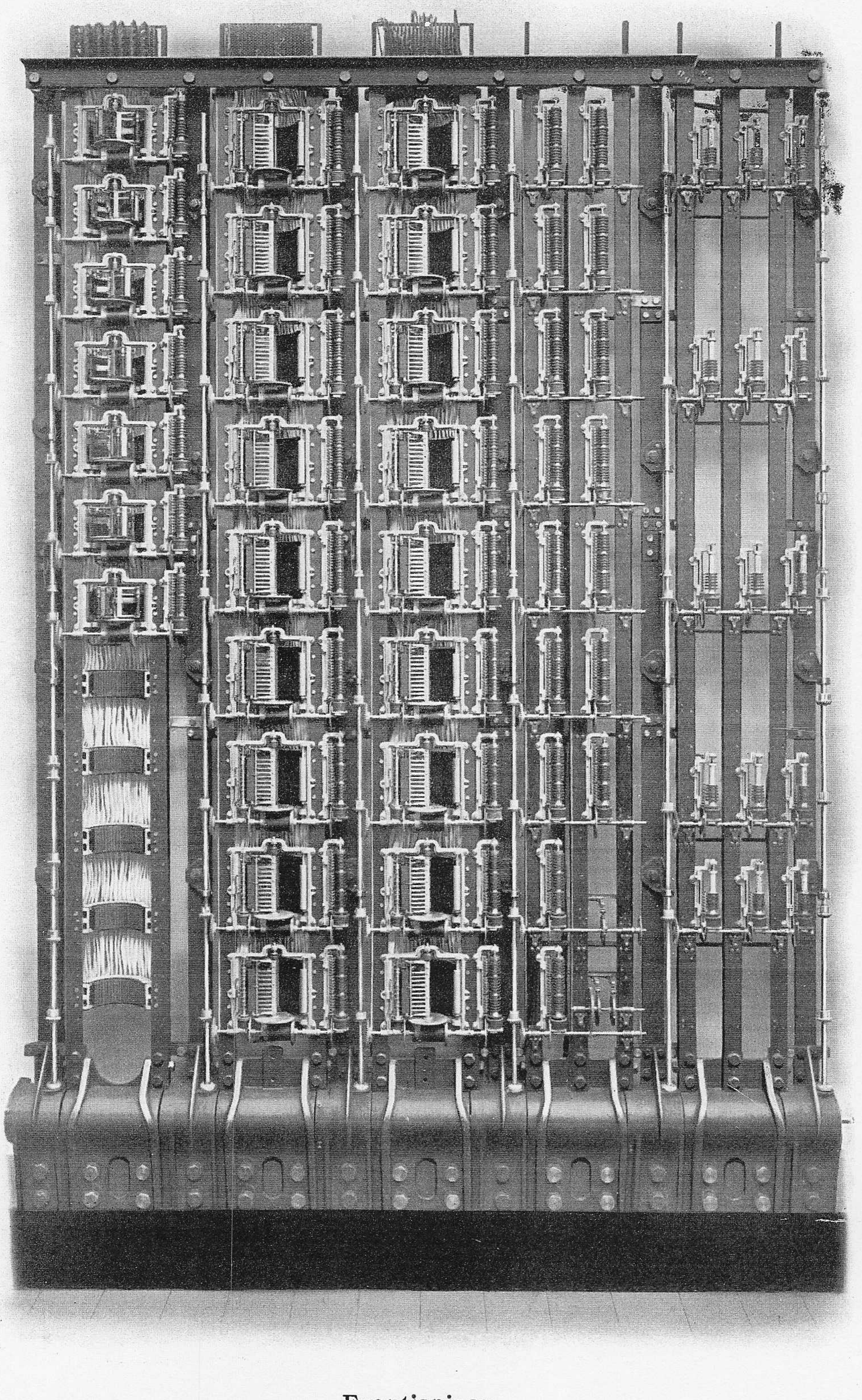
Western Electric Machine Switching System

Western Electric Company Limited.
London.



Frontispiece.

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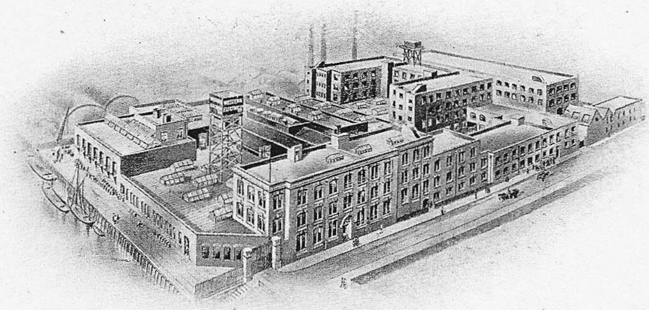

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THE WESTERN ELECTRIC MACHINE SWITCHING SYSTEM.

PART I.

INTRODUCTION.

The Telephone Machine Switching System brought out by the Western Electric Co. after 14 years of investigation and development work, represents the most notable advance made by the Company in the evolution of the telephone switching problem since the well-known Common Battery System, now generally used and adopted as standard, was brought out in 1896.

The Machine Switching System in its present form, uses switching machines of novel design to perform switching operations now done by hand, while introducing new and desirable operating features, looking towards the improvement of the service to the subscriber, and the reduction of operating expense. Many of the features of the Common Battery System, which have withstood successfully the test of time and service have, whenever suitable, been retained in the Machine Switching System, to assure its successful operation.

