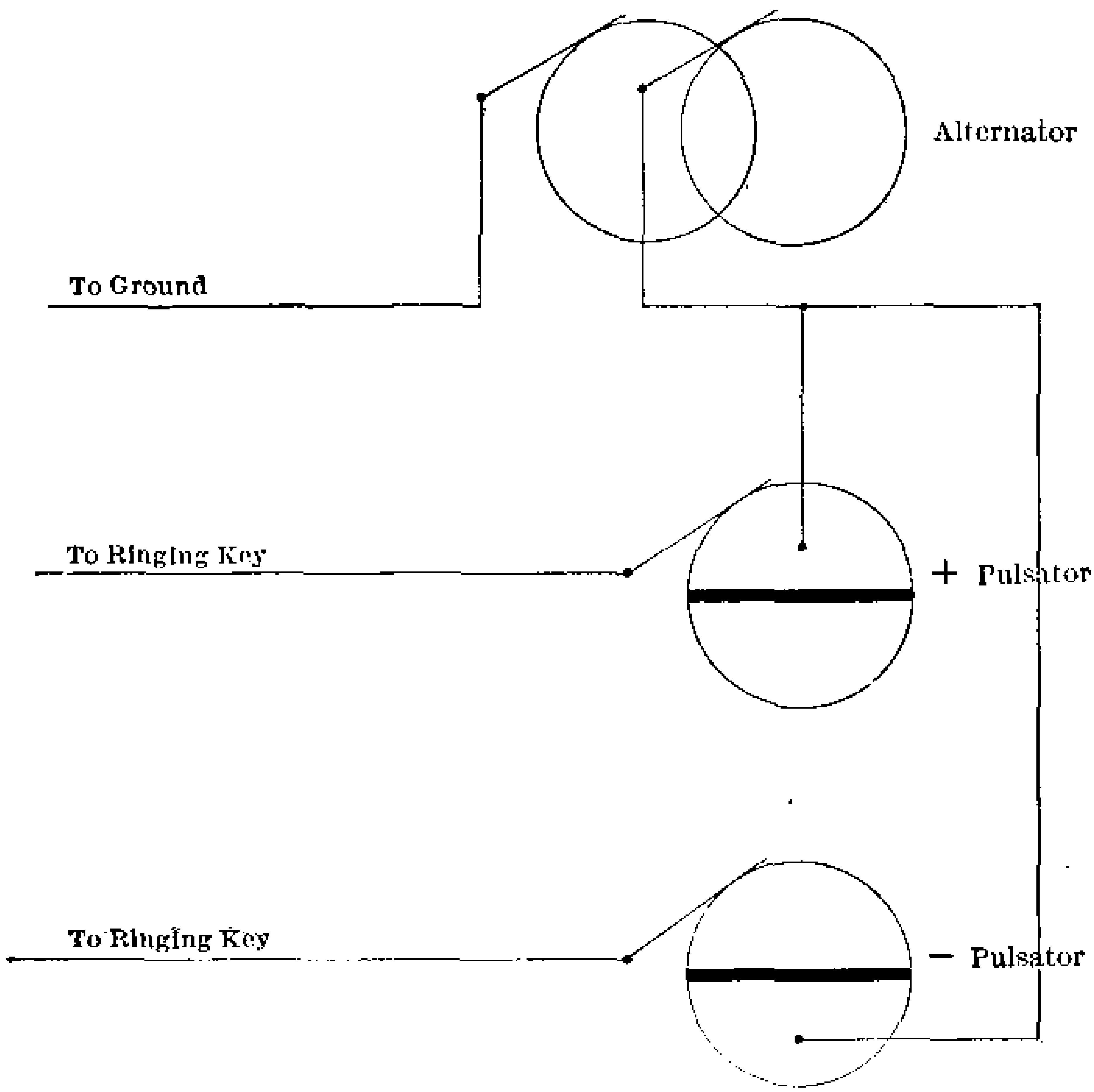


Fig. 132.—Pulsator Circuit.

Fig. 136 shows the general arrangement of the ringing and charging apparatus of a large exchange, mounted on a substantial foundation of pressed brick.

The ringing machine is a larger and more expensive apparatus than is necessary for small exchanges. To meet the wants of this class, the so-called pole changer is useful. There are many forms in use, but the Warner was the pioneer representative and is typical to-day. The apparatus consists of a cabinet, in the base of which from sixty to one hundred cells of battery are placed. In a cupboard just above there is a second battery consisting of half a dozen cells, used to operate the pole changer, which is an electro-magnetic device placed under a glass cover

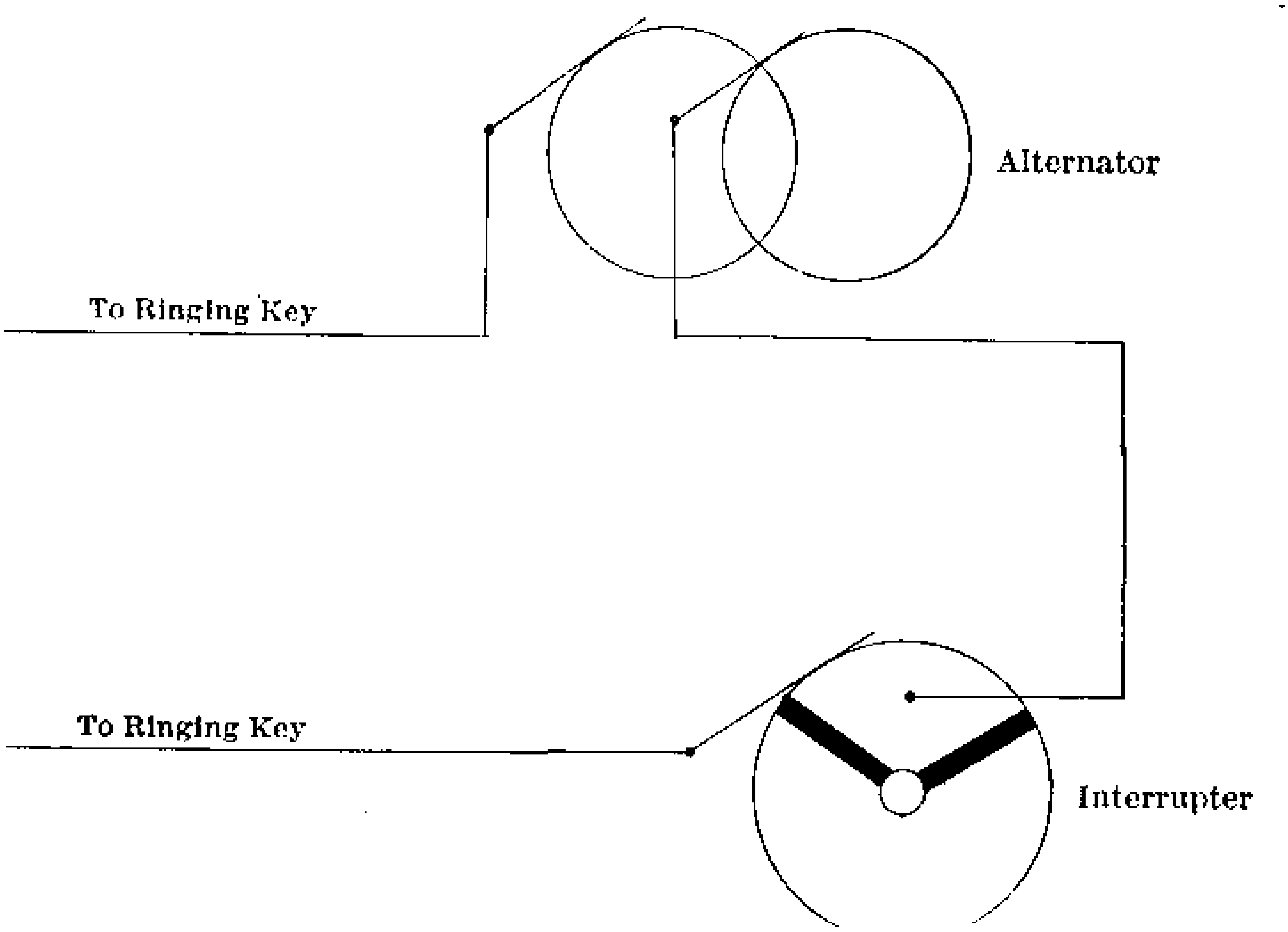


Fig. 133. — Interrupter Circuit.

resting upon the top of the cabinet. The office of the pole changer is to alternately make and break the circuit of the large battery placed in the bottom of the stand, and to deliver correspondingly positive and negative impulses to the switchboard to be used as ringing current. The apparatus is mounted upon a slate base 21 (Fig. 137), and consists of an electro-magnetic vibrator having a magnet 34, the necessary circuit terminals, a condenser, a knife switch for opening the battery circuit and relay to control the operation of the condenser. Turning to Fig. 138, the magnet 34 is connected by wire 33 through the switch 95, to the main battery 31. This is usually a set of gravity cells, or

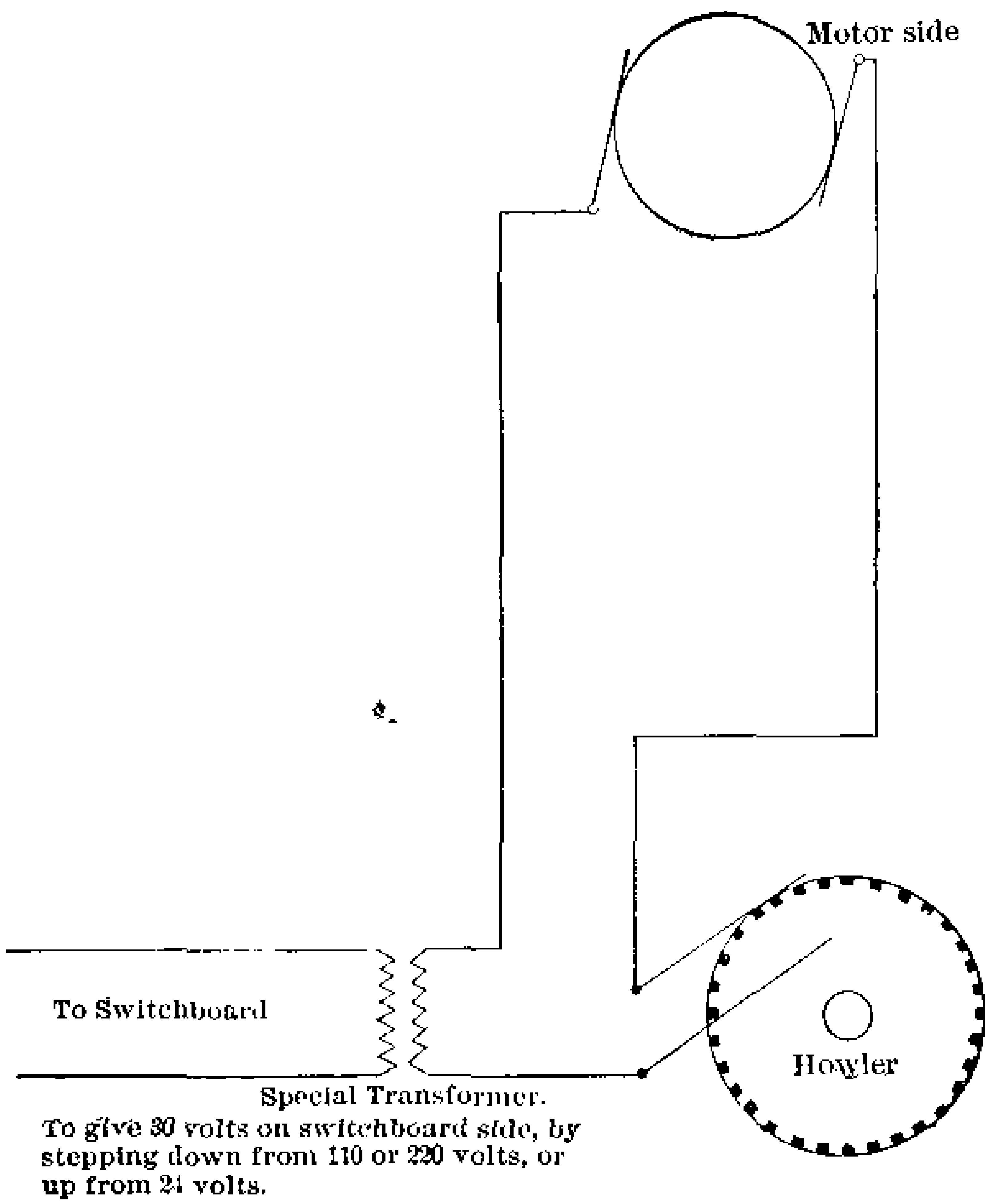


Fig. 134.—Howler Circuit.

other desirable form of closed-circuit battery, although sometimes dry cups are employed for the purpose. By wire 32 the circuit extends to post 28, and through the spring 26, contact 25 to support 24, and thence by wire 35 to the magnet. The arm 23 is thus maintained in vibration, by the pulsating magnetism impressed in the magnet 24, by the circuit breakers 25 and 26. The arm carries four contacts connected by wires 51 and 55 to battery 50,

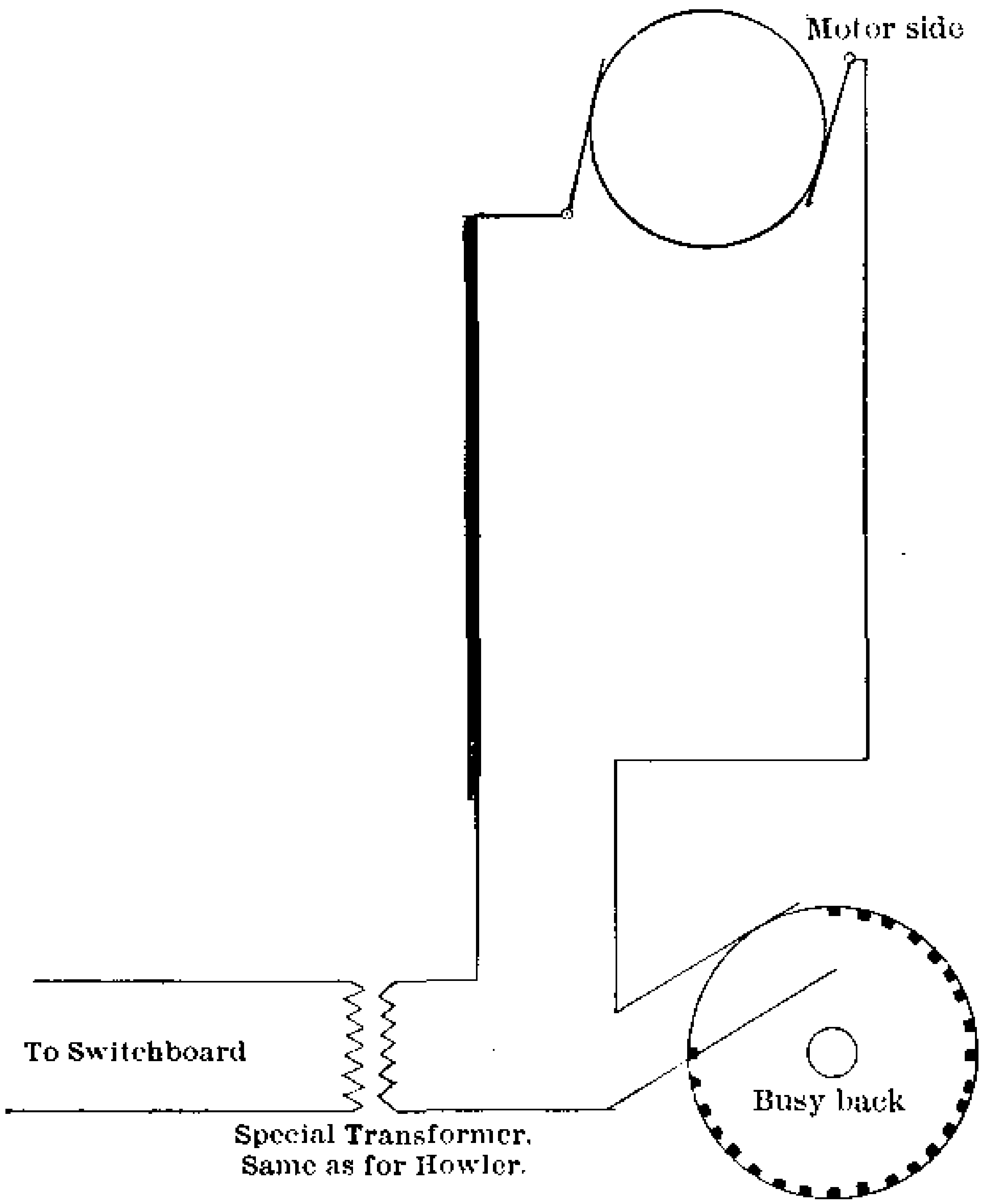


Fig. 135.—Busy Back Circuit.

which is usually some form of open circuit battery. The circuit includes the relay 56. Only when the ringing circuit is closed is the relay energized. On opposite sides of the arm 23 are the posts 61, 62, 63 and 64; 61 and 63 are connected together and to the post 71; 62 and 64 are similarly connected to the pole 72. These posts form the *terminals of the leads* passing to the ringing keys and all the switchboard positions. In the diagram, this is represented by the bell 66. As the arm swings to and fro, alternations of current will go to the posts 71 and 72. When a ringing key is closed, relay 56 connects condenser 75 across the circuits 65 and 67. The object of this condenser is to prevent objectionable sparking at the contacts, and also to smooth over the sharp current waves so that objectionable induction upon neighboring circuits will not be produced.

The *battery, charging machine*, and *ringing generators* form a complicated outfit, and it is necessary to provide leads to the various positions which shall conduct the electrical energy delivered by the battery, and the current from the ringing machine in such a manner as to be safe and available for the operator's use. So a switchboard is required upon which the necessary apparatus for controlling the motors, charging generators, ringing machines shall be mounted, to which the buss bars of the battery run, from which the various leads to the switchboards diverge, and where the proper fuses in these leads for protecting them from accidental overloads may be placed. The various circuits must have proper measuring instruments, such as ammeters, voltmeters, wattmeters, etc., whereby the amount of electricity which is purchased from the supply mains and distributed to the switchboard may be easily and accurately measured. The care of the battery requires frequent voltmeter readings of the cells, as well as of the entire battery. These are best made by means of a switchboard voltmeter. Thus the telephone

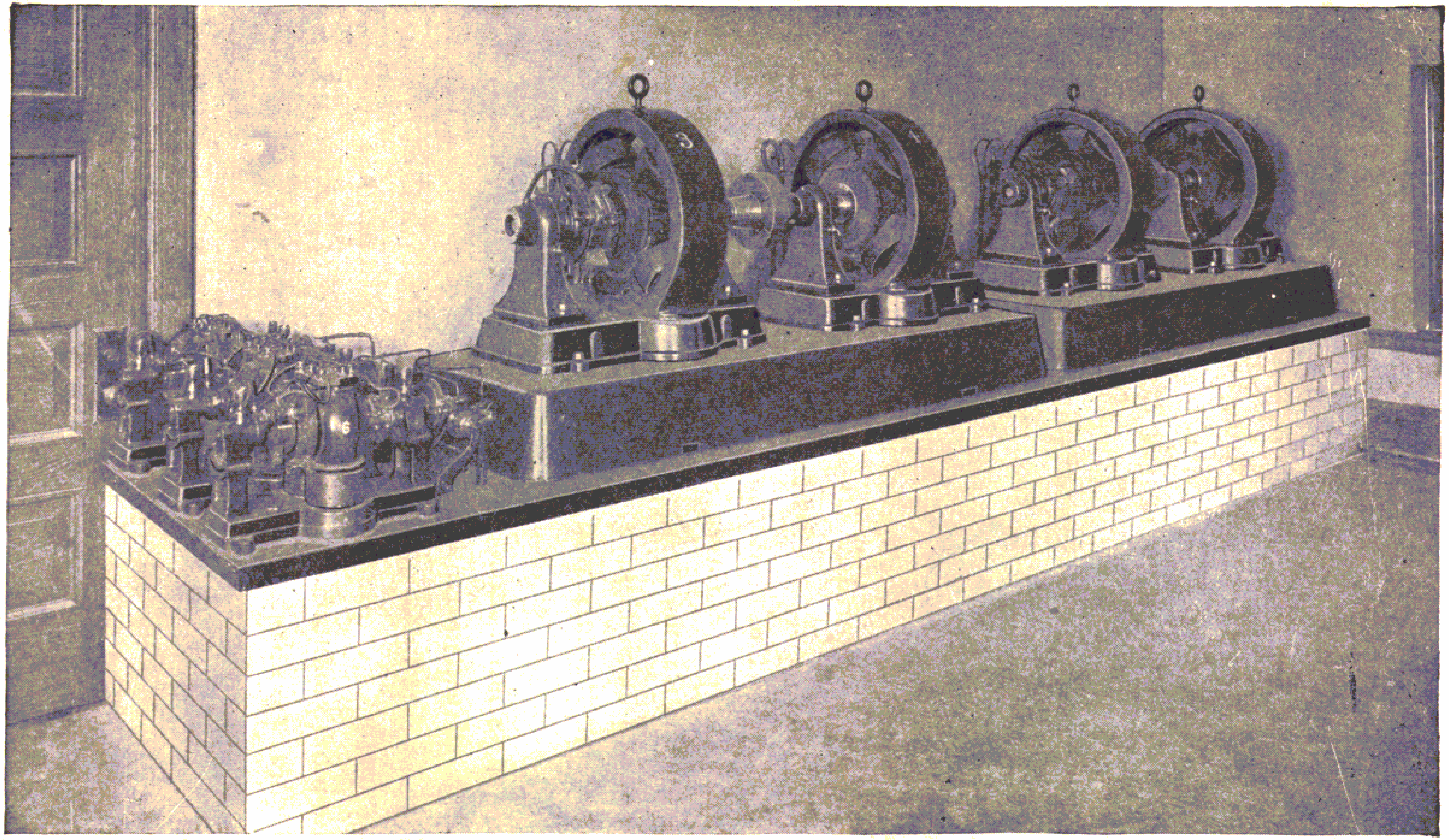


Fig. 136. — Ringing and Charging Outfit.

power switchboard, while it does not carry the quantity of electricity that passes through the board of a power station of magnitude, becomes an affair of some complication. Switchboards are made after all sorts of designs. One design of power plant switchboard is shown in Fig. 141. Nearly every manufacturer has a different design for such switchboards.