The Western Electric Machine Switching System permits either full automatic or semi-automatic operation. In its full automatic form, the subscriber sets up his own connection by operating a sender ; on the other hand, in its semi-automatic form, the subscriber passes the desired number to an operator, who presses keys to establish the desired connection. The Machine Switching System also allows both full and semi-automatic operation in the same exchange, and is readily convertible from one to the other.

LINE OF DEVELOPMENT.

In an automatic system for telephone traffic, the characteristic feature will be found, in the logical analysis of the telephone switching problem, to be the division and distribution of the traffic into groups, due to certain imposed practical limitations.

Switching machines, having capacities equal to that of a large exchange, are not practical because of the excessive cost of their construction. Consequently, much smaller switch capacities must be employed, which obviously involve the division of the traffic. The number and size of such groups are, however, controlling factors in determining the number and size of the mechanical switches and their character.

A careful study of the subject revealed that the resulting division of telephone traffic is not haphazard, but follows the well known laws of probability. As a result of an elaborate investigation, in which the behaviour of telephone traffic was carefully observed, a mathematical method was developed for computing and forecasting the probable distribution of telephone traffic under any given set of conditions.

The junction group efficiency problem, which concerns the relation of the number of calls in a group for a busy period and the maximum number of junction lines required to take care of these calls, presented itself among the first to be investigated by the probability charts which were evolved. On the basis of this work, cost studies for large offices were undertaken, presupposing switching machines of different sizes. These studies made it possible to select that most economical size of machine which would make the cost of the exchange a minimum.

It is of great importance to determine the size of selector most economical. An exchange using such selectors costs less than an exchange using fewer and larger but very much more costly selectors, also it costs less than an exchange using smaller and cheaper selectors but in much larger quantities. The Western Electric selector serves 200 lines.

The charts also allowed the investigation of other matters relating to design as affected by traffic density, and, in general, permitted the calculation of the minimum number of selectors required for a given number of lines and traffic. It permits in this way, minimum apparatus to be furnished which shall be just enough for a given traffic, thus avoiding an excess of costly plant as well as a lack of it with the consequent choking of traffic.

TRANSLATION.

These studies showed conclusively that an automatic system, to possess a minimum of machine plant, must allow any predetermined size of selector to be used, and not merely one built on the 10 by 10 or decimal basis. In a system with such non-decimal selectors, subscribers send the number into the machines by a series of impulses on the decimal basis ; clearly, such a series must be rearranged on some other basis if the brush of the final selector is to reach the terminal of the called line located in the selector arc of say 200 lines.

This automatic conversion of a series of impulses from a decimal to a non-decimal basis is known as «translation».

REGISTERS.

The register is a new device in the practical automatic telephone art. It was introduced in the system to accomplish a variety of purposes, mainly among these, the concentration of the control of the switching machines. It plays an important part in the operation of the system.

The register is a mechanical device which receives and stores the impulses as they are sent out by the subscriber's sender, or which records the number depressed on the operator's keys. It then controls the various selectors in their motion towards the terminals of the line wanted.

Registers perform other important functions. They send out the impulses, properly timed, so that all mechanisms concerned in the establishment of the connection are able to work at their highest speed. If a group of junctions should be busy, the register will wait, until an idle junction is found and only then proceed with the building up of the connection.

They made possible the « reverse impulse control » method for setting switches, to be referred to later on, which combines high accuracy with speed in selectively controlling switches.

They permit automatic systems of widely different types to work together accurately.

They readily permit « carriage call » or the setting up of a visual number before a manual B operator, who is to complete connections to a manual subscriber.

They not only translate series of impulses from a decimal to a suitable non-decimal basis, but convert the name of a depressed office key into the corresponding number.

FULL AUTOMATIC OPERATION.

In the full automatic machine switching system, the subscriber, in removing his telephone, causes a register to be connected automatically to his line. The register then receives the impulses he sends out by his sender, stores them, translates them and finally controls the selecting machines in their movements to establish the connection. When the connection has been completed, the register disconnects automatically and is ready to attach to another calling line.

The subscriber is informed by a characteristic buzz, when ringing begins ; and by one of a different tone, in case the wanted line is busy.

When the conversation is completed, the restoring of the receiver automatically breaks down the connection. At this time a successful call is registered. A busy or a no-answer call is not registered.

A failure of machines is indicated by the continuous burning of a lamp advising the trouble-man of the trouble and where it is to be found. In the hunt for the fault, he is greatly assisted by the numbered positions of the sequence switches.

Private branch exchange service with automatic junction hunting and party line service on a terminal per station basis, are readily provided for.

SEMI-AUTOMATIC OPERATION.

In the semi-automatic machine switching system the subscriber, in removing his receiver, causes an operator's telephone set to be connected automatically to the calling line. The operator receives the number of the line wanted and depresses keys before her, corresponding with the number. The keys cause a set of registers, which have connected in the meantime to the key-set, to be moved to corresponding positions, after which the key-set is freed, while the register controls the distant switches to establish the connection. On account of the use of registers, only one key-set is required per operator, there being two registers, however, of which one receives a number while the second is setting up a connection.

The operator's desk has four lamps corresponding to each connection, which allow the operator to follow visually the progress of each connection and to assist all those subscribers who require an operator to correct any error or difficulty. It is found that supervision does not decrease operator's loads, but allows them rather to be increased, as all irregular calls are handled more rapidly, intelligently and in a manner more satisfactory to the subscriber than in the non-supervised system.

In case the machinery has failed, the operator presses a key which frees the subscriber and locks the switches in their operated position ; she then turns them over to the trouble-man, much as she now knots a pair of defective cords to be handed over to the mechanic for repairs.

In the supervised system, the operator presses a button when the connection is to be released ; this also operates the message register. In case a connection is to be released without registration, as, for example, in the case of a connection to the wrong number or to a line out of order, the operator presses a master key when releasing.

In case the operator's position is busy, the calling line will automatically be connected to the operator on the left or on the right hand, so that the latter can obtain the number and depress the keys. By means of this automatic team work feature, operators' loads can be considerably increased, without increasing the time a subscriber must wait before an operator answers.

NEW MECHANISMS USED IN THE SYSTEM.

Power drive. The characteristic feature of the mechanical equipment is power drive. The advent of reliable commercial electric motors permitted the direct application of power taken from such motors, to the mobile parts of the selecting mechanisms for producing motion. Such mobile parts can then be made heavy, rigid and unchangeable, and contacts can be made firm and certain. Again, the motion given to the mobile parts is smooth and free from vibration, reducing wear, while speeds can be increased to any degree limited only by the accuracy of stopping the mobile parts.

The power is delivered to the selecting machines over a small shaft rotating continuously at about the rate of 31 rev. per minute. The speed is so slow that the wear in the bearings is negligible. The power is applied directly to the mobile parts by means of a simple two disc friction clutch operated by fixed electro-magnets.

Selecting apparatus. There are broadly two types of apparatus to be considered :—

the selecting mechanisms, which take the form of line finders, group switches or final switches ;

the controlling mechanisms, which take the form of sequence switches or registers.

Selectors. The selecting mechanisms consist of a set of brushes mounted on a brush carriage which sweep over a semi-circular terminal arc. The mechanisms are massively built and are free from all adjusting springs, screws etc. The terminals are held in pressed insulating material. Only rotary motion is introduced and sliding motion with its wear and friction is excluded. Contacts are vertical, dust-free and very firm. A reliable commutator is provided instead of cords.

In the type of selector serving as group switch or final switch, the brush carriage carries ten sets of brushes, connected in multiple. Normally the brushes are all held back or latched so as to be out of engagement with the terminals. If a set of brushes is to sweep over a given row of terminals, it is tripped by a tooth of a trip spindle, which was previously moved into position.

In the line finder, the brush carriage has only three sets of brushes placed at 120° and spaced along the axis so as to sweep successively over three levels of terminals.

Sequence switch. The sequence switch is an ingenious mechanism which replaces a score of relays. It consists of a power driven spindle carrying a series of ebonite cams which engage contact springs to hold contacts open or shut, until an impulse sends the spindle into its next position. There are 18 such positions ; in each one, a different kind of circuit is closed as required for controlling the switches. The contacts are firm and of platinum. No electric power is consumed by the switch while holding contacts closed.

The control exercised by the sequence switch, is best understood by a study of the circuits. It permits a large variety of circuits to be set up, solving any particular circuit problem that arises.

The register is a modified sequence switch with a special arrangement of cams. It performs translation in a simple and ingenious manner to be described in detail later.

Cable. In any automatic exchange, there are a large number of terminals on the selectors and finders which must be connected by cable in multiple. A simple and novel form of ribbon cable has been designed making it possible to do the original cabling work at small expense and yet leave all soldered joints at all times exposed and accessible for inspection and repair.