As it falls to the duty of the wire chief to ascertain the nature of and remedy all troubles which arise in the subscriber's line and switchboard, he must have the necessary apparatus therefor. It is customary to provide the wire chief with a desk, upon which the testing paraphernalia and circuits necessary to the transaction of his business are installed. The desk is placed in the wire chief's quarters conveniently to the distributing board. Such a desk and its general relation to the other exchange apparatus is shown in Fig. 143. The special circuits required are as follows:

1. Cord circuit.
2. Observation lines.
3. Lines to multiple board.
4. Local trunks to other officials.
5. Testing trunks to main distributing board.
6. Testing trunks to multiple board.
7. Test cord circuit.

1. *Connecting Cord Circuit.* — The wire chief is provided with a cord circuit, as shown in Fig. 144. The plug Q is provided with three keys, one to the ringing generator, another to the telephone set, and a third to a retardation coil.

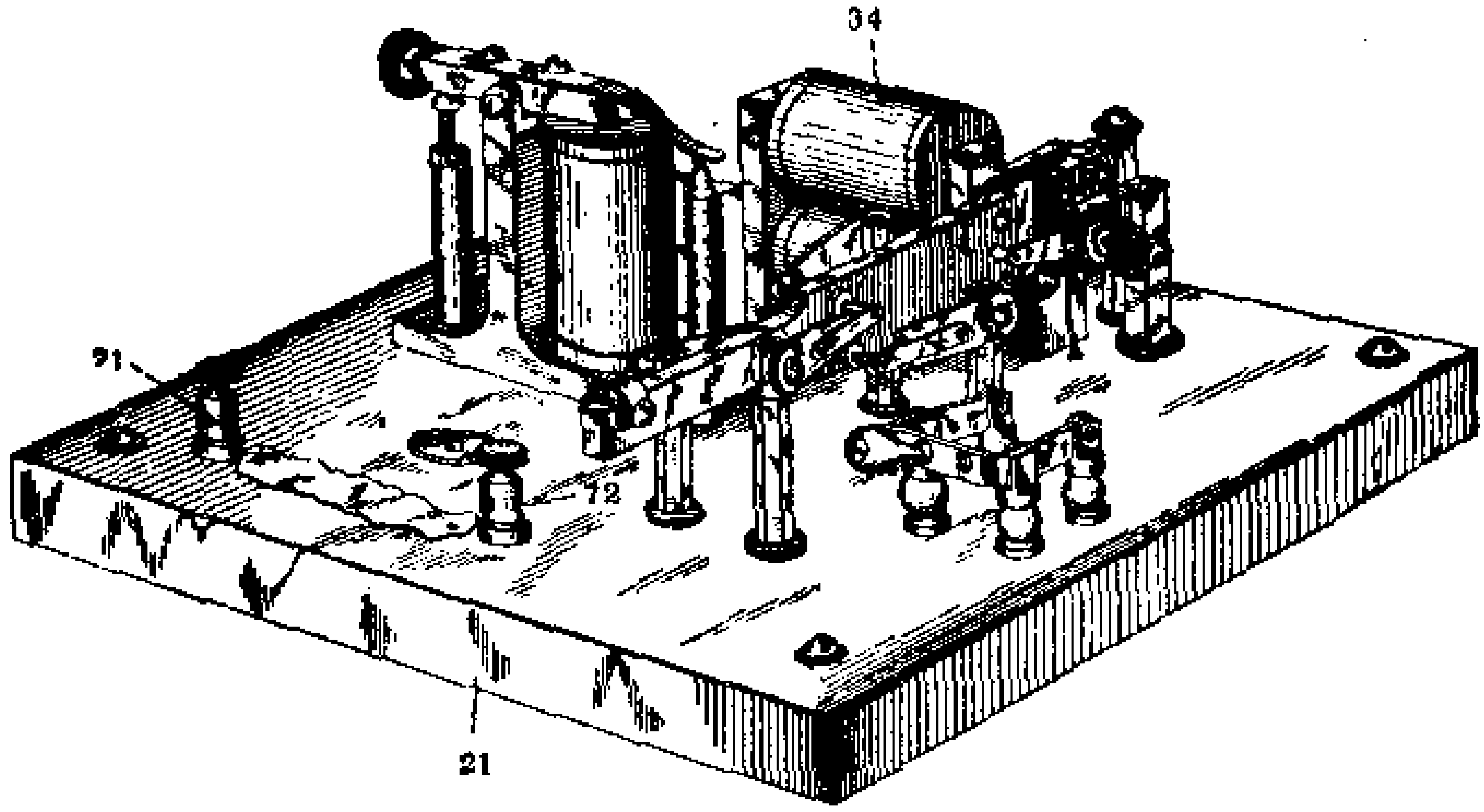


Fig. 137.—Warner Pole Changer.

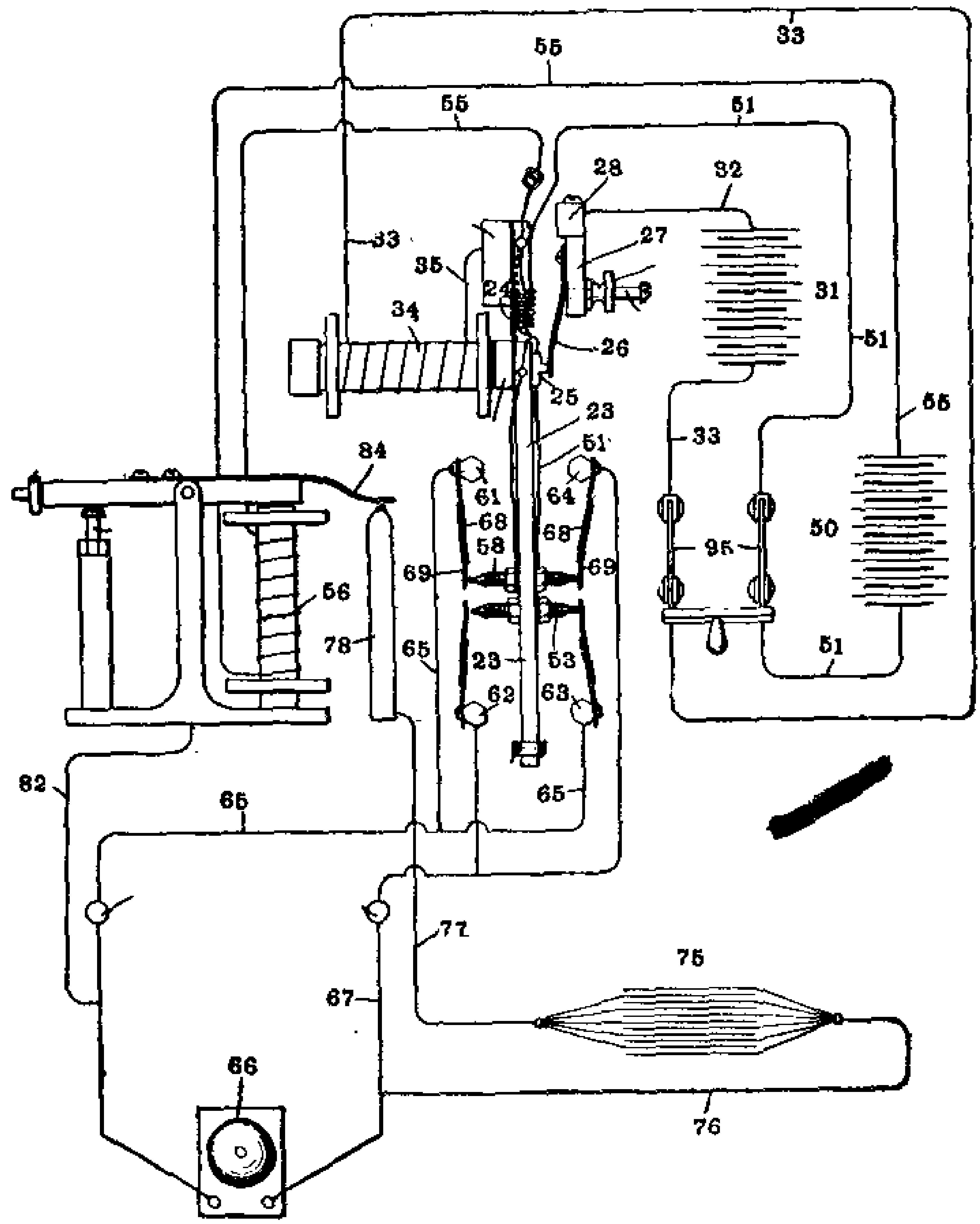


Fig.—138.—Circuit of Warner Pole Changer.

2. *Observation Lines.* — The wire chief must have a number of observation lines, which are precisely similar to those described for the chief operator and used in the same manner.

3. *Lines to Multiple Board.* — Between the wire chief's desk and the multiple board, there are circuits similar in all respects to those installed for the chief operator, and are used in the same way. If a local operator calls the wire chief over such a circuit he will answer with plug *Q* of Fig. 144, and when the retardation coil key is thrown, the supervisory signal in front of the local operator is extinguished. Then the wire chief throws the listening key and carries on any conversation that may be desired; to disconnect, the retardation coil key is returned to its normal position, and then the operator receives the proper signal. When the wire chief desires to call the multiple board, he plugs into the jack of this circuit and by throwing the retardation coil key lights the line lamp in front of the local operator, who answers in the usual manner.

4. *Local Trunks to Other Officials.* — The wire chief is provided with local trunks to other officials, in the same manner as the chief operator.

5. *Testing Trunks to Main Distributing Board.* — By removing the heat coils in the front of the main distributing board, any line may be divided into two parts, one extending to the substation outside of the office and the other running through the switchboard, therefore the heat coils form the logical point at which tests upon all circuits in trouble may be made. For this purpose the wire chief is provided with the circuit of Fig. 145. The apparatus at the left of the dotted line is located upon the wire chief's

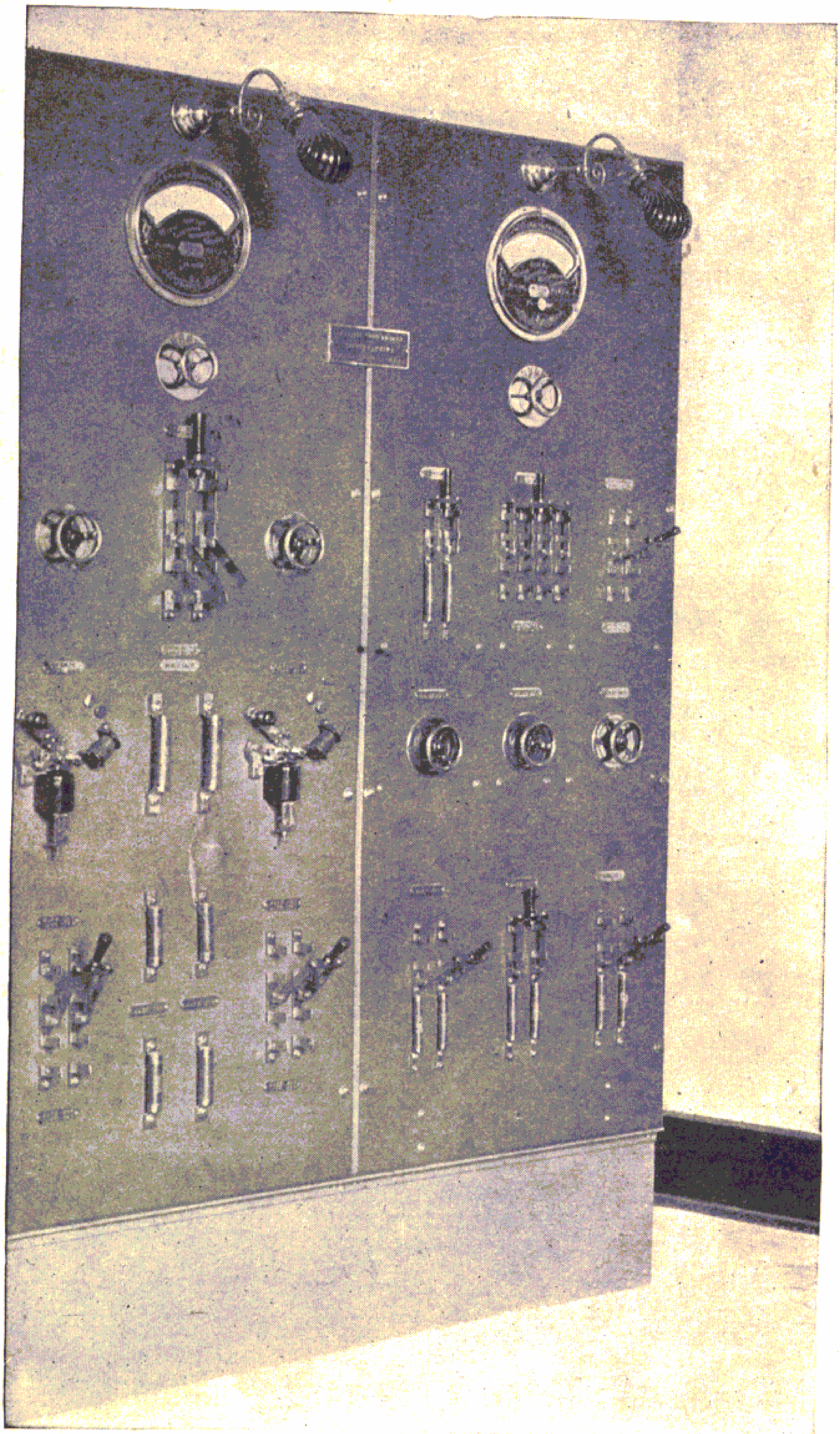


Fig. 141.—Power Board, Design A.

desk, while the trunk line extends to the main distributing board, there, by means of a flexible cord it can be made to reach any terminal. When the four-way plug *P* is inserted in place of the heat coils, on the main distributing frame, all the traffic of the line under test will pass through the wire chief's desk. When the receiver is removed the line lamp is lighted, and also current flows from the battery through 600-ohm winding of relay *B*, back contact of relay *R'*, armature *a* to the substation and back to the rear contact of armature *a'* of relay *R'*, thence to the ground and the battery. Relay *B* is excited, its armature falls, lighting lamp *M*. The wire chief answers by inserting plug *Q*, Fig. 144, into jack *K*, Fig. 145. There is then a circuit from the battery through the 210-ohm resistance coil of the cord, the ring of the jack, the 30-ohm relay *R'* to the ground, and also through the restoring coil of relay *B*, hence lamp *M* is extinguished and relay *B* restored. If a local operator happens to ring a subscriber while the testing plug is in use, she will ring down relay R^2. This will light lamp *L*, and the wire chief, by inserting the answering plug *Q*, Fig. 144, can listen or talk upon the circuit. Besides providing a testing trunk this circuit can be used in connection with the test cord circuit, presently to be described, to enable the wire chief to inspect the service upon the line of any subscriber.

6. *Testing Trunk to Multiple Board.* — This circuit is shown in Fig. 146. The plug *P*, upon the right hand of the dotted line, is placed at one of the positions of multiple board. The remainder of the apparatus is on the wire chief's desk. When a line works improperly the operator reports the fact to the wire chief, who orders the testing

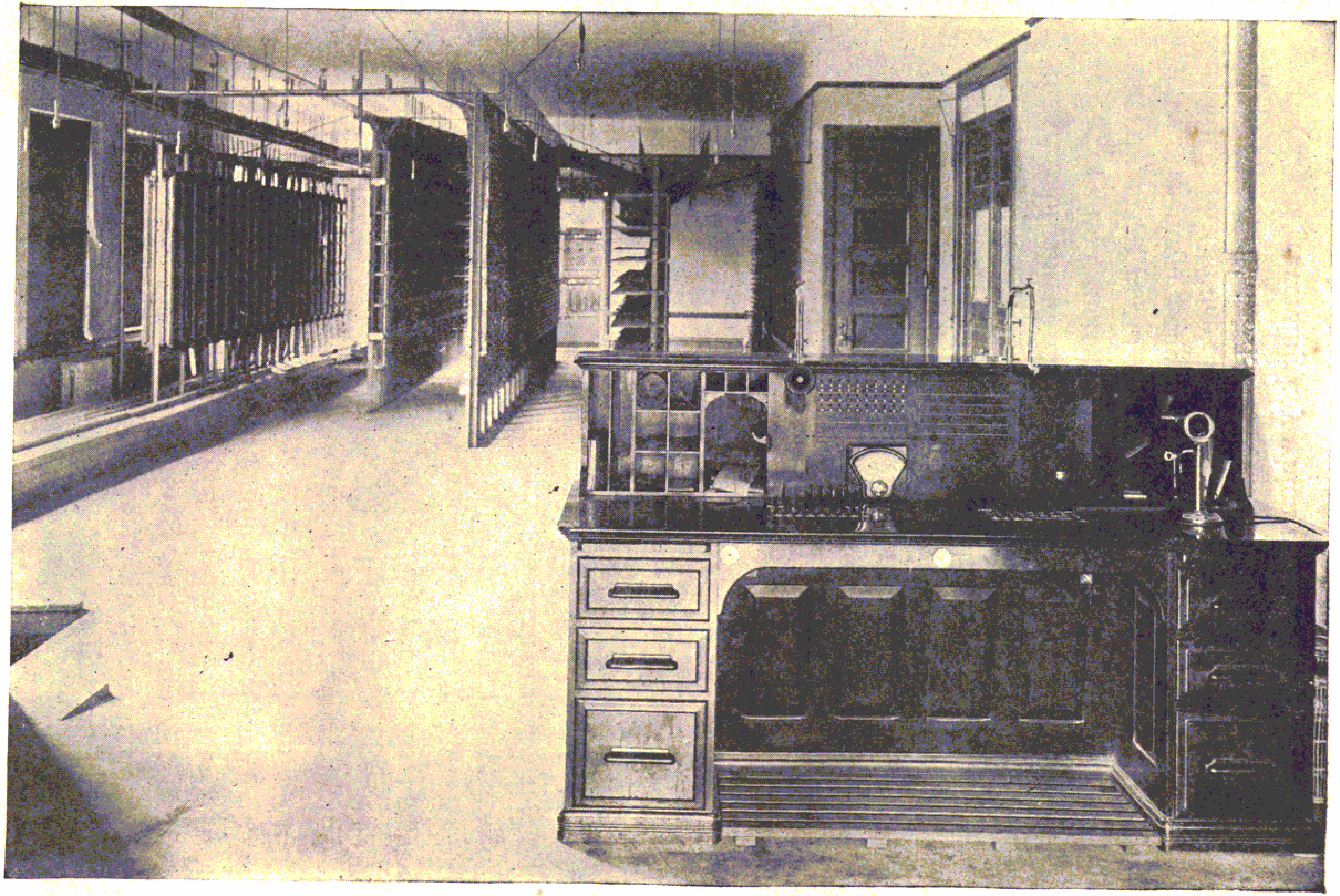


Fig. 143. — Wire Chief's Desk.

plug P inserted in the jack of the line in question. When plug P, Fig. 146, enters the jack, current will flow from the interrupter, winding C, key K and lamp L to ring of jack, through cut-off relay to the ground. The cut-off relay will be excited, extinguishing the line signal, lighting white lamp L as a notice to the wire chief, who will proceed to test the line. If, while the testing plug is in the subscriber's jack, the subscriber calls, there will be current through the 600-ohm winding of relay r, to the substation and back through the back contact of relay R and to the battery. Relay R will be excited, and will illumine red lamp M. The wire chief can then answer the call and make such disposition of it as he sees fit. As soon as the wire chief has cleared the trouble he will, over a call wire, order the plug P removed. The extinguishment of the white lamp 1 shows that this has been done. In case the trouble requires the services of an outside lineman, the testing plug is left in the subscriber's jack, so the lineman can signal the wire chief by crossing the line and lighting the red lamp M. The insertion of plug P places a peculiar tone test upon the sleeves of the jack by means of the interrupter. The object of this is to notify operators, who have occasion to call the line, that it is in trouble.

7. *Testing Cord Circuit.*—To locate the position and nature of any difficulties which may arise upon a subscriber's line, the wire chief must be enabled to rapidly and easily make a great variety of electrical measurements; for this purpose the apparatus provided in Fig. 147 is installed on the desk top.

(1.) A ringing key to enable the chief to ring any line.

(2.) A reversing key which reverses the position of the

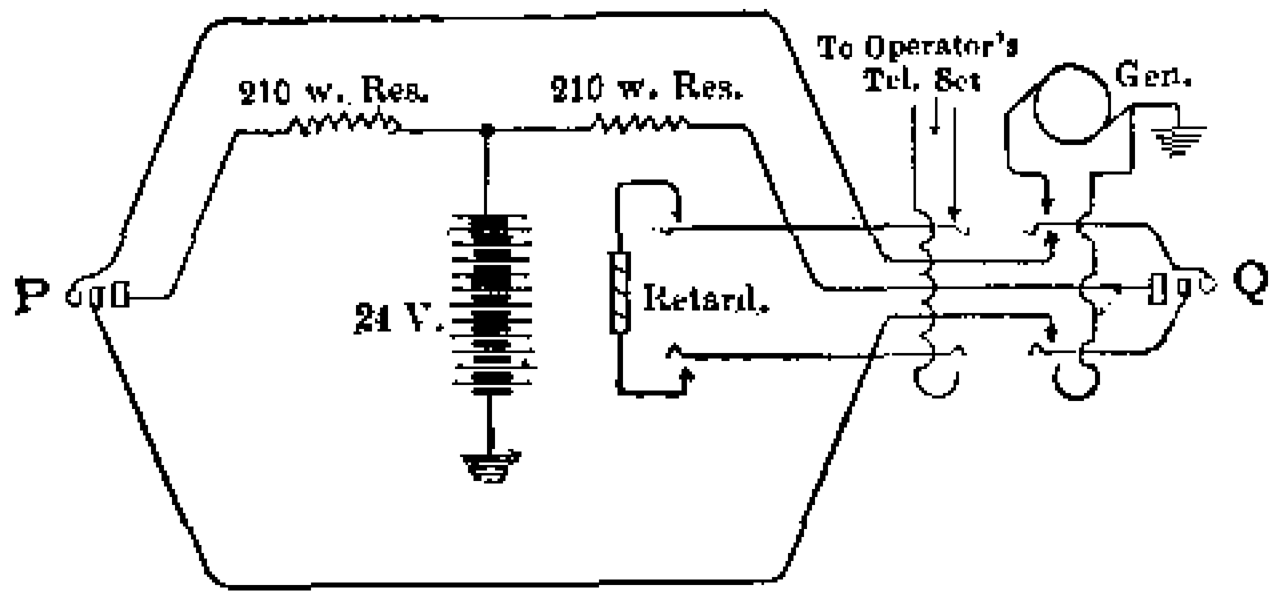


Fig. 144. — Connecting Cord Circuit.

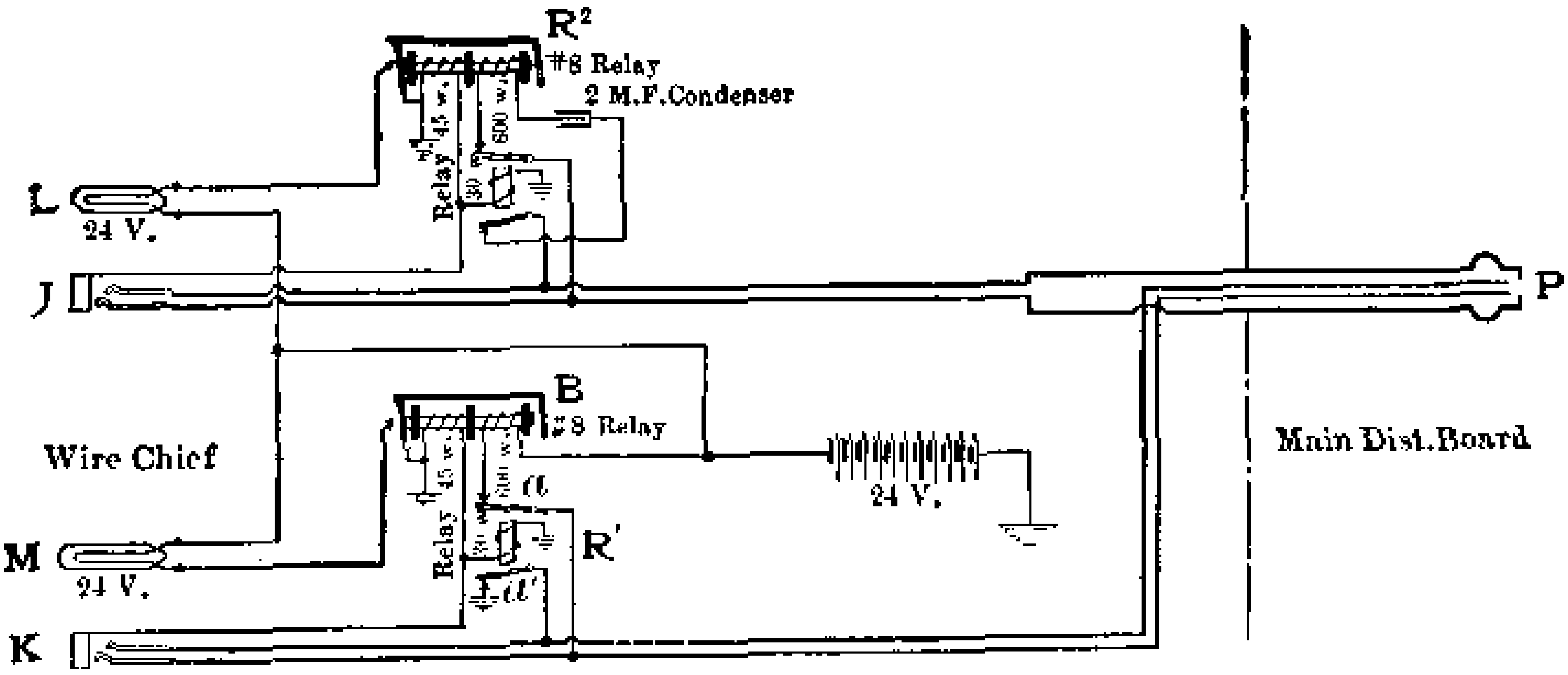


Fig. 145. — Testing Trunk to Main Distributing Board.

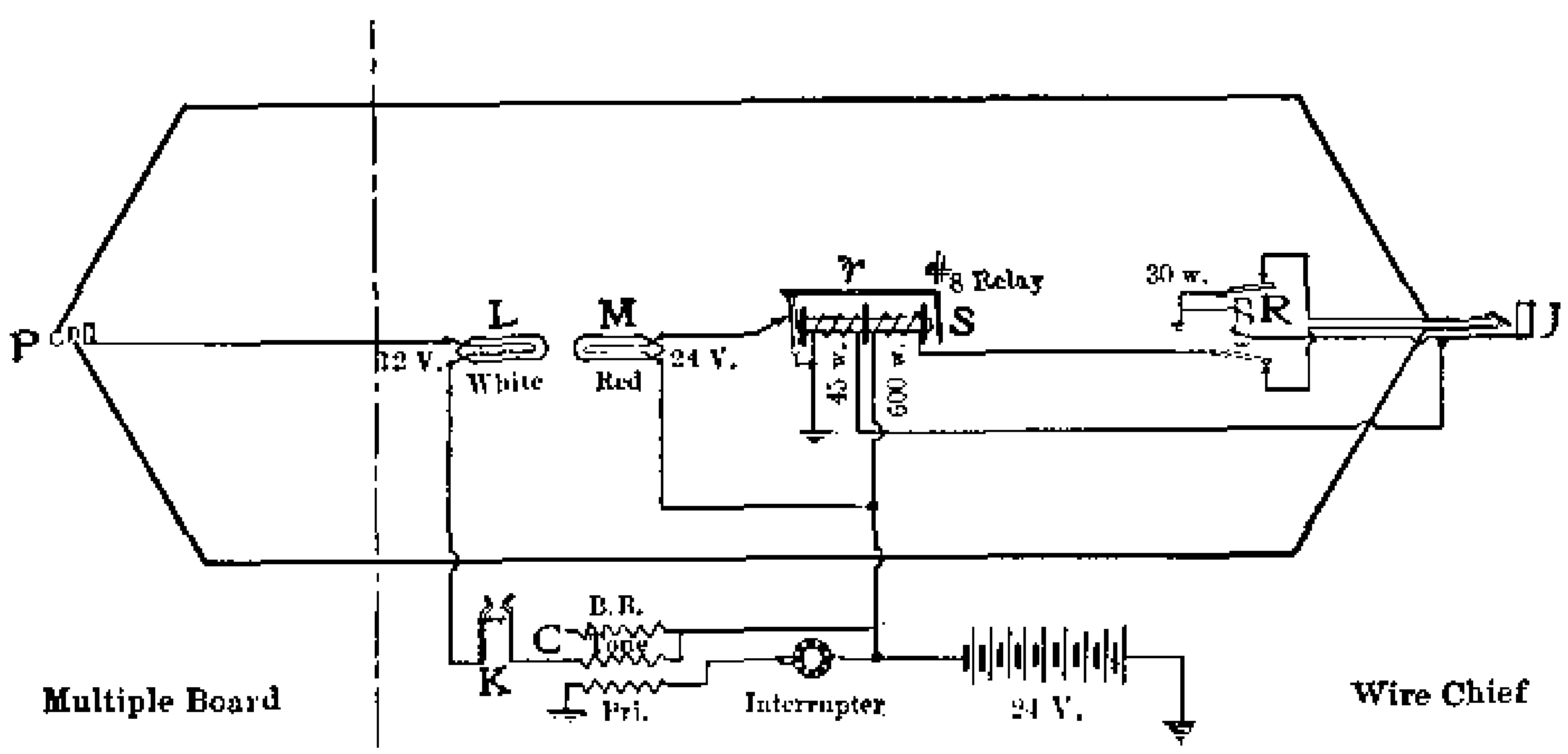


Fig. 146. — Testing Trunk to Multiple Board.

testing apparatus with respect to the tip and ring of the line.

(3 and 4.) Grounding keys. One for the tip side of line, the other for the ring side.

(5.) A voltmeter key which bridges a voltmeter across the cord circuit.

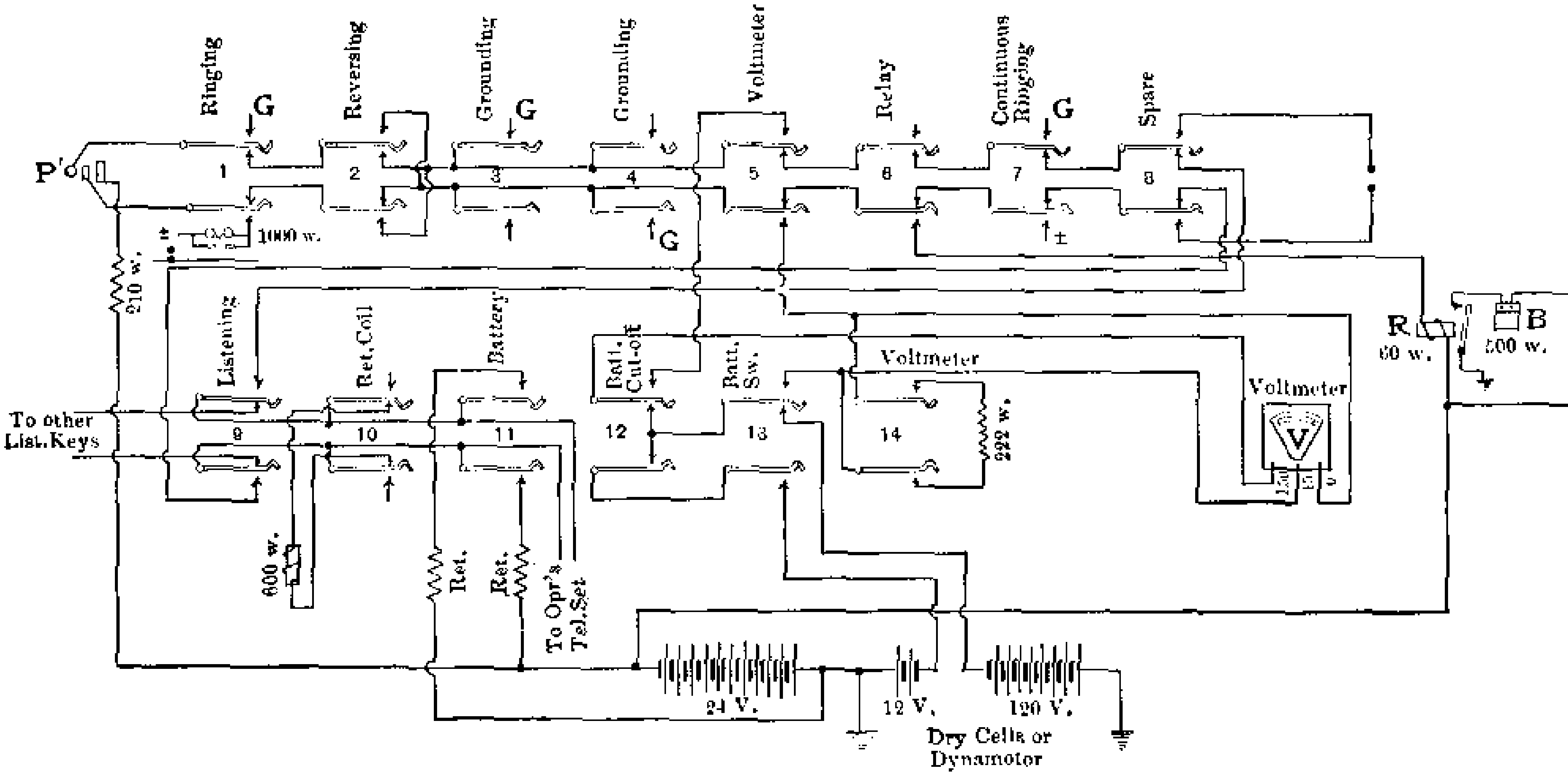


Fig. 147.—Testing Cord Circuit.

(6.) A relay key to test for grounds.

(7.) A mechanical ringing key for ringing automatically.

(8.) A spare key to be used for any purpose.

(9.) A listening key to connect the wire chief's telephone set across the cord circuit.

(10.) A retardation coil key to be used in a similar manner as the retardation coil key, Fig. 143.

(11.) A battery key to connect a battery to the cord circuit through a repeating coil or retardation coil.

(12.) A battery cut off to remove the battery from the voltmeter.

(13.) A battery switching key to connect a 12-volt battery to the low scale of the voltmeter.

(14.) A shunt key for the voltmeter (low scale).

Whenever a line is reported in trouble, plug *P* of Fig. 146 is inserted in a jack in the multiple board, and the test plug *P'*, Fig. 147, is placed in jack *J*, Fig. 146. Then wire chief by the keys shown in Fig. 146 can make all of the customary electrical tests for continuity, short circuits, capacity, resistance, etc. The object of this circuit is solely to enable the necessary apparatus to be placed quickly in position to make the various well-known electrical measurements, so fully described in numerous texts, that it is unnecessary to repeat them. The circuit of Fig. 146 employs a voltmeter for the purpose of making most measurements, because with this instrument the work can be performed most quickly. Sometimes a Wheatstone bridge is substituted, so arranged that it may be conveniently and rapidly connected to any line to be tested.

CHAPTER VIII.

TRAFFIC.

THE telephone company sells transportation just as a railway company sells transportation. The railway plant consists of a track on which runs the locomotive, drawing a train of cars loaded with passengers or merchandise collected from many sources. The telephone company provides tracks in the shape of wires to each subscriber, over which intelligence is hauled, not by a tangible locomotive, but by the more impalpable but equally real energy of an electric current. It is folly for a railroad manager to operate in ignorance of the number and size of his locomotives, and their tractive power, or the capacity of his freight cars, and the ability of his organization to handle the goods offered for carriage. It is equal folly for the telephone manager to be in ignorance of the capabilities of his operators and the possibilities of his switchboard, trunk lines, and other apparatus. The telephone exchange exists solely for the purpose of carrying intelligence from point to point, so it is a vender of traffic in absolutely the same sense as any other transportation company. It is a highly organized and specialized set of facilities, and is valuable only in proportion to its ability to perform with the greatest economy and highest efficiency this task. To attain that end the general manager must be thoroughly informed as to the following essentials:

1. The amount of traffic presented.

2. The possible capacity of the several facilities at his command.

3. The efficiency at which the plant from time to time works.

The desirable efficiency, namely, such a point of loading as is on the whole found to be commercially most preferable.

The answers to these questions can only be derived from extensive practice. For *a priori* it is impossible to predict how many messages the average subscriber will originate, the number of calls a trunk line can satisfactorily handle, or the load at which operators are best fitted to work, and it is only by the comparison of prolonged experience from many sources that reliable information of this character can be obtained. Hence the study of *traffic* is the ever present and most important investigation which confronts the general manager.

The originating business is the starting point. It is well to catalogue the subscribers from all view points, such as residence and business substations, the latter to be separated into such salient groups as druggists, bankers, brokers, railway freight houses, newspapers, theaters, small retailers, grocers, butchers, markets, laundries, etc., wholesale supply houses, lumber dealers, and many other subdivisions which will naturally suggest themselves to the reader.

Next the facilities which are supplied to each group should be noted, such as the relative proportions of one, two, three, and four party lines, the relation between the number of measured service and flat-rate subscribers. The proportion of the various kinds of substation equipments, such as desk sets, extension desks, coin boxes, which are demanded by the varying needs of the various groups of subscribers.

In exchanges which embrace a number of subsidiary offices, this inventory should be made for each one separately, and then the different lists tabulated as percentages of the whole, so that when complete, the general manager has before him a carefully analyzed statement in detail, of the kind of subscribers with which he has to deal, and the facilities that serve them. This tabular information should be accompanied by a statement of the office and trunk line equipment, so arranged that at a glance the relation between the subscribers and the facilities can be observed.