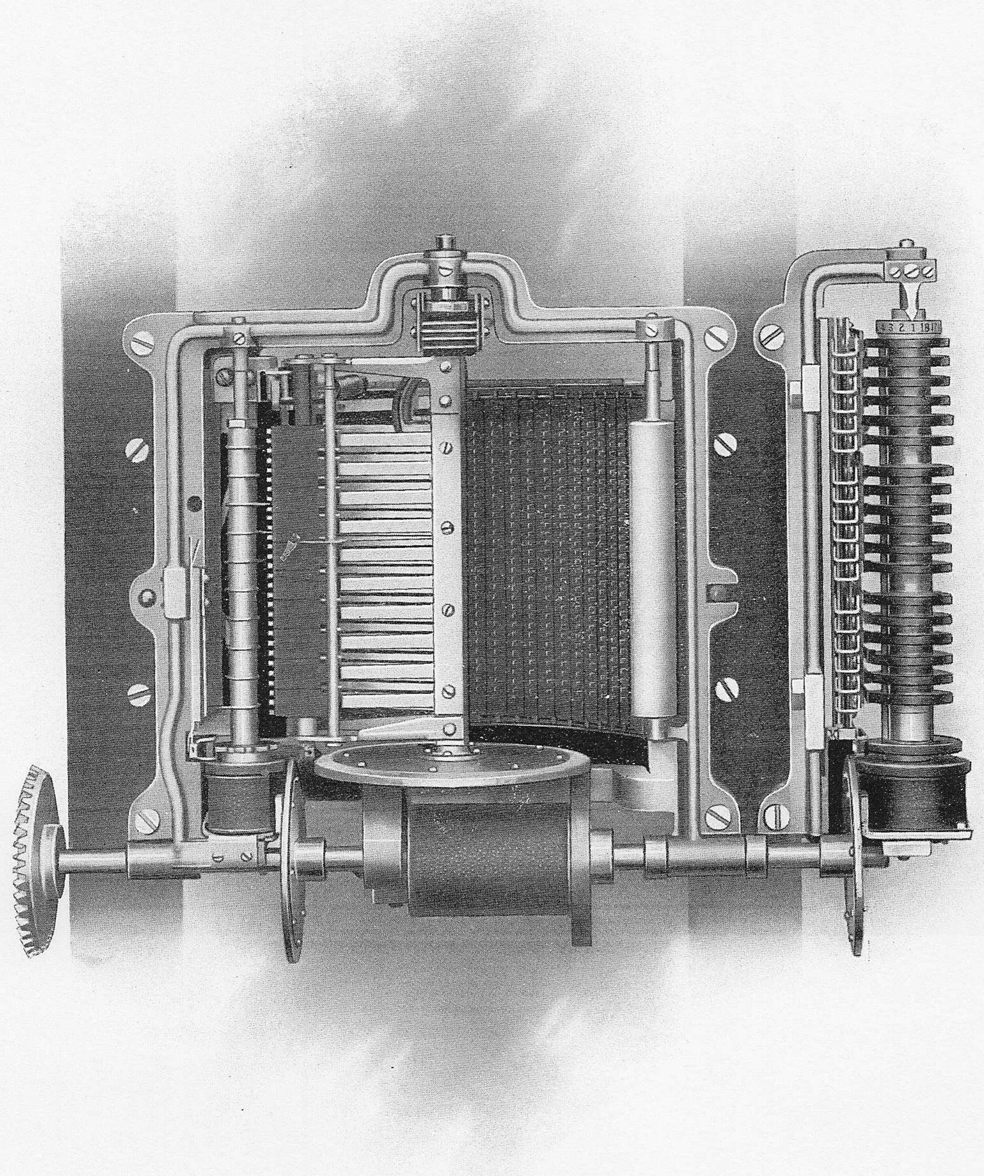
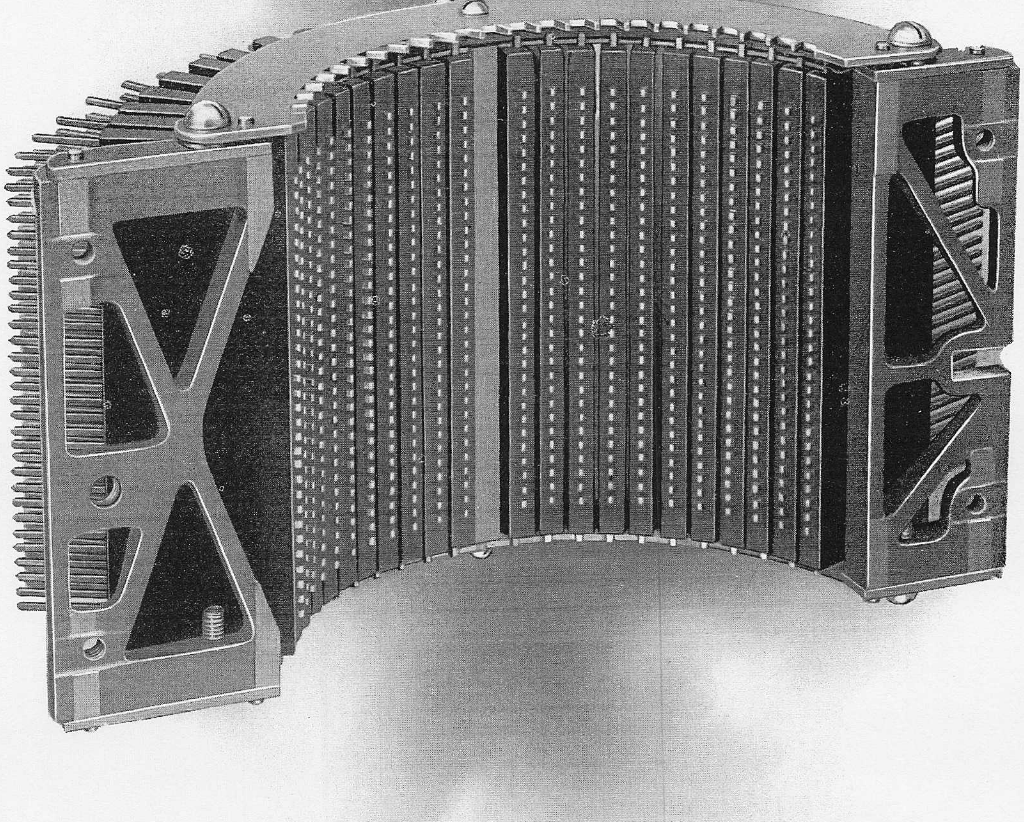


Figure 1.