A convenient method is to use a long sheet of profile paper mounted in a case upon rollers, so that it may be easily moved back and forward, then by using colored inks and a combination of dotted and dashed lines, the statistics of subscribers and equipment can be recorded from time to time, and in this way the effect of changes, and the tendencies in growth appeal to the eye at a glance. Such a record shortly becomes not only a most interesting business history, but is almost infallibly prophetic in indicating future changes in the grouping of subscribers, and the facilities which will be demanded.

The next step is the determination of the business which the subscribers originate and concomitantly the rate at which the various parts of the plant are working. Accumulated records of this description soon reveal the proper loadings at which the different elements of an exchange should be worked to secure the highest efficiency, and by comparing such statistics with similar data, which traffic studies from other sources reveal, the manager can at once discover whether his apparatus is operating under the most favorable conditions, and if not what remedy should be applied.

It must not be for a moment inferred that the unit loads, which in the past have been found suitable, are final — they are not. They are useful in three ways. **1.** To determine whether from time to time the various elements are working at such loadings as experience has indicated are desirable, and if not, to point out what changes should be made. 2. To indicate whether the plant as a whole is working harmoniously, for a telephone exchange is so complex, and so sensitive that no one portion can be seriously under, or over-loaded, without reflecting this condition upon the other groups and seriously interfering with the best results of the whole. 3. Telephony is a constantly growing art, new methods both in apparatus and in operating are constantly being tried, and unless the effect of each change be carefully noted and studied in relation to the results of the whole, the highest development is impossible.

In some forms of transportation business, traffic records become automatic, thus in a railway, freight is paid for by weight and distance, and passengers by number and distance, hence the ton miles, and the passenger miles, are automatically recorded by the way-bills and tickets; but in a telephone exchange, even with measured service, complete traffic statistics do not automatically record themselves, and so special traffic investigations are necessary.

The most prevalent method is from time to time to count the number of originating calls and trunk messages handled at each switchboard during a period of twenty-four hours. Usually enumerations of this kind are made monthly, and in addition whenever extraordinary occasions demand a special study. The easiest way is to provide each operator with a wooden peg about the size of the ordinary plug, so that it may easily fit the jack, having a head which will prevent it from entering too far and become lost. Each operator is instructed to use the set of 100 multiple jacks nearest in front of her. Commencing at midnight of the predetermined twenty-four hours, all operators are instructed to insert their pegs in the zero jacks of the banks, and then each operator is to move her peg along one jack for every call that is received. At the end of each hour a monitor visits the board and makes a memorandum of the number of the jack in which each peg stands, and removes it to the zero hole, thus securing the number of calls which each position has answered during the preceding hour, and starting the record afresh.

From the use of the wooden peg such a traffic enumeration has been termed a "peg count." Recently many improved methods of recording have been devised. Of these the simplest involves a substitution of some mechanical device, such as a revolution counter, a bicycle cyclometer, or street-car fare register. Attempts have been made to equip each cord with a mechanism which should automatically record each time that it is used, but such devices have proved both expensive and unreliable.

For toll line work, or measured service, where tickets are made for each call, the traffic record becomes largely automatic. If lines are supplied with a message meter located in the exchange, an hourly inspection of each meter is all that is required to determine the number of originating calls, but where the registers are located at the substations, the task of collecting the records is too arduous to be undertaken.

When counting is done by the operator, either by a peg or other device, each call should be registered the moment the signal lamp lights, or the drop falls, for if this is not done, particularly during rush hours, the operator invariably makes errors in endeavoring to peg from memory the right number of messages. Experience has shown that it is necessary that the operators should be unaware of the number of calls which their neighbors have recorded; otherwise the lazy ones will compare notes with the more industrious operators, and stuff the ballot box by increasing records so that they shall compare favorably with each other.

At first sight it would appear that the labor of recording would injure the service by inflicting an extra burden upon the operators, but experience has shown that such is not the case, for operators quickly become so experienced that subscribers never know when a peg count is in progress; and further, by a judicious cultivation of the spirit of emulation, the operators become anxious to have peg counts taken in order that from time to time their improvement may be noted and brought to the attention of the management.

With whatever form of recording device is used, the supervisor is supplied with a series of blanks, somewhat after the fashion of Fig. 148, and opposite each hour re-

Traffic Record X.Y.Z. Telephone Co.

Dated.............. Weather.............................. Summary Sheet.

Item No.	Items.	Derrivation of Items.	Designation of Offices. Office A. Returns.	Office A. Difference from Last Count.	Office B. Returns.	Office B. Difference from Last Count.		Totals.	Difference from Last Record. Greater.	Difference from Last Record. Less.
	Section A. Circuit & Station Statistics									
1	No. of Flat Rate Stations.									
2	" " Measured " "									
3	" " Single Line "						Form to be made wide enough			
4	" " Party " "						to accomodate as many			
5	" " Residence "						Offices as may be desired.			
6	" " Business "									
7	" " Pay "									
8	Total Stations									
9	No. of Lines.									
10	Average Stations per Line.									
11	No. of Incoming Trunk Circuits.									
12	" " Outgoing " "									
13	" " Toll "									
14	" " Positions A.									
15	" " " B.									
16	" " " Toll.									
17	" " Cords Circuits A.									
18	Calls per " " A.									
19	No. of " " B.									
20	Calls per " " B.									
	Section B. Origination Traffic.									
21										
22	Form to be made long enough to accomodate as many Sections as desired.									

Fig. 148. — Traffic Record.

cords the number of calls received in each position. As soon as the count is completed these records are forwarded to the traffic department and placed in the hands of clerks equipped with adding machines, slide rules, and other tabulating devices, whereby the results obtained from each office may be collected and quickly tabulated, in such a manner as to be most useful in determining the loads which the various parts of the exchange are carrying.

A great variety of forms have appeared from time to time for this purpose. On the whole, experience is now tending toward the plan of recording the results of each position in each office upon a sheet similar to Fig. 149, so that the general manager has placed before him an itemized statement of what each position accomplishes. Then a summary sheet is made, in which all of the items for all offices are collected so as to present a comprehensive statement of the whole. Subsequently all the detail sheets and the summary are bound together forming a complete "*traffic record*." The general form of a summary sheet is shown in Fig. 148. Each item is given a number indicated in the column on the extreme left. Column 2 contains the items which are subdivided into nine sections. Column 3 shows the derivation of the items, that is to say, the arithmetical process by which the various quantities are obtained. The body of the table contains two columns for each of the subsidiary offices, the first one showing the return which the office gives for the particular count, and the second one the difference, whether greater or less, than that shown by the preceding count for the same item. It is obvious that the body of the table may be made larger or smaller, depending upon

Date. ....

Detail Sheet .... A-B .... Office. ....

Hours.	Originating Calls.							In Trunk Calls.						
	Positions No's.							Positions No's.						
	1	2	3	4	5	6	Totals	1	2	3	4	5	6	Totals
12 to 1 A.M.														
1 " 2 "														
2 " 3 "														
3 " 4 "														
4 " 5 "														
5 " 6 "														
6 " 7 "														
7 " 8 "														
8 " 9 "														
9 " 10 "														
10 " 11 "														
11 " 12 "														
12 " 1 P.M.														
1 " 2 "														
2 " 3 "														
3 " 4 "														
4 " 5 "														
5 " 6 "														
6 " 7 "														
7 " 8 "														
8 " 9 "														
9 " 10 "														
10 " 11 "														
11 " "														
Totals.														
Pos. Hrs.														
Lines.														
Calls per Line.														

Fig. 149. — Detail Traffic Sheet.

the number of subsidiary offices, and similarly that the items of the various sections may be extended or curtailed to fit the particular service. Finally, upon the extreme right there is a column giving the totals for all offices, and the difference between the count recorded and the preceding one. In order to save space in printing, the various items which compose the several sections in column 2 are shown below, and by this means any items may be rejected that do not apply to such particular exchange under consideration now.

SEC. A.—*Circuit and Station Statistics.*

Number of flat rate stations.
Number of measured rate stations.
Number of single lines stations.
Number of party lines stations.
Number of residence lines stations.
Number of business lines stations.
Number of pay stations.
Total stations.
Number of lines.
Average stations per line.
Number of incoming truck circuits.
Number of outgoing truck circuits.
Number of toll circuits.
Number of positions *A*.
Number of positions *B*.
Number of cord circuits *A*.
Calls per cord circuit *A*.
Number of cord circuits *B*.
Calls per cord circuit *B*.

SEC. B.—*Originating Traffic.*

Number of calls.
Average number of calls per line.

Average number of calls per station.
Average number of calls per business station.
Average number of calls per residence station.
Average number of calls per pay station.
Number of *A* operators in busy hours.
Number of calls per position, average.
Number of calls per position, maximum.
Number of calls per position in busy hour, average.
Number of calls per position in busy hour, maximum.
Number of calls per operator in busy hour, average.
Number of calls per operator in busy hour, maximum.
Number of *A* operator hours.
Hours per operator.

Sec. C. — *Trunk Traffic.*

Number of out trunk calls.
Number of in trunk calls.
Number of out toll calls.
Number of in toll calls.
Total toll messages.
Number of out trunk calls per circuit, average.
Number of in trunk calls per circuit, maximum.
Number of in trunk calls per position, average.
Number of in trunk calls per position, maximum.
Number of in trunk calls in busy hour.
Number of in trunk calls per position in busy hour, average.
Number of in trunk calls per position in busy hour, maximum.
Number of *B* operators in busy hour.
Number of *B* operator hours.
Hours per operator.
Number in trunk calls per operator, hour.
Per cent out trunk calls to originating calls.
Total messages.

Sec. D. — *Statistics of Labor.*

Total operators.
Total operators, hours.
Other employees.

Other employee hours.
Total employee hours.
Messages per position hour.
Messages per operator hour.
Messages per employee hour.
Hours per employee.

SEC. E. —*Statistics of Flat Rate Service.*

Number of stations.
Number of lines.
Stations per line, average.
Total calls.
Calls per line, average.
Calls per station, average.
Number of positions.
Calls per position, average.
Calls per position, maximum.
Calls per position in busy hour, average.
Calls per position in busy hour, maximum.
Number of position hours.
Calls per position hour.
Number of operators.

SEC. F. —*Statistics of Measured Service.*

Number of stations.
Number of lines.
Stations per line, average.
Total calls.
Calls per line, average.
Calls per station, average.
Number of positions.
Calls per position, average.
Calls per position, maximum.
Calls per position in busy hour, average.
Calls per position in busy hour, maximum.
Number of position hours.
Calls per position hours.
Number of operators.

SEC. G. — *Statistics of Party Line Service.*

Number of stations.
Number of lines.
Stations per line, average.
Total calls.
Calls per line, average.
Calls per station, average.
Number of positions.
Calls per position, average.
Calls per position, maximum.
Calls per position in busy hour, average.
Calls per position in busy hour, maximum.
Number of position hours.
Calls per position hours.
Number of operators.

It is very convenient to prepare the record thus illustrated by printing it upon tracing muslin. As soon as the statistics are completely worked out, a blank muslin is placed in a book typewriter and the statistics quickly transferred to the proper columns. The cloth sheets may be then placed in a blue-print frame, and as many copies made as desired. It is customary in large exchanges to complete the peg count by binding the detail sheets upon the back of the summary sheet, and it is found that there is no greater incentive to good service than to distribute copies of each peg count to the managers of the several subsidiary offices. Finally it is advantageous, three or four times a year, to convene all of the managers and to discuss with them the results which the peg counts have shown; for in this way their attention is forcibly directed to the returns, and ways and means discussed for improving and bettering the service.

Another method of recording the results is that of plotting upon cross-section paper, and while this does not afford so searching an analysis, it depicts graphically the

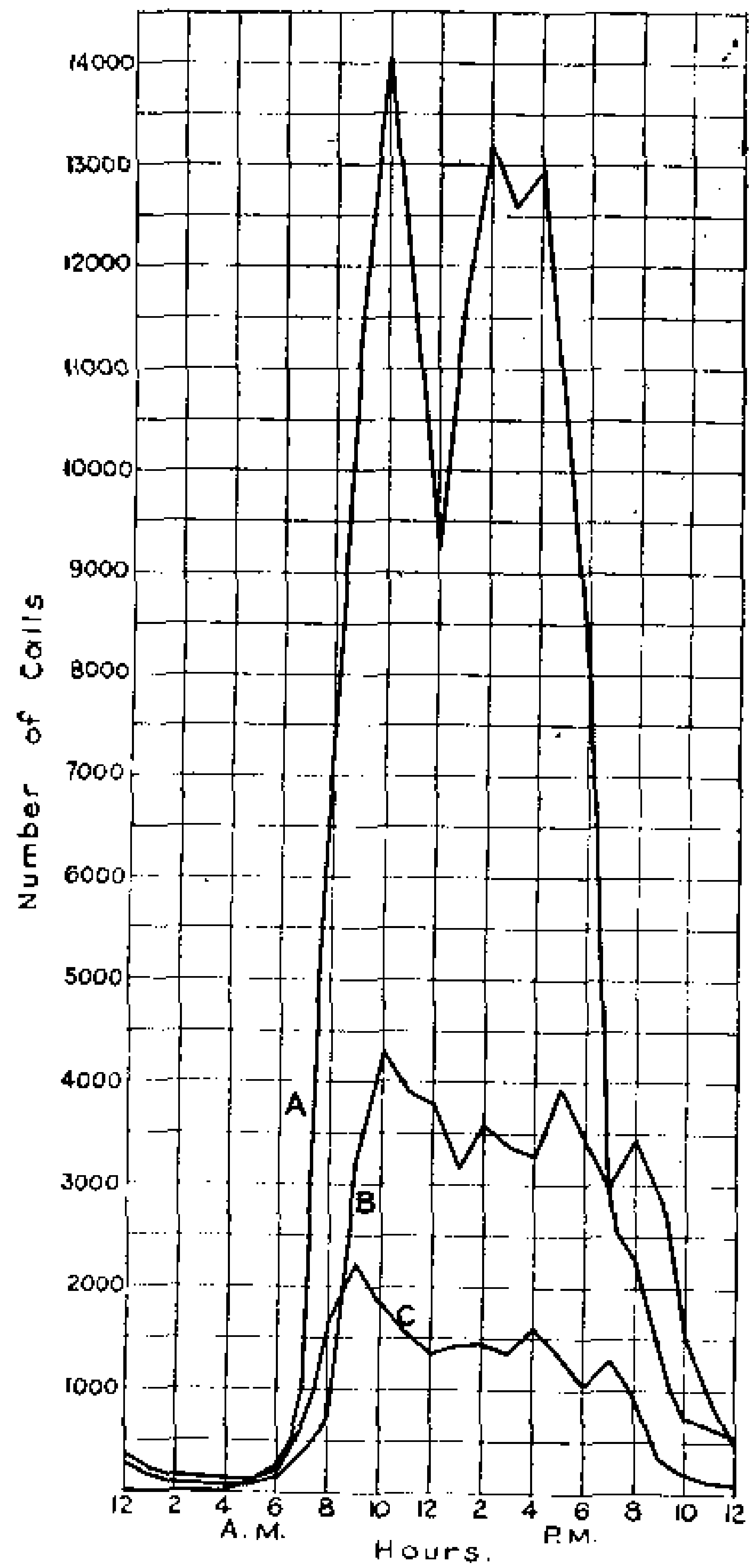


Fig. 150.—Traffic Record, Large City Originating Calls.

general returns in a manner which appeals much more forcibly to the eye than any array of figures. As examples of this method, Figs. 150 to 156 inclusive may be consulted.

In all of these diagrams the left hand horizontal scale shows the number of originating calls which occurred during each hour, represented on the horizontal scale.

These and the following statistics have been gathered from an examination of several score peg counts, collected from as wide a field as possible, embracing large and small centers, and exhibiting the results secured, from upwards of one thousand operators. The rough specification has been adopted of denominating large cities as those of half a million inhabitants or over, medium-sized cities, those from fifty thousand to five hundred thousand, towns, as containing from ten to fifty thousand, while villages embrace centers of under four thousand.

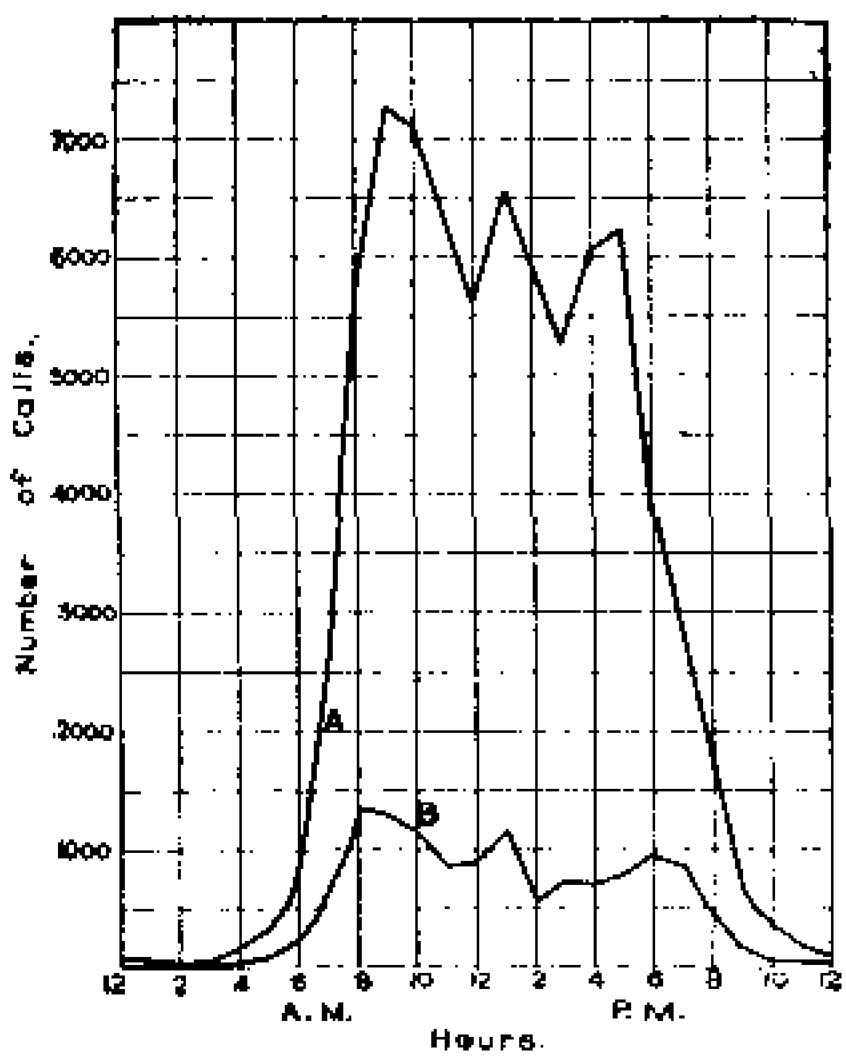


Fig. 151.—Traffic Record, Medium-Sized City Originating Calls.

Fig. 150 is the diagram obtained from a large city. Three curves are shown. Curve A is the load line of a large office, say four or five thousand subscribers, curve B that of a medium-sized office, twenty-five to three thousand, in a residence district, and C is of a small office of from eight hundred to one thousand, in the outskirts.

Diagram 151 is obtained from an exchange in a medium-sized city, curve A relating to the main office of the business district, B to a branch office.

Diagram 152 is from a farming town of about ten thousand inhabitants, while No. 153 is obtained from a manufacturing town of about the same size. Finally, No. 154 is the load line of a small village. Diagrams 150 and 151 are plotted to the same scale, so as to be readily comparable. In the same manner, Nos. 152 and 153 are to the same scale, but considerably enlarged over the scale of

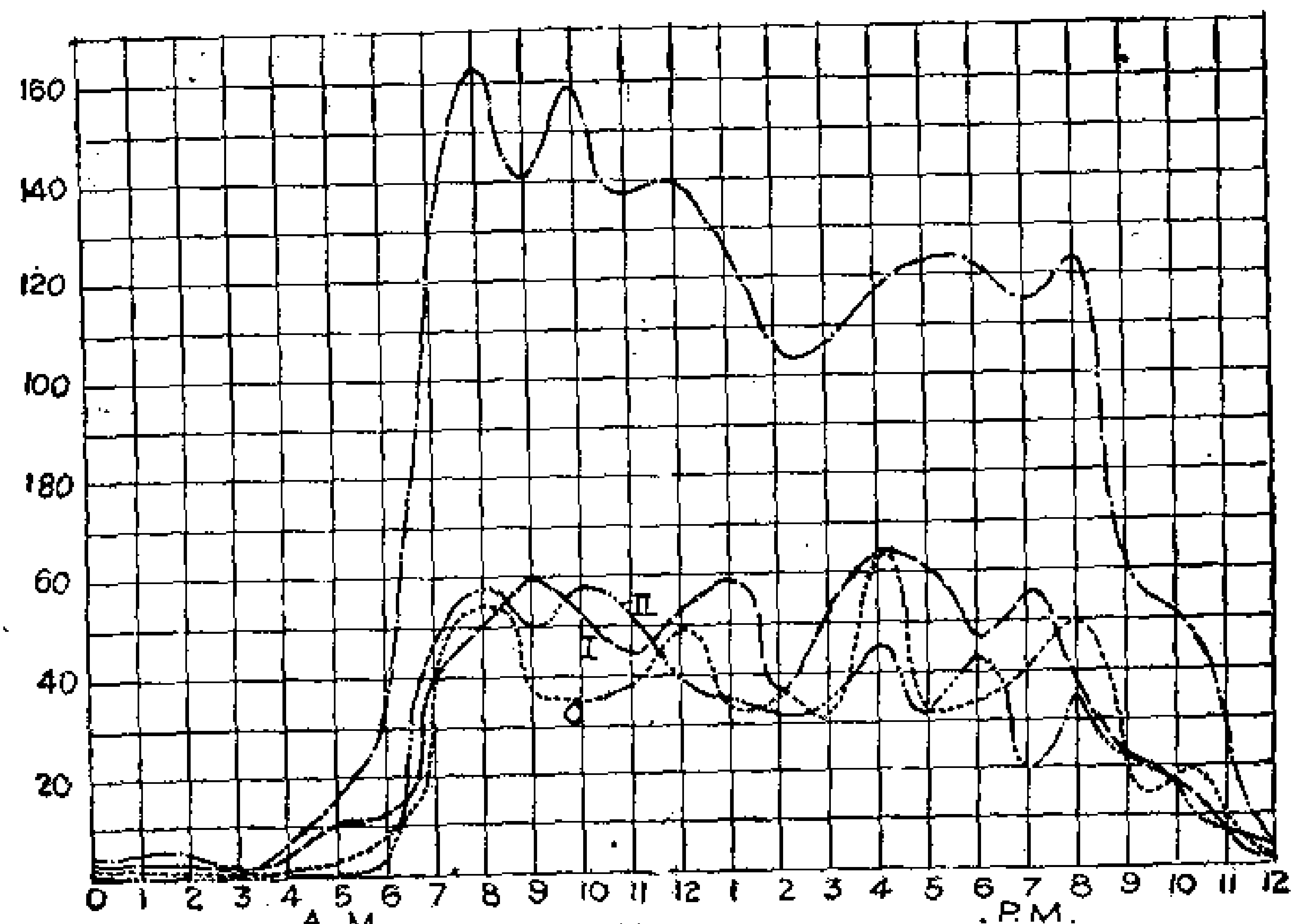


Fig. 152.—Traffic Record, Farming Town Originating Calls.

Nos. 150 and 151. On Figs. 152 and 153 the loads of the individual positions of the switchboards of three positions which were employed in these exchanges. There is a general resemblance between all of the diagrams. In large cities the peak of the load occurs later in the day than in those of medium size, and the falling off of traffic during the noon hour is more marked. In the manufacturing town two peaks occur, which are relatively early and late in the day, while in the small village there

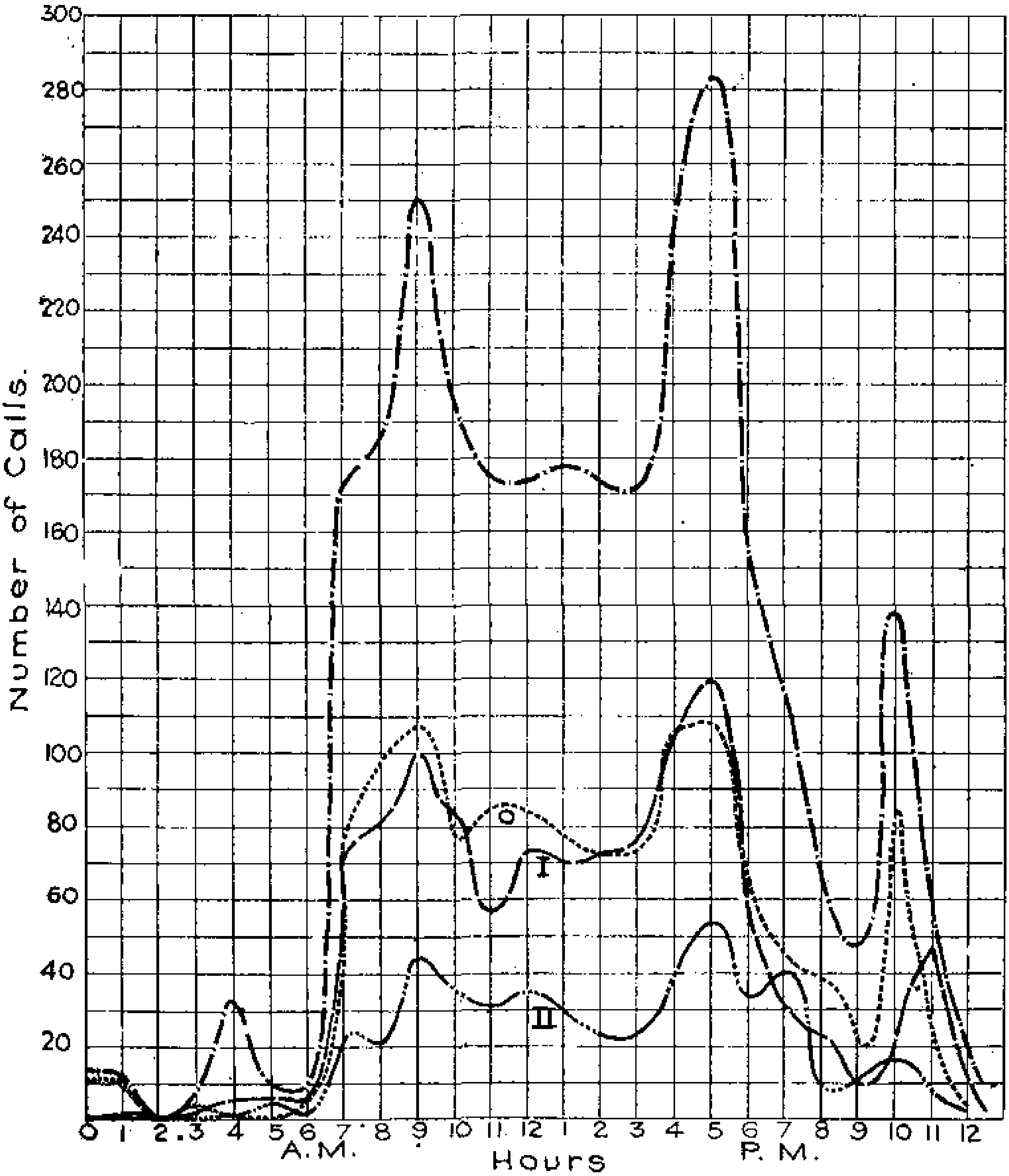


Fig. 153.—Traffic Record, Manufacturing Town Originating Calls.

are three distinct peaks, one in the morning and two after noon, the one at 2.30 P. M. being the highest.

It is instructive to transform the preceding diagrams, which show total originating calls, in such a manner as to show calls per line. In diagram 155 this transformation is performed for diagram 158. The salient change is the difference in the relative heights of the curves in the main office and the subsidiary offices, for when the loads are plotted in calls per line there is a far less proportionate difference than that which seems to be indicated by the total load lines. In Fig. 156 a similar transformation is made for Fig. 151, and here the change in the relative ordinates is still more marked.

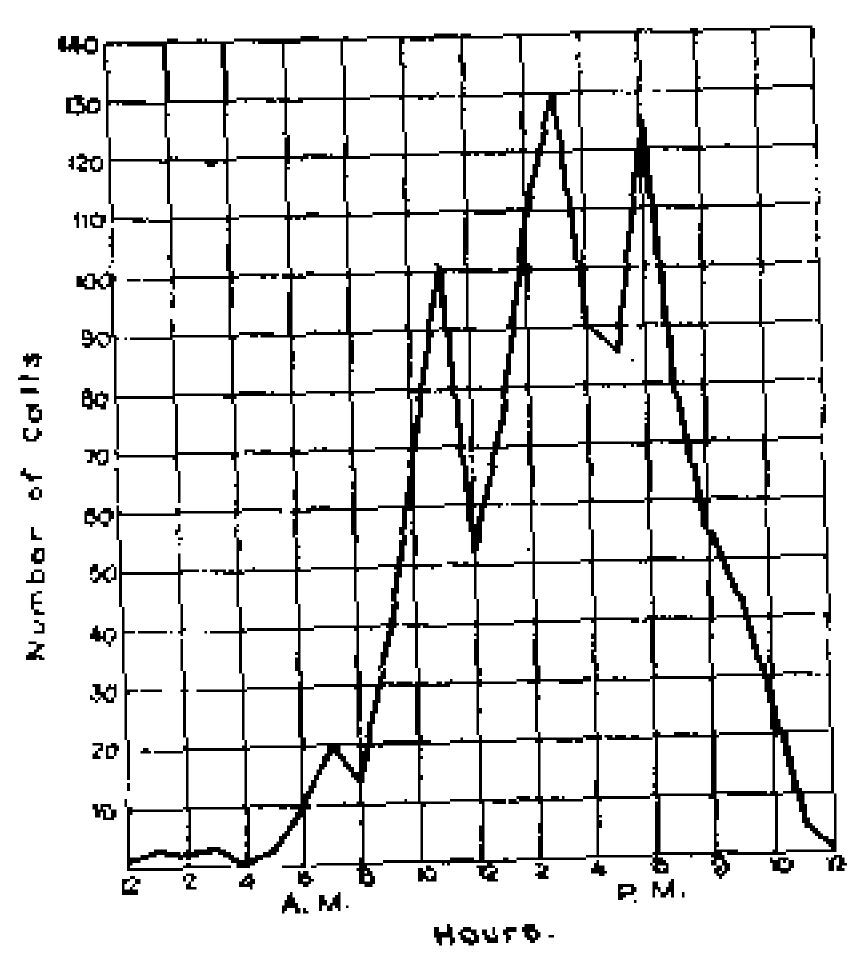


Fig. 154.—Traffic Record, Small Village Originating Calls.

Statistics showing unit loads are valuable both to the general manager as indicating whether the exchange is working at proper loading or not, and also to the engineer as affording data whereby the equipment can be proportioned. In diagrams 151 to 163 inclusive, various operating statistics are set forth. All of these are constructed upon the same plan. Upon the left hand of each sheet a percentage scale is placed, the total number of returns being taken as 100 per cent. On the bottom of each sheet is a scale denoting the number of calls. The use of these diagrams is best indicated by an example. Fig. 157 gives the operator's load for subscribers' positions in a large city. The full line, No. 1 curve refers to operators handling flat-rate service, while the dotted line No. 2 to those handling

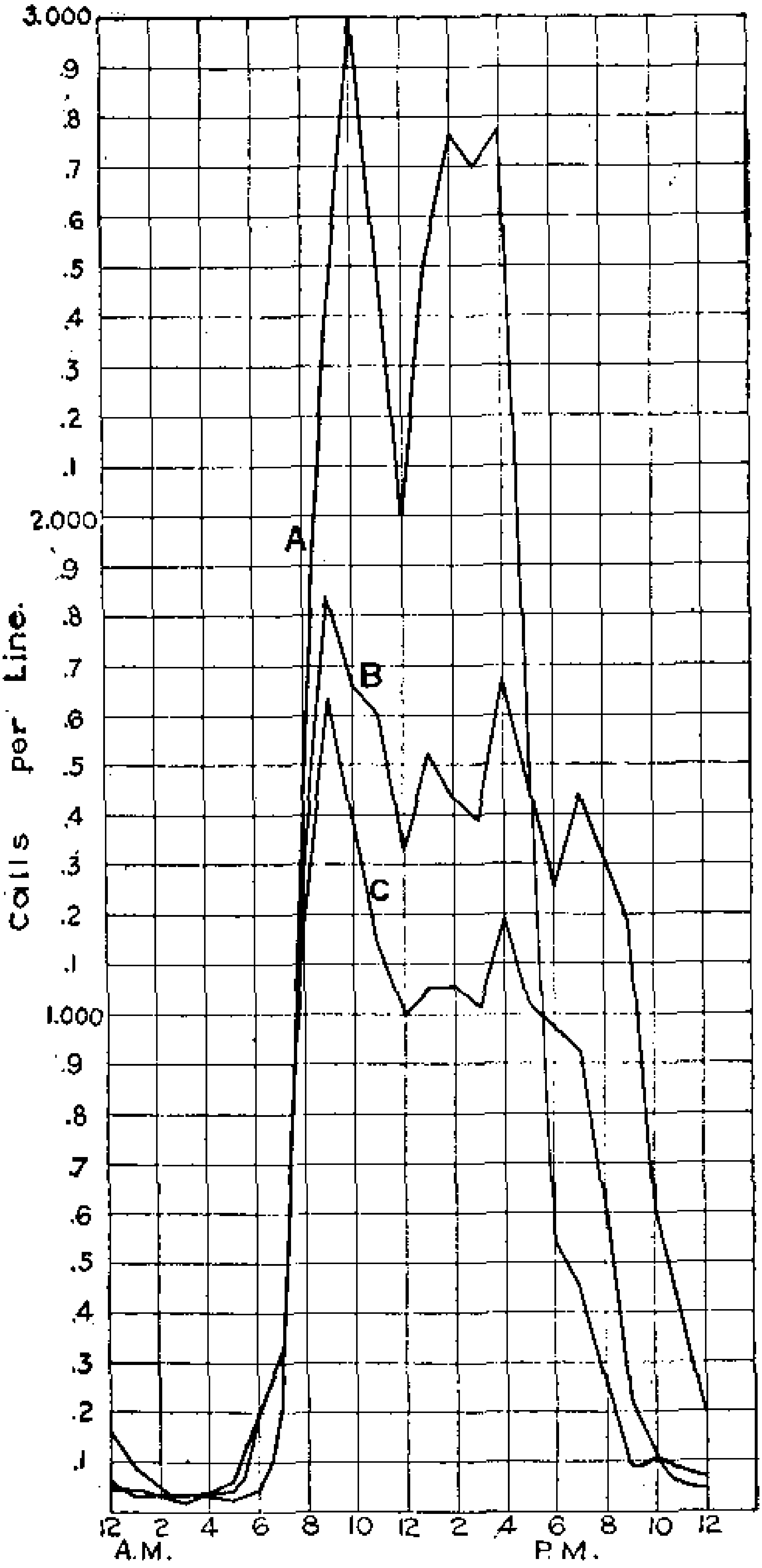


Fig. 155.—Originating Calls per Line Large City.

measured service. The lower scale gives the number of calls per day per position.

Take, for example, 1700 upon the bottom scale, follow vertically to an intersection with curve-headed flat rate, No. 1, then a horizontal to the left-hand scale finding 55 per cent; this means that 55 per cent of operators handled

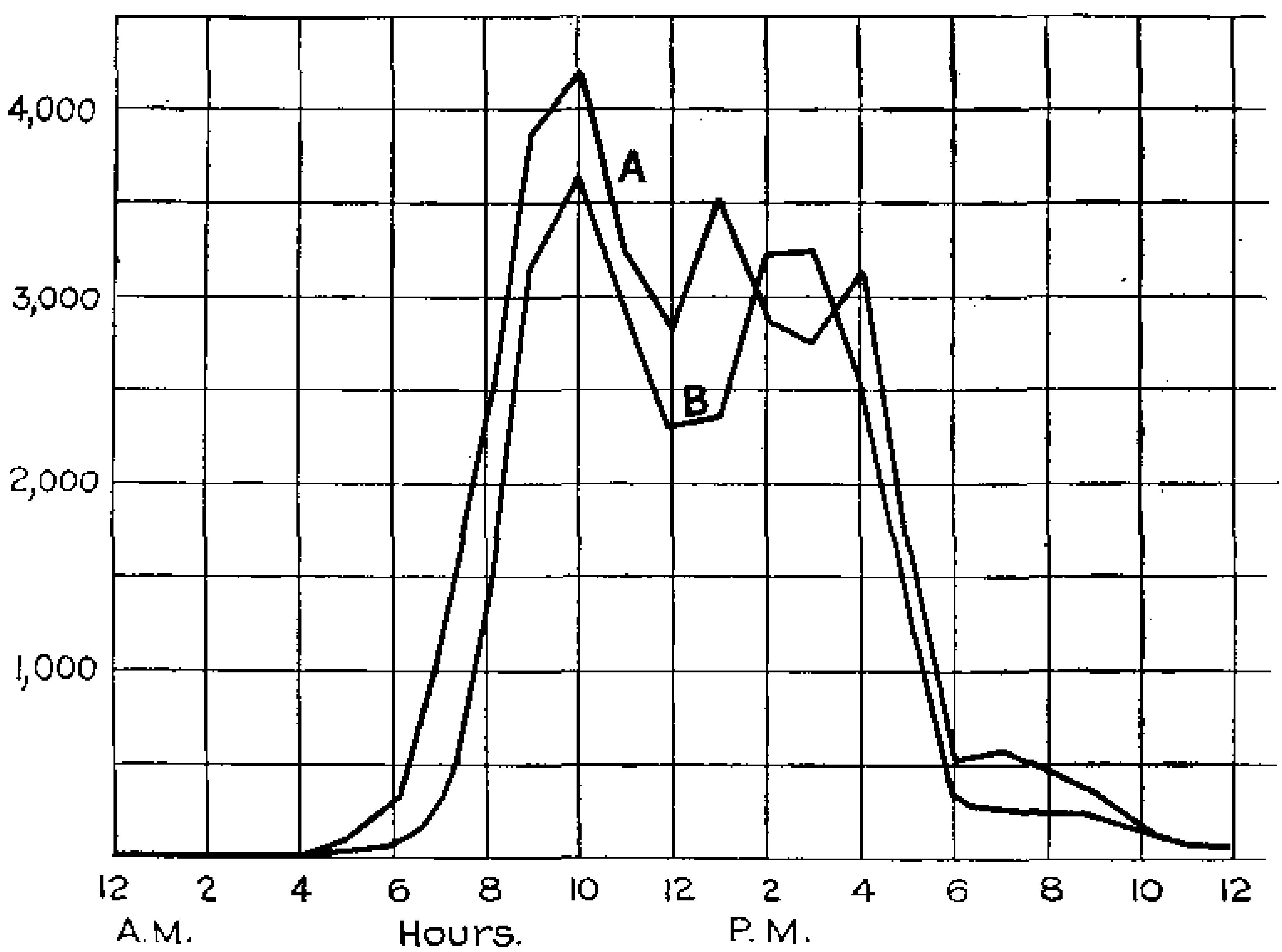


Fig. 156. Local Diagram Medium City Calls per Line
A. Main office in business district. B. Office in mixed residence and business district.

1700 or more calls per day, and 45 per cent handled 1700 or less calls per day. Again selecting 2100 upon the bottom scale and following a vertical to the same curve, it is seen that 9 per cent of the operators handled 2100 or more calls, and 91 per cent 2100 or less calls per day. Curves Nos. 3 and 4 are plotted in the same manner to the same scales, but give respectively the number of calls handled during the busiest hour of day. Curve No. 3 refers to flat-rate position, and curve No. 4 to those handling measured service. These curves are interpreted in the same manner.