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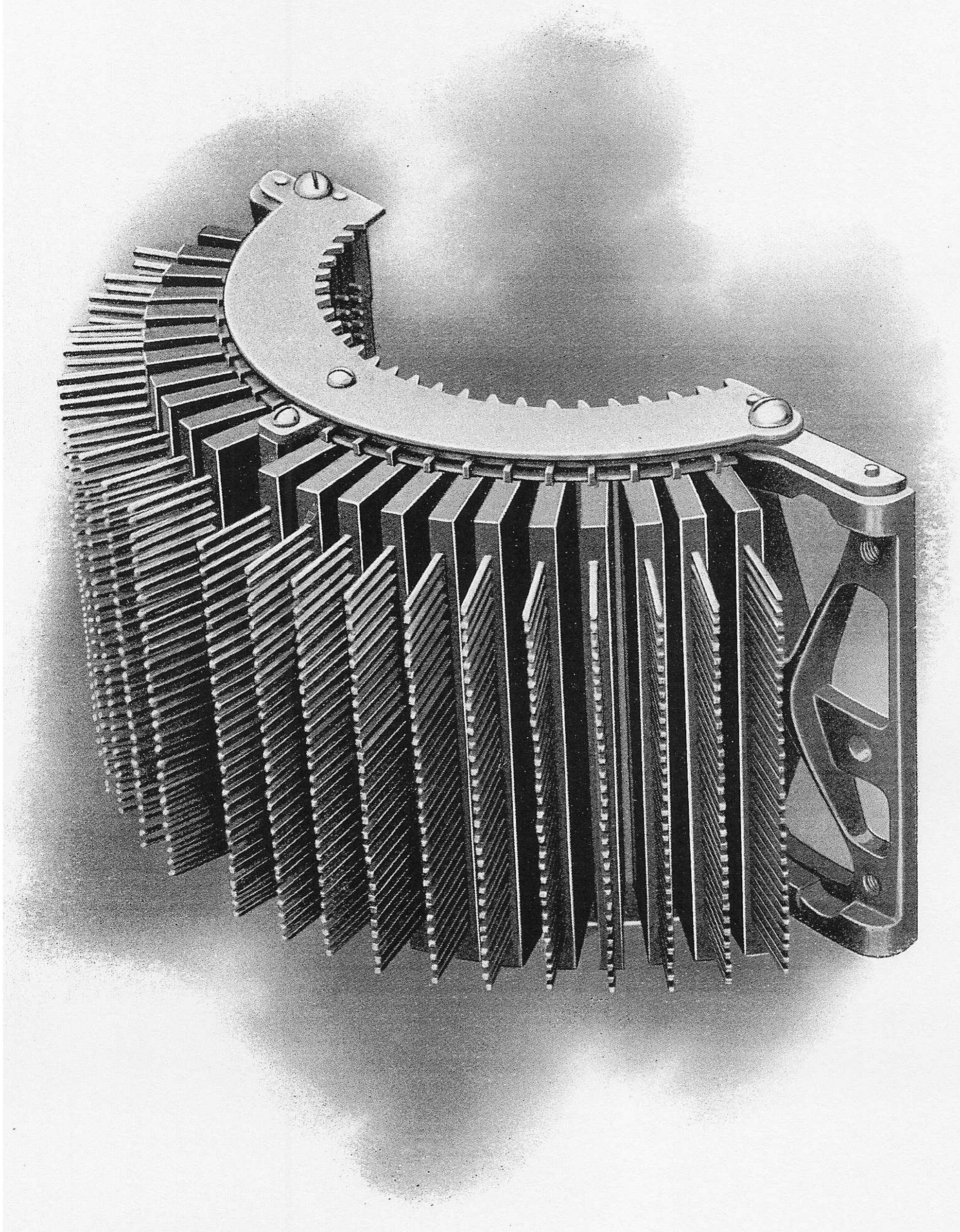

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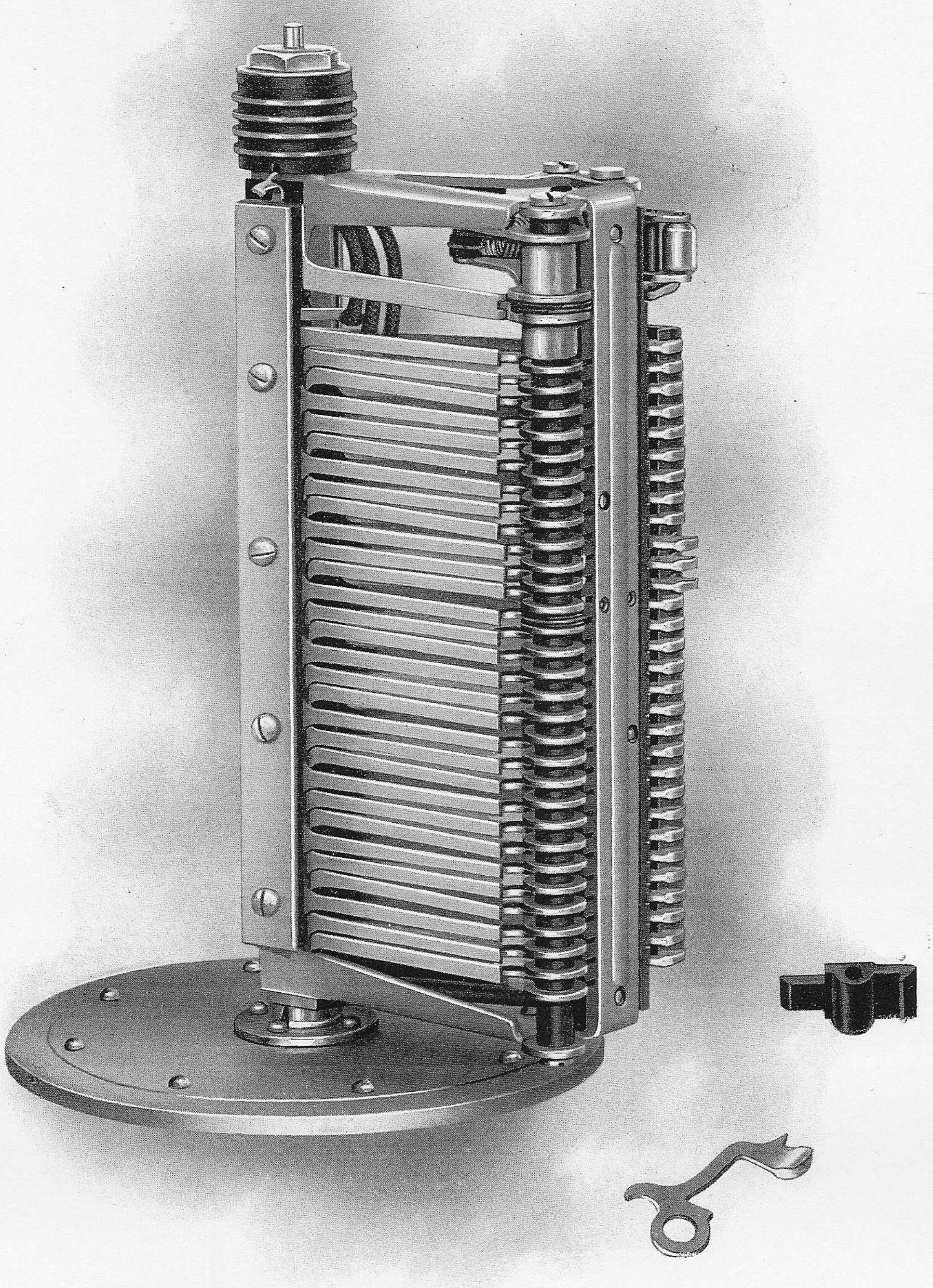