Upon the top of sheet 157 is a percentage scale which

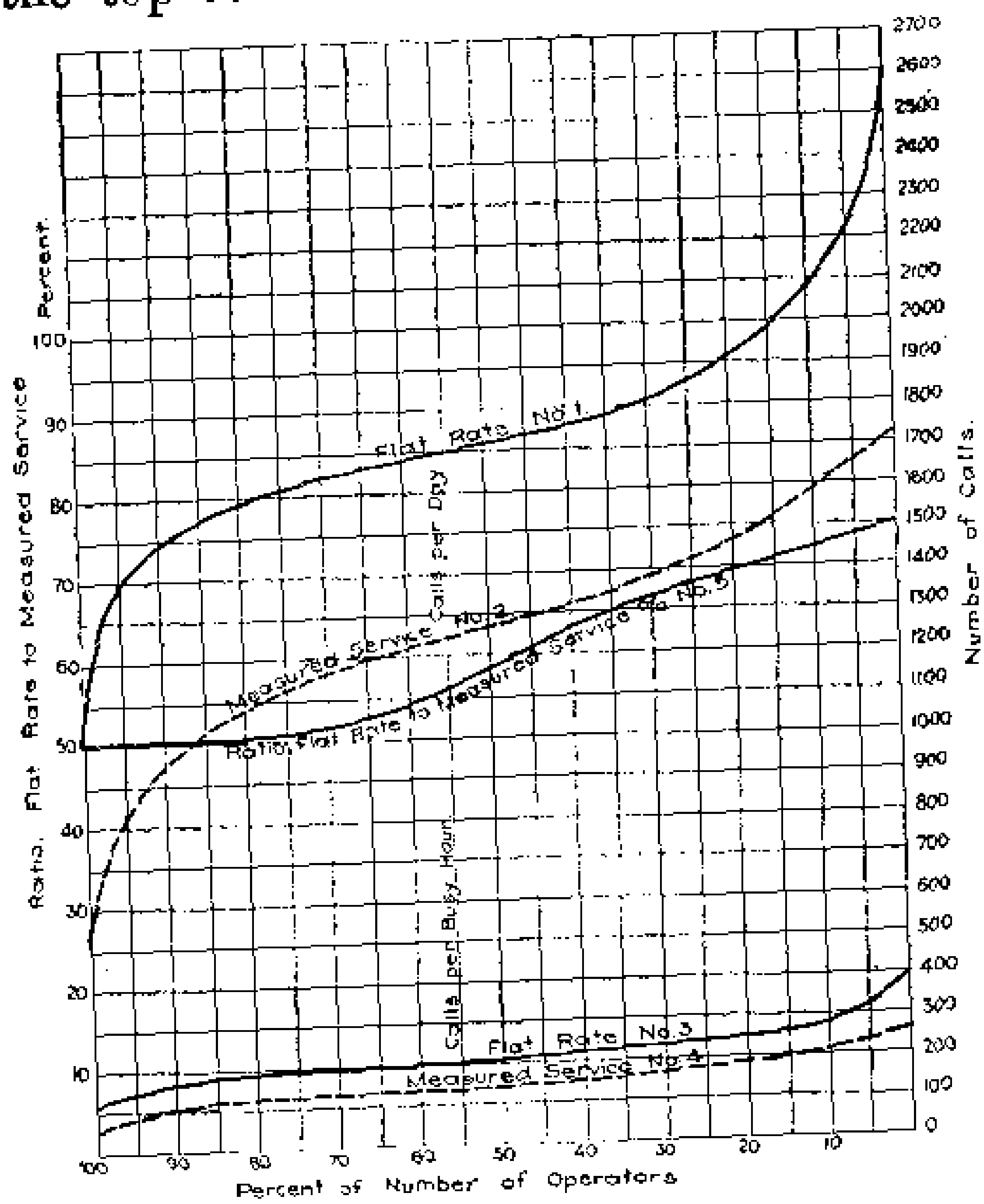


Fig. 157.—Operators' Load.
Subscribers' Positions, Large City.

refers to curve No. 5, showing the ratio between the loads of measured-service operators and those handling flat-rate subscribers. For example, taking 40 per cent on the left-hand scale, and following a horizontal to curve No. 5, and thence a vertical to the top of the sheet, 67 per cent is found, meaning that 40 per cent of the operators, working on measured-service positions, handled more than 67 per cent as much traffic as the operators at flat-rate positions, and 60 per cent of the operators handled less than 67 per cent at many calls.

The titles of the succeeding diagrams, 158 to 163 inclusive, are sufficiently explanatory of the statistics which

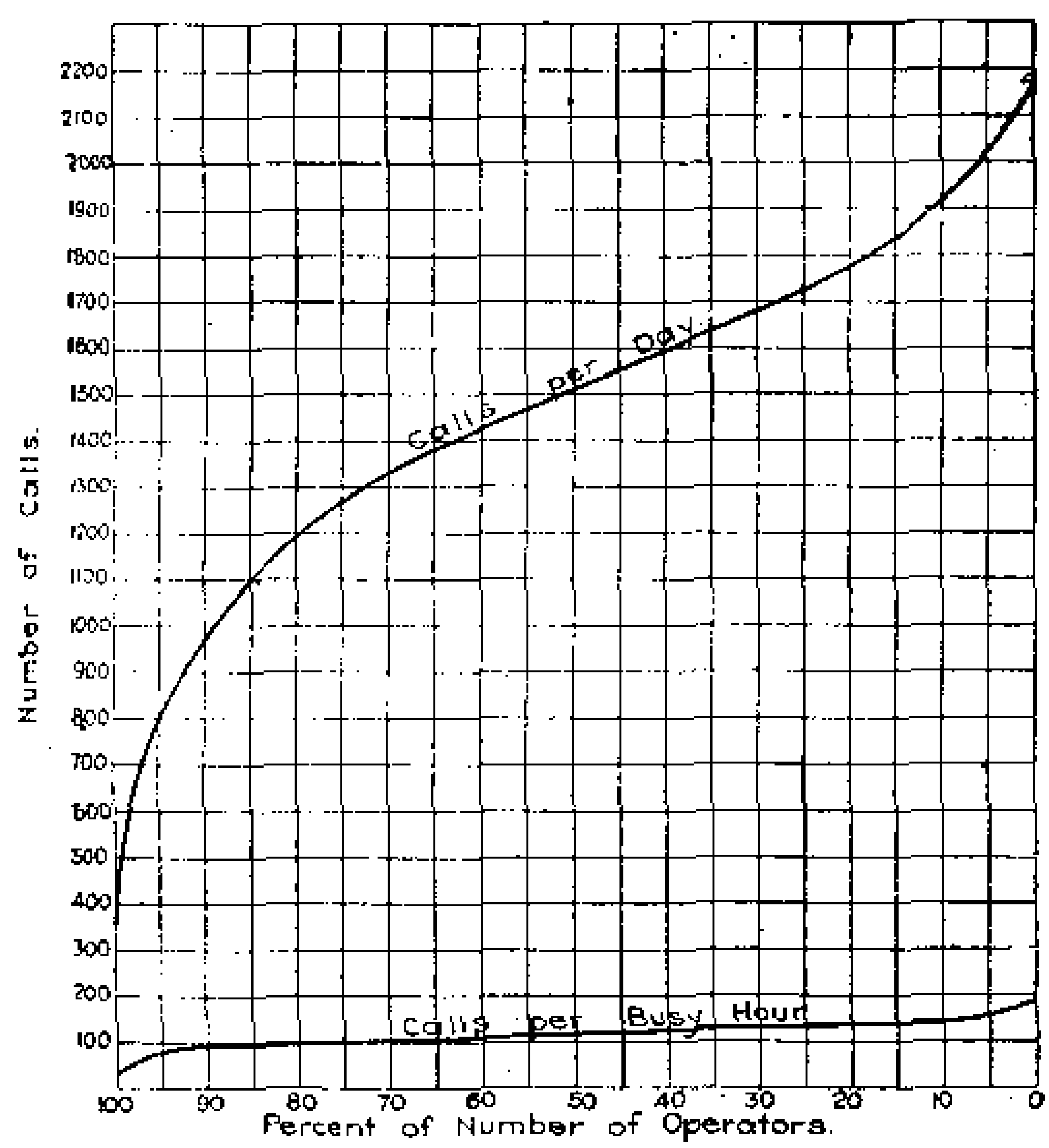


Fig. 158.—"A" Operator's Load. Subscribers' Positions, Party Lines.

they set forth — all are to be read in the same manner. No. 158 deals with operators' loads working at positions equipped with party lines. By comparing the data here given with No. 157, the so-called "drag" due to complex ringing and other causes inherent to party-line operating is clearly evidenced. Nos. 159 and 160 are respectively:

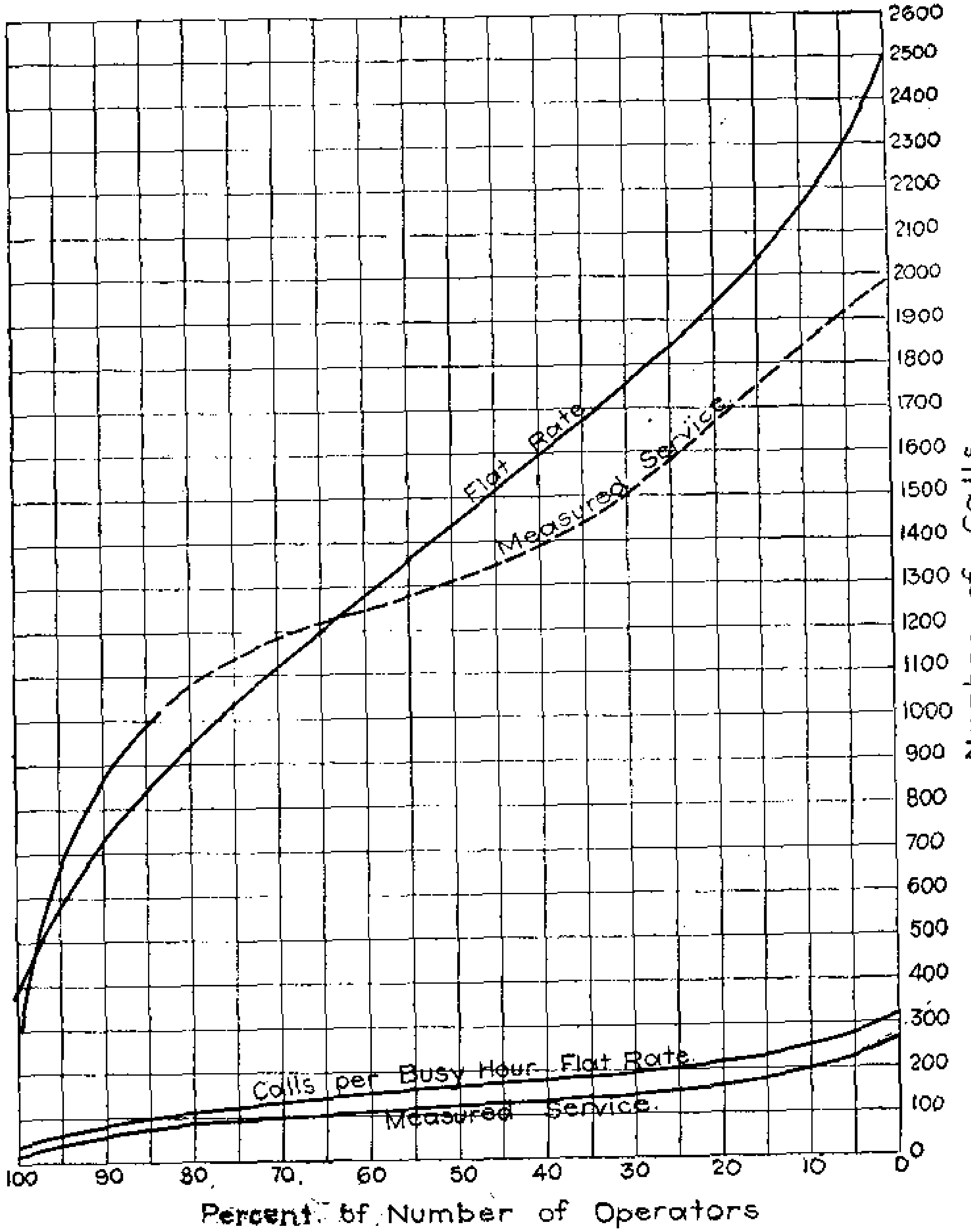


Fig. 159.—"A" Operator's Load.
Subscribers' Positions, Flat-Rate and Measured Service in Medium-Sized City.

An operator's load in medium-sized cities, and small villages. Curves are given for total daily load and for the busy hour. A comparison between Nos. 157, 159, and 160 shows at once a rapidly decreasing efficiency. This is partly due to less efficient apparatus in smaller commun-

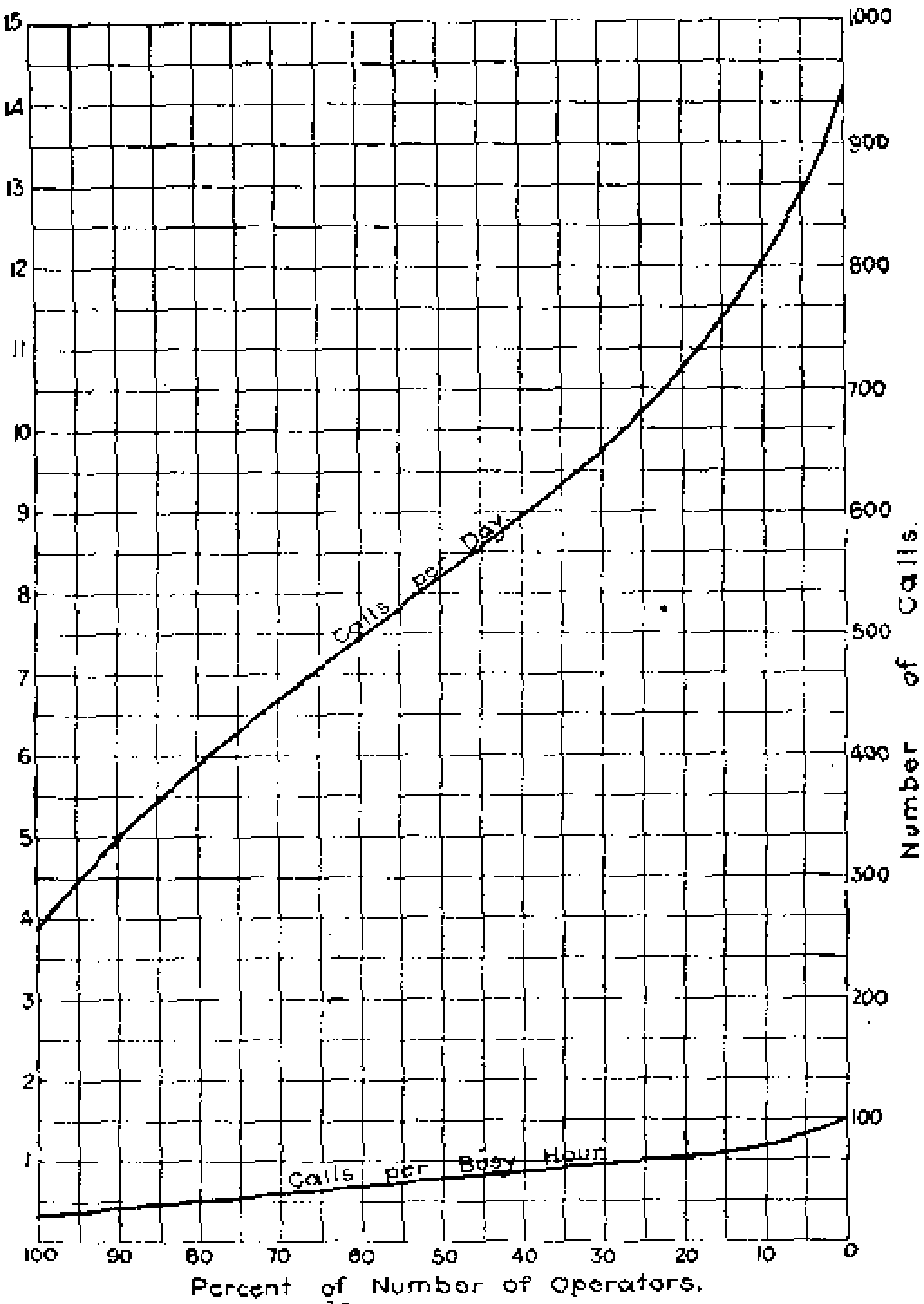


Fig. 160.—"A" Operator's Load.
Subscriber's Position, Small Town Flat Rate.

ities, partly to poorer discipline, partly to less systematic training and partly to the nature of the load imposed. Diagrams 161 and 162 deal with the loads carried by trunk-line positions. No. 161 refers to large cities and No. 162 to medium-sized ones. Towns and villages are too rarely equipped with more than one office to make their statistics of trunking of value. No. 163 gives the trunk circuit loads

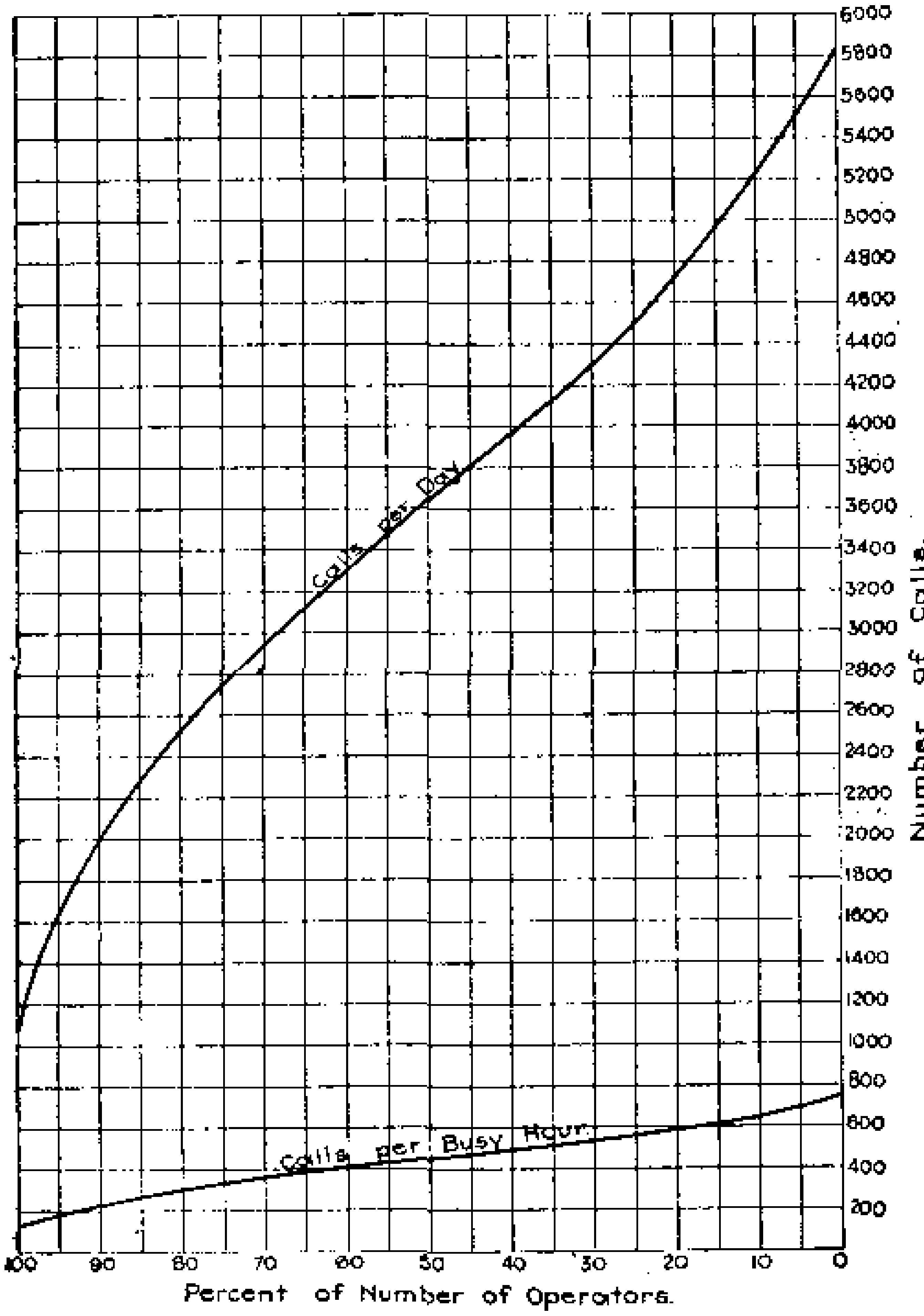


Fig. 161.—"A" Operator's Load. Trunk Positions in Large City.

that experience indicates permissible and the ratio between total daily load and that of the busy hour.

One of the most important uses of the peg count is to determine the distribution of work over the switchboard.

Fig. 164 is taken from a peg count in a medium-sized city and shows the first three positions of the switchboard. In the busy hour, No. 1 handled 338 messages, No. 2, 219; and No. 3, 162. During the 24 hours, No. 1 took 2039

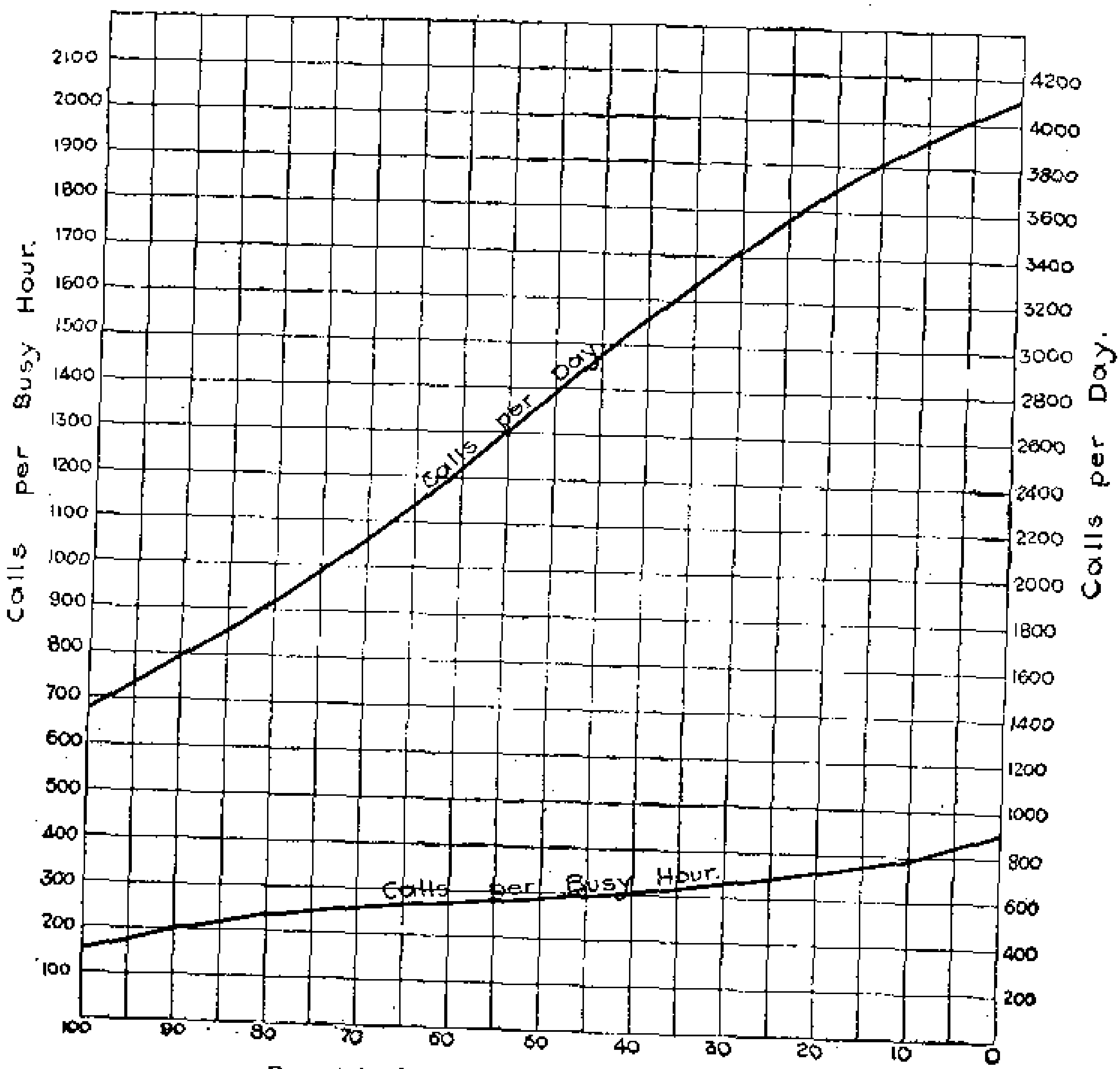


Fig. 162.—"B" Operator's Load.
Trunk Calls per Position in Medium-Sized City.

messages, while No. 2 and No. 3 jointly 2333, or a little more than half. Such a condition is deplorable, for either No. 1 was overloaded and required to do more work than could be adequately performed to give good service, or else No. 2 and No. 3 were underloaded, and nothing is more injurious to a uniform highest standard of service than unequal loading. The astute manager on discovering such conditions would immediately repair to the distributing board, and so rearrange the lines terminating in the several positions as to more nearly equalize the load over

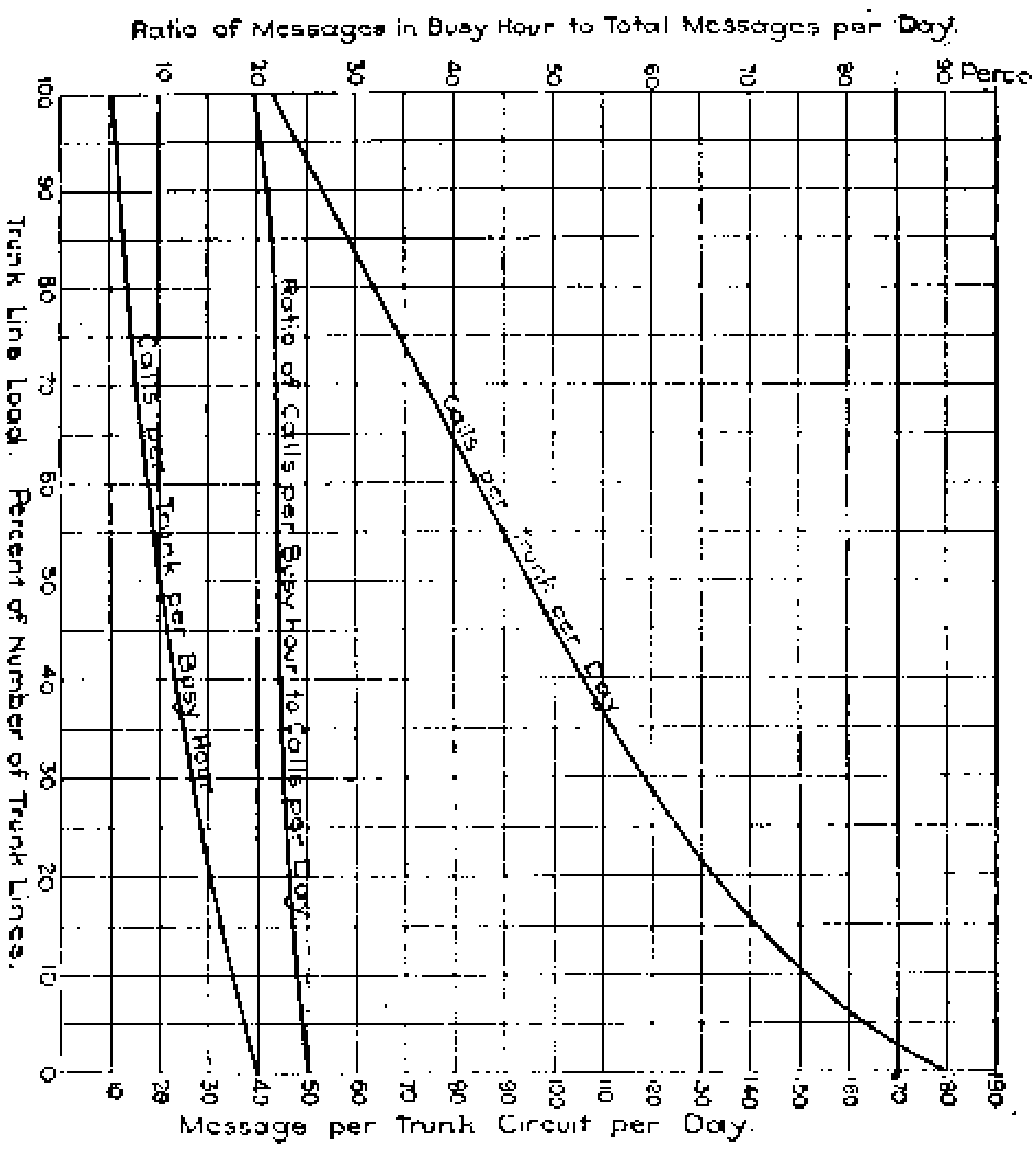


Fig. 163.—Trunk Line Load.

the three operators. It is, of course, possible that such a condition is due to exceptional conditions on the particular day of the peg account. To determine this, the three positions should be carefully watched for some time, and if similar results recur, a rearrangement of the lines is necessary.

A telephone plant has one marked peculiarity; it has no inertia. When a subscriber calls, he must be answered upon the *instant*; it is impossible to store up his message and handle it at leisure, and consequently at best the work of every position fluctuates from minute to minute with the most alarming irregularity. In the various diagrams the total number of calls per day is plotted together the number of calls in the busy hour. These statistics show that from 8 per cent to 15 per cent of the total traffic of the day takes place during that period. Indeed the study of a large number of peg counts tends to the belief that this ratio is a very uniform one, and that by counting the calls during the hour of the peak, and multiplying by eight, one can always arrive at a very close approximation to the total traffic.

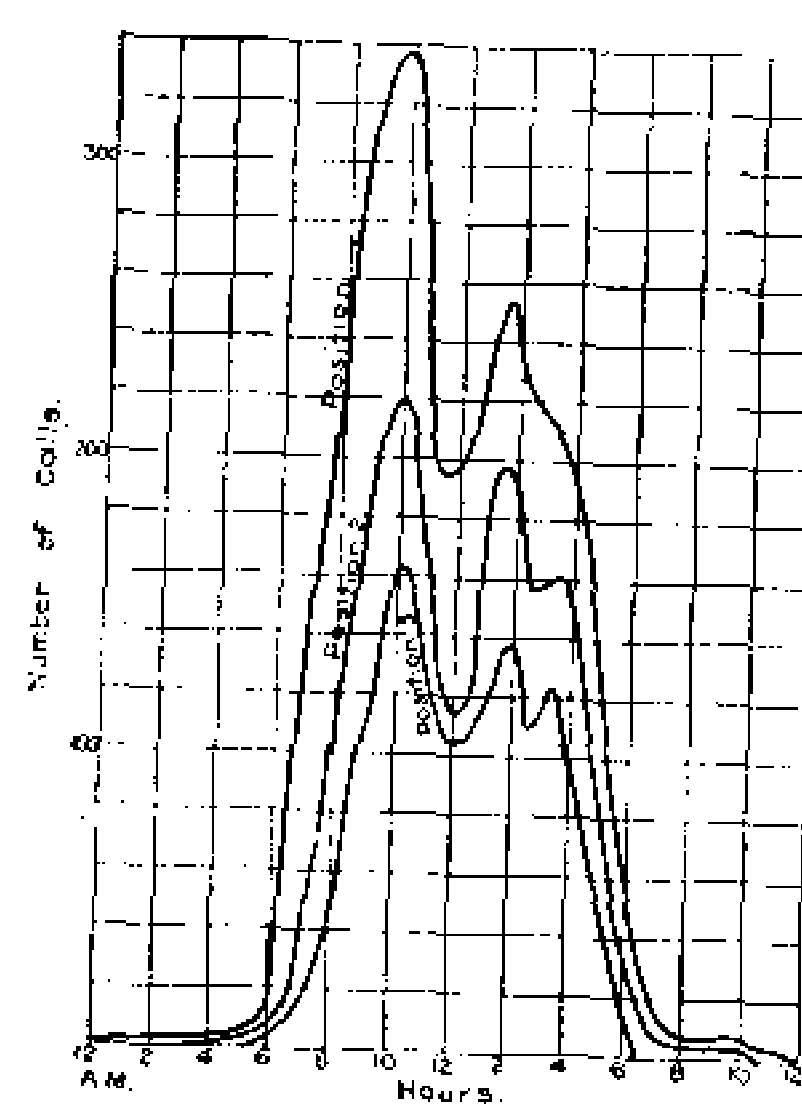


Fig. 164.—Relative Position Loads.

If some means of equalizing the load line could be devised, the operator's task would be rendered much easier and a notable reduction in operating expense secured.

A great many plans have been offered in the hope of securing some regulation of the line load. Most of these have attempted a solution by providing a certain number of reserve operators to which calls were to be transferred during rush of business. In fact all the various forms of "divided switchboards," "transfer systems," "express boards," and "overflow operators," are efforts in this direction. So far, however, little permanent success has attended these attempts, for the additional complications in the switchboard and methods of operating, together with unavoidable decrease in speed has cost more than it came to.

Theoretically an operator's capacity is limited to the number of calls which she can handle and not delay the call of any subscriber beyond a prescribed limit.

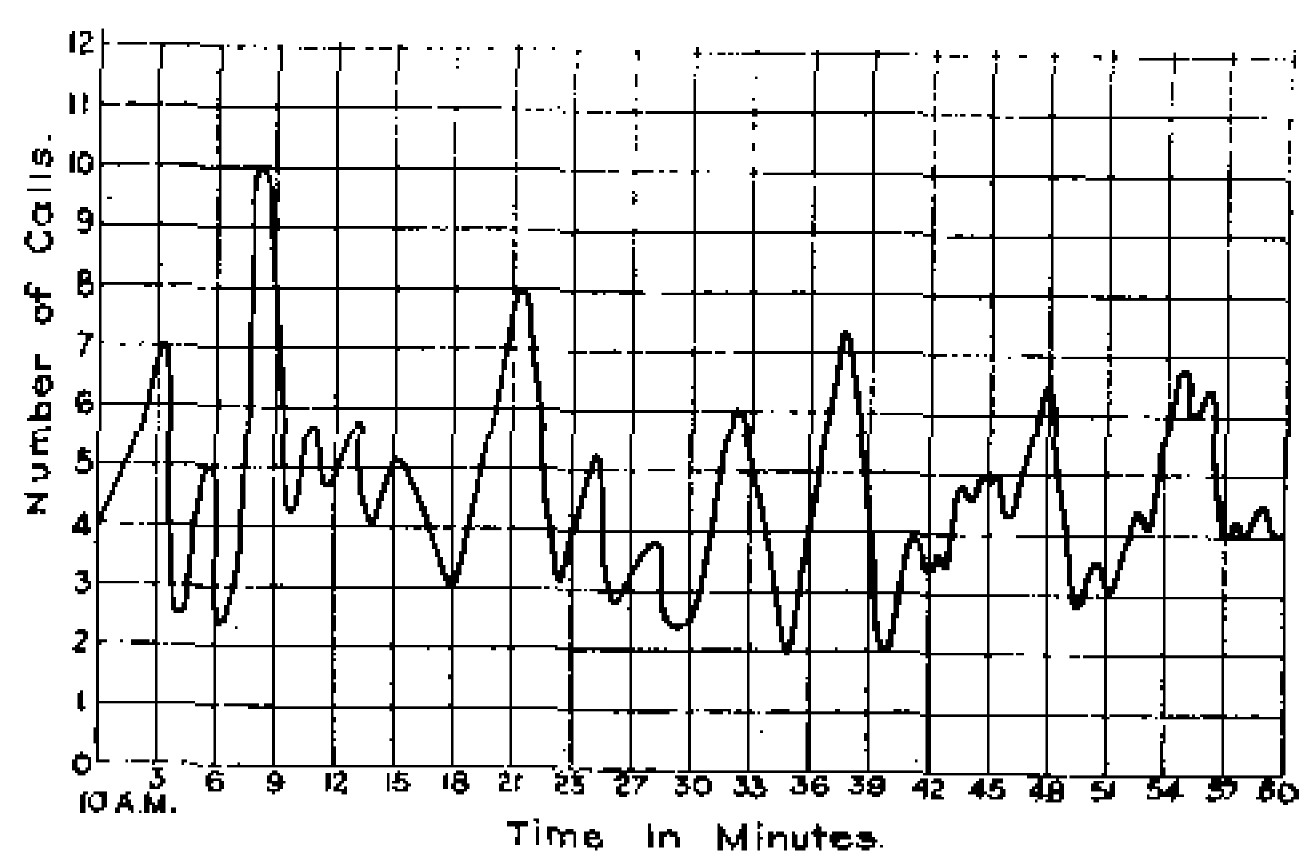


Fig. 165.—Hourly Local Variation.

Some telephone companies assume to give what is called three-second service, that is to say, the operator answers the subscriber within three seconds from the time the receiver has left it, but while such service is frequently claimed, impartial and thorough tests show it is rarely secured. Five-second service is tending to become a so-called standard, while an average of eight-second service during the busy hour is considered permissible. So if the capacity of the operator is limited to the number of calls each one can handle alone without keeping subscribers waiting, operators must be very lightly loaded. Fortunately, however, in what is called "team" work there is a remedy. Operators are seated side by side in such proximity that it is not difficult for neighboring operators to help each other. It is rare to find three positions simultaneously rushed, and so if the operators are adequately trained, each one will help out her neighbors on either side

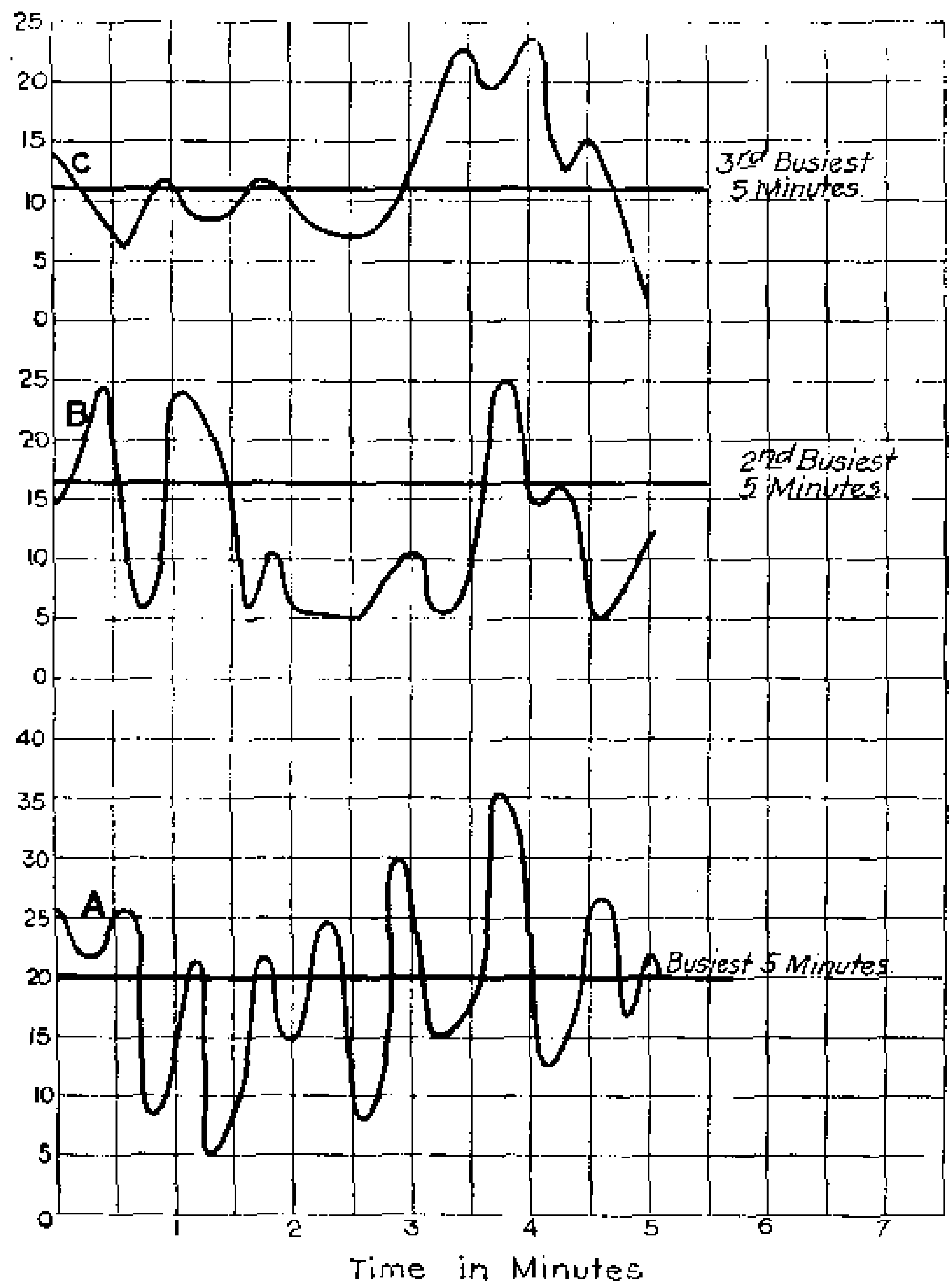


Fig. 166.—Variation of Load by Minutes.