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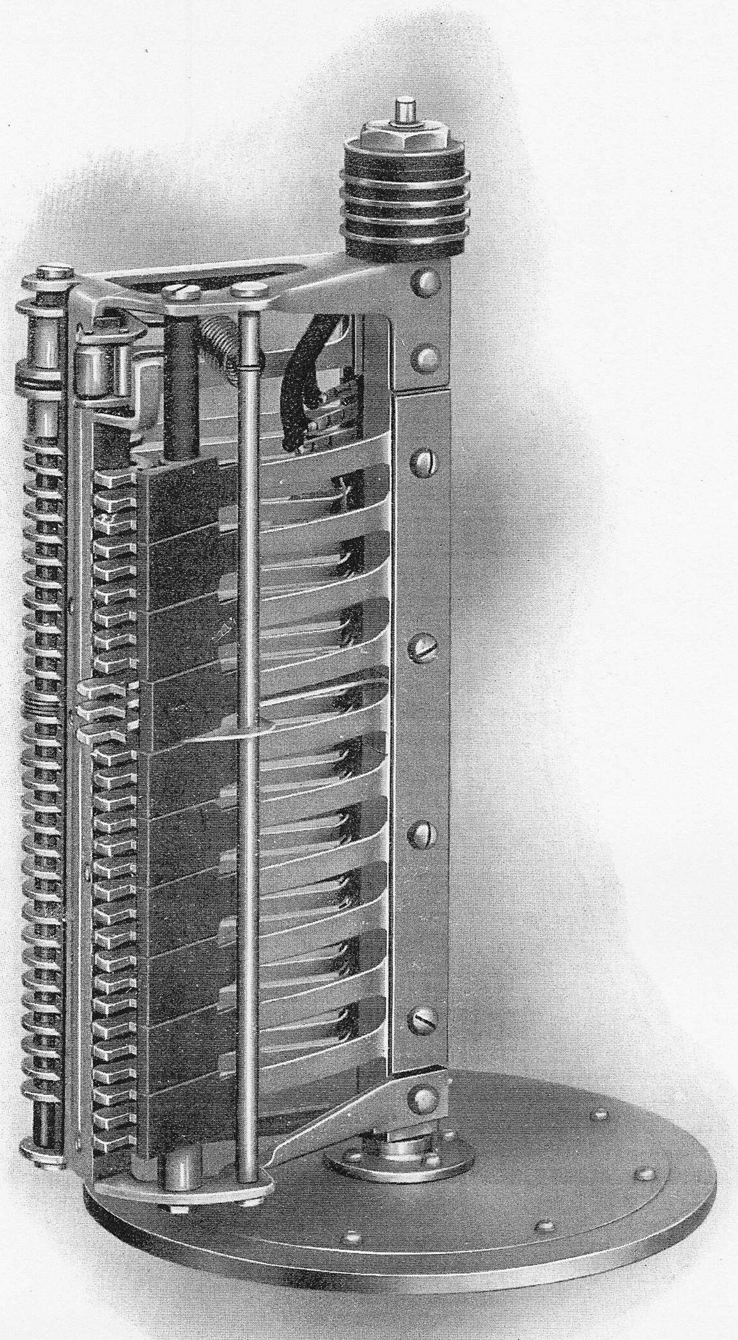

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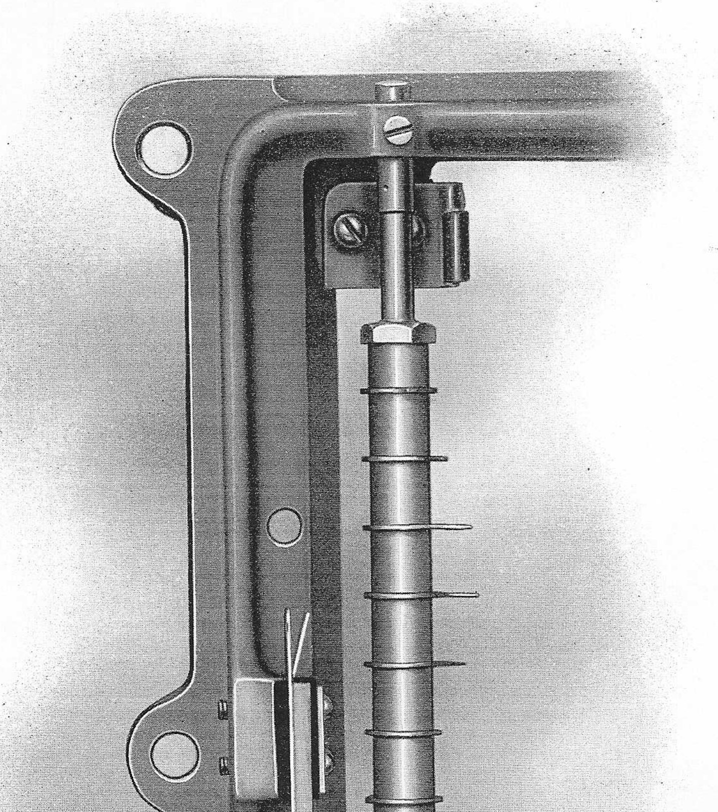

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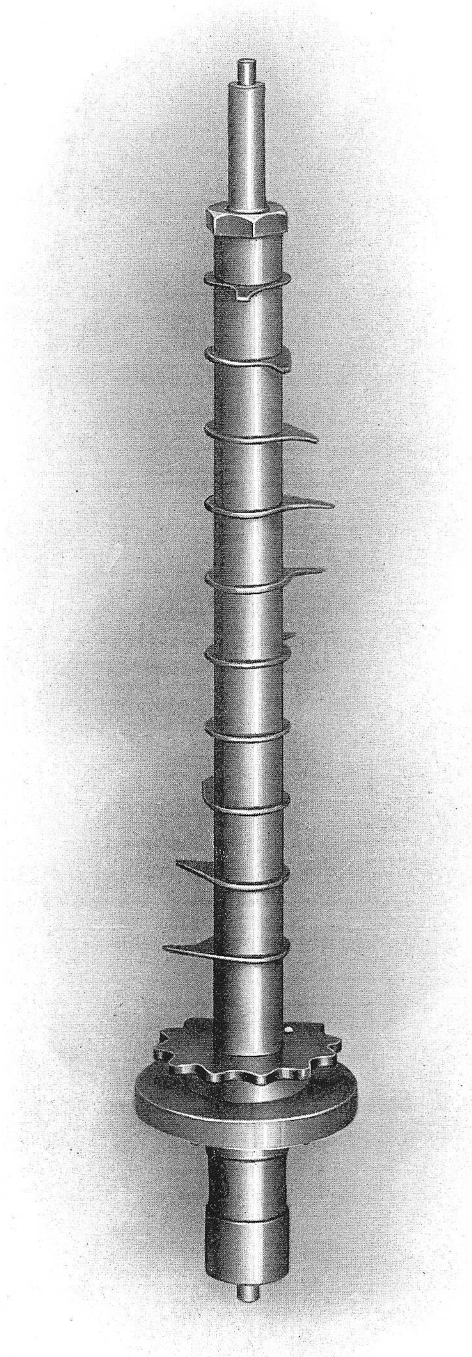

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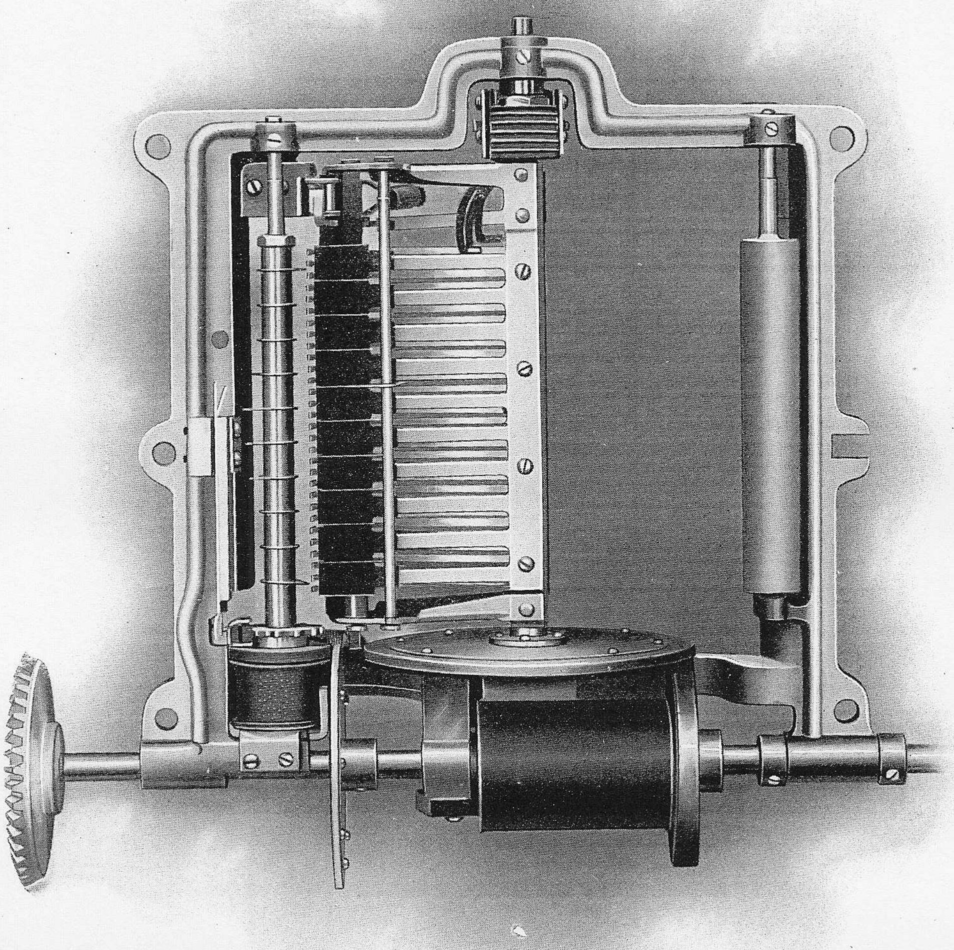


Figure 8.

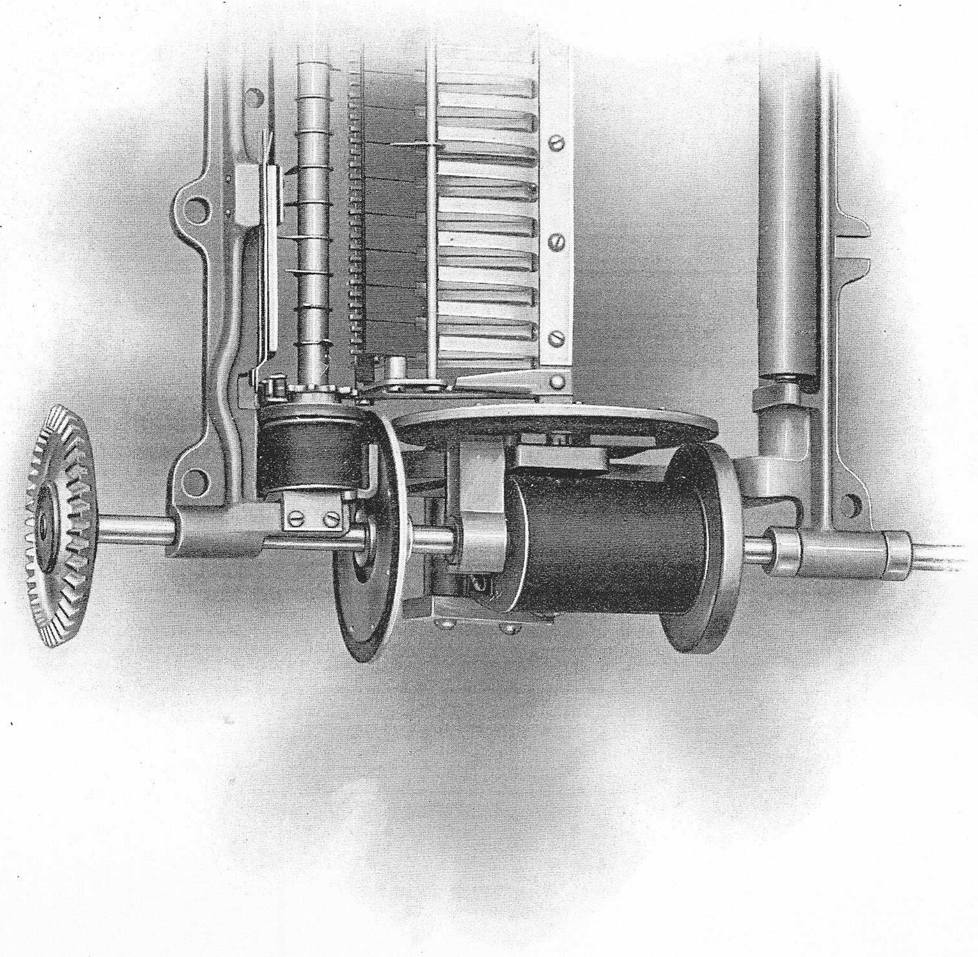


Figure 9.

PART II.

INTRODUCTION.

In the Western Electric Machine Switching System, connections for conversation between two telephone circuits are established by means of switching machines, instead of having operators complete such connections by means of plugs and jacks.

The switching machines performing this function, are of three kinds, which are all, however, modifications of a characteristic single type. In this, the fixed terminals are arranged in a semi-circular arc, at whose centre is pivotted a movable brush carriage with several sets of brushes, connected electrically in multiple and arranged to rub or sweep over the fixed terminals. The brush carriage has only a rotary and no sliding motion, the proper row of terminals being reached by taking into use one of the several sets of brushes. The three forms of this type are the line finder, the group selector switch and the final selector switch. In the line finder type, the brushes are moved forward, until they make contact with the terminals of the calling line. In the group switch type, the brushes are moved forward, until they make contact with the terminals of an idle trunk leading to the next group of switches. And in the final switch type, the brushes are moved forward