during every rush. By this means a far greater number of lines can be placed before each operator, and still give satisfactory service, and it is impossible to lay too much emphasis upon the value of the most systematic and thorough training in cultivating this method to securing a high uniform average of work, and to maintain the quickest and most satisfactory service. Not only does the load line vary from time to time in the day, as is clearly shown by diagrams Figs. 150 to 154, inclusive, but it fluctuates from minute to minute with the most trying irregularity. Fig. 165 is a load line for a busy hour plotted by twenty-

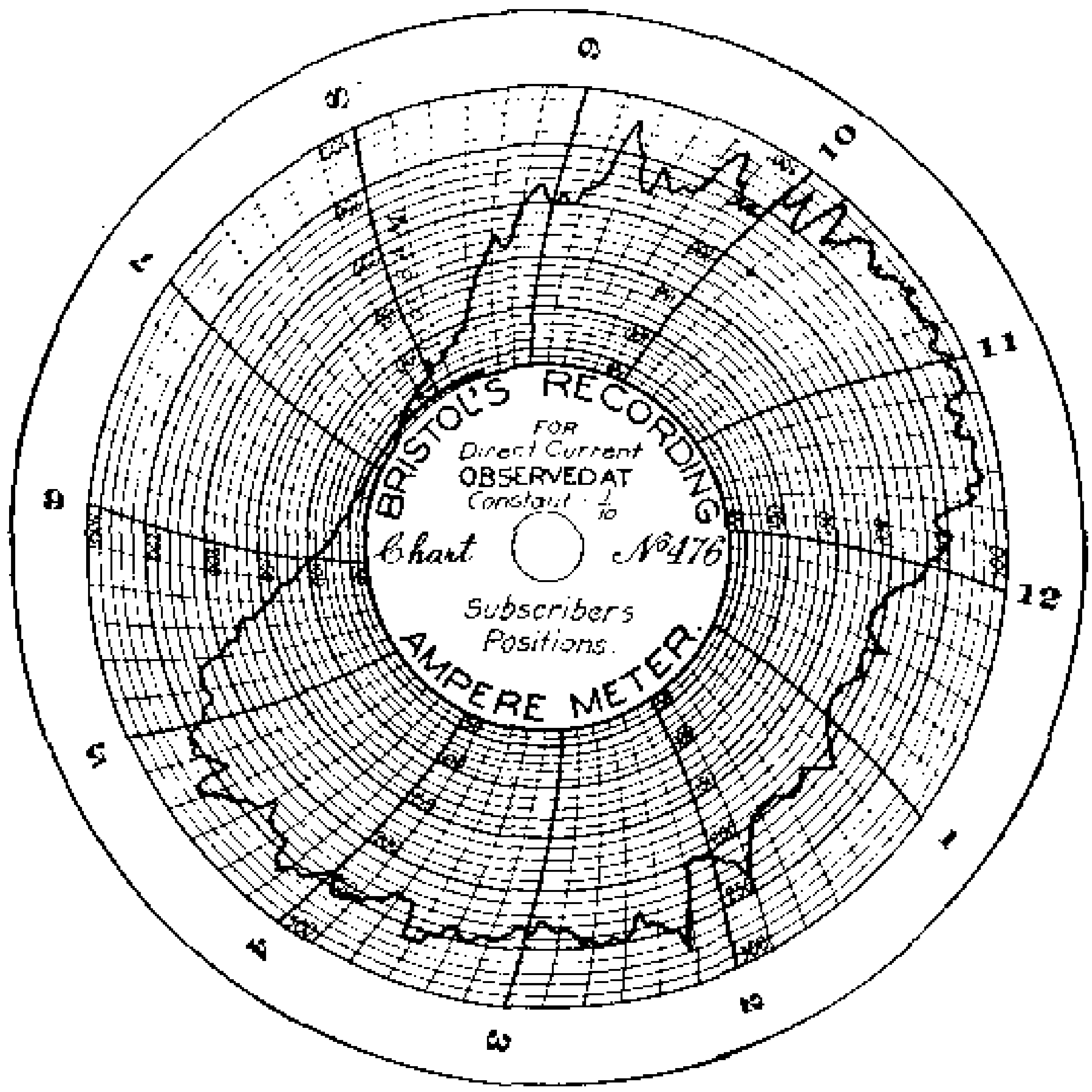


Fig. 167.—Automatic Load Line. Subscribers' Positions.

second intervals. This curve gives some idea of the "rushes" to which all operators are subjected, but the diagram can carry no conception of the nervous strain that such irregularity produces. At one time messages were arriving at the rate of 24 per minute or 1800 per hour; at another time 30 per minute or 1440 per hour. Could such speed have been maintained and the load uniformly spread over the entire twenty-four hours, one position could care for 43,000 messages, whereas it is rare for one operator to take 2500 calls per day. The average rate is 4.2 calls per minute or 2500 calls per hour. This is rapid work, yet the diagrams show that about 1 per cent of operators exceed even this.

In Fig. 166 three curves are shown, giving an analysis by minutes of the work of a busy operator on an automa-

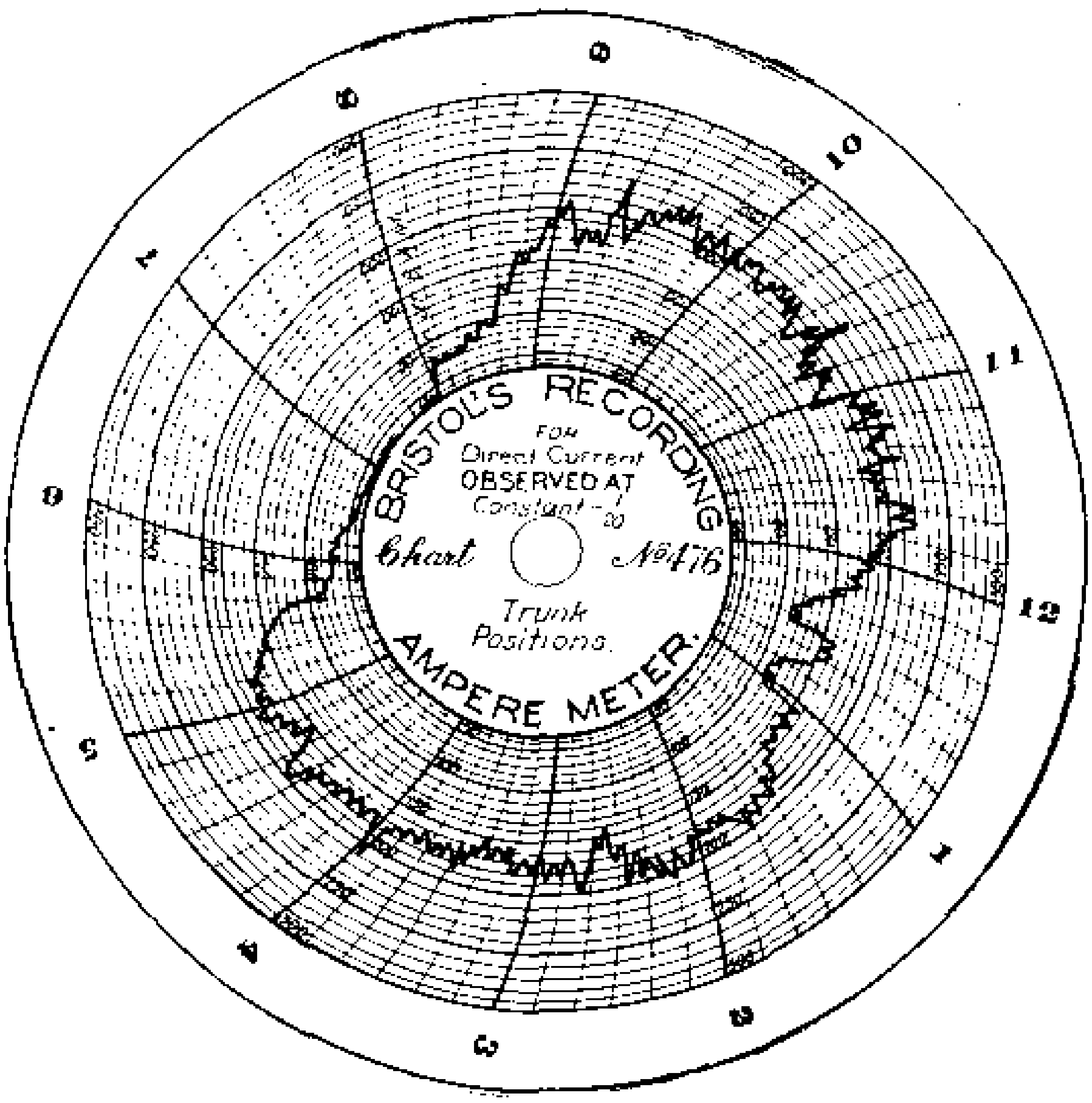


Fig. 168.—Automatic Load Line. Trunk Positions.

tic signal switchboard. Curve *A* curves the results of the busiest five minutes of a busy hour. Curve *B* the second busiest, and Curve *C* the third busiest. From Curve *A* it will be seen there were nine rushes, three of which caused the operator to work at a rate of 23 to 35 messages per minute; one at the rate of 26; one at 30 and one at 36

— equivalent to 2160 messages per hour, or over 50,000 messages per day. The average rate for the busiest five minutes is 20 calls, equal to 1200 calls per hour, or 28,800 per day. From Curve *B* it is seen that the second busiest five minutes there were three rushes, of 24 to 25 calls per minute and an average rate of 16 calls per minute, while Curve *C* shows only two distinct rushes of 22 to 23 calls, with an average of 12 calls a minute.

Some telephone companies employ a method of checking peg counts which has been denominated a "plug" count. This is accomplished by counting at short intervals, from 5 to 10 minutes, the number of answering jacks which contain plugs. From such records the approximate average number of plugs in actual use for each hour of a given 24 hours is readily obtained. From the peg accounts it is easy to find a ratio between the average number of plugs in place and the number of originating calls per hour. Of course, this method is open to the objection that it is based upon the thing that is to be determined. Nevertheless, when checked by considerable experience it may be made to yield fairly accurate results.

A still better method, but which is limited to common battery switchboards, involves the use of an ammeter to measure the current which is delivered to the switchboard. It is obvious that during each call the subscribers are consuming a certain amount of electricity, and if the average length of conversation be known and the total current measured from time to time, the rate at which the switchboard is working can be determined. So it follows that a recording ammeter placed in the leads to such a switchboard will give a diagram, whose ordinants, multiplied

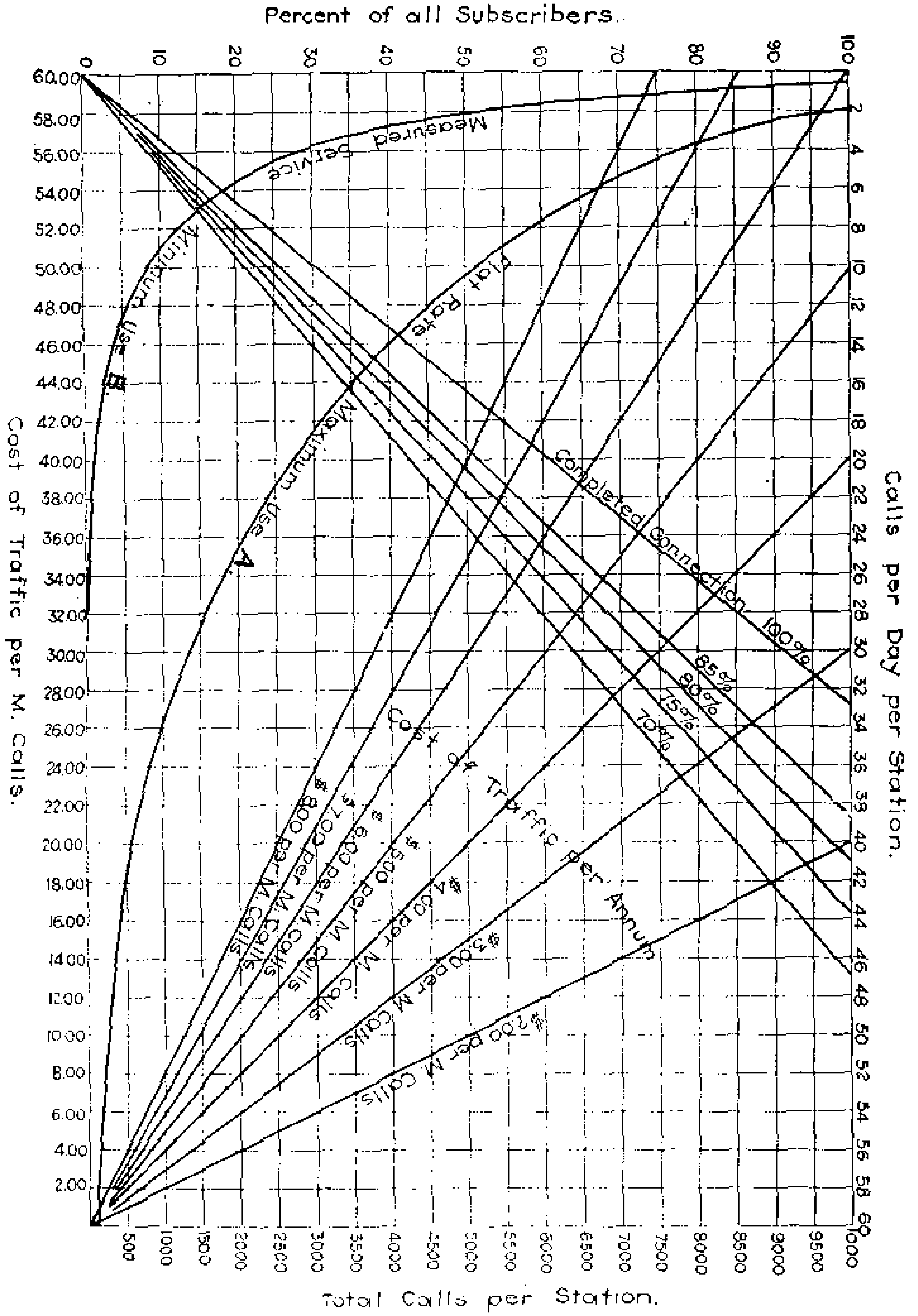


Fig. 169.—Probable Use of Telephone.

by a proper constant, will show the number of connections from hour to hour.

Fig. 167 is such a diagram given by a recording ammeter in the circuit of the subscriber position of a common battery load swing, about three thousand subscribers in a large city. Fig. 168 is a similar record for the trunk positions. As the shunt was removed from the ammeter the true value of the current ordinates is obtained by multiplying the scale readings of the chart by $\frac{1}{10}$. For this particular case a comparison with the peg counts showed that each cord demanded .218 amperes, and the average length of conversation was 110 seconds, hence the number of cords in service at any time is found by dividing the corrected current ordinate by .218, while the number of calls per hour is found by dividing the current ordinate .0057. The expense of the recording ammeter is so small compared with the value of a continuous traffic record, that this method deserves a wider adoption.

While the peg count provides general information regarding the operation of an exchange, modern practice goes still further and is continually studying the individual idiosyncrasies of traffic, in order to determine the needs of the subscriber and to maintain a constant check upon the conduct of both subscriber and operator. This is done by providing special traffic clerks who are experienced stenographers, and a set of inspectors, whose duty it is to constantly make service tests. The traffic department is fitted up in such a manner that any subscriber's line may be switched to a desk provided with a listening telephone. A traffic clerk is equipped with a head receiver and is instructed to listen upon the subscriber's line, perhaps for days at a time, and to make a complete record of all transactions that occur. Such a record is necessary in all cases of special service and to determine to validity of complaints. Subscribers frequently aver that their line is constantly reported busy, and an inspection of this kind determines at once whether the allegation has foundation or not, and either enables the general manager to refute the complaint or to point out to the subscriber that his telephonic business is too great for his facilities and that the only remedy is the introduction of another line or a private branch exchange. This method further enables the manager to keep an unsuspected watch upon operators and to ascertain whether their conduct at the switchboard is such as conforms to the rules of the exchange and is proper and decorous toward the subscribers.

An important function of this record, particularly in exchanges that offer measured service based upon the number of completed connections, is the determination of the percentage of busy calls, or those which cannot be charged.

The following table is a record from an exchange in a large city, showing by various offices the number of busy calls at different times during the day:

Hour.	Designation of Office.									
	A	B	C	D	E	F	G	H	I	J
8 – 9 A.M.	18	13.6	20.46	17.8	12.4	15	19	09	16.3	23
9 – 10	25	23.4	13.42	19.5	17.6	21	21	12	24.0	31
10 – 11	22	21.4	23.50	16.8	14.0	21	20	11	21.1	21
11 – 12	19	23.0	16.03	18.8	12.7	26	17	15	19.1	21
12 – 1	14	14.5	8.76	11.8	13.2	13	08	11	17.1	11
1 – 2 P.M.	19	19.6	12.92	14.1	13.0	14	15	06	13 7	23
2 – 3	19	14.5	18.38	12.4	16.2	20	16	14	23.2	28
3 – 4	22	22.6	16.10	15.7	15.5	18	15	20	20.2	21
4 – 5	22	21.0	16.40	15.6	15.6	18	18	14	21.4	15
5 – 6	15	13.7	12.99	15.1	11.4	15	12	13	16.8	16
Total	20	19.3	16.38	16.1	14.4	19	17	13	19.7	21

Knowing the amount of traffic that an exchange is likely to receive, the data in diagrams Nos. 157 to 163 inclusive will enable the engineer to determine the size of the switchboard and number of trunk lines. But to estimate the amount of probable traffic is the most difficult problem, for the number of originating calls depends on complex local conditions that must be determined for each case by itself. Fig. 169 gives two curves that may be used to determine the probable use of the telephone. The left-hand scale is the per cent of the number of subscribers; the top scale the number of originating calls per station per day. Curve *A* applies to flat rate or probable maximum use of the telephone; curve *B* to measured service or minimum use. For example, 60 per cent of flat rate subscribers are likely to make eight calls or less per day, and 40 per cent eight calls or more; while 40 per cent of measured service subscribers will probably make less than two and one-half calls per day, and 60 per cent more than two and one-half. Two sets of diagonal lines are added to this chart to enable the annual cost of traffic per station to be determined. The curves running to the lower left-hand corner show the percentage of completed connections; those to the lower right-hand corner the cost of traffic per thousand calls. The right-hand scale gives the total calls per station per year, and the bottom scale the annual traffic cost.

EXAMPLE. — What will be the number of calls and annual cost of traffic from a station originating 16 calls: 80 per cent completed connection; cost of traffic $5.00 per thousand calls. From 16 on top scale follow a vertical to line from left-hand lower corner headed 80 per cent, thence a horizontal to line from lower right-hand corner headed $5.00, thence a vertical to bottom scale finding 18.80 cents.

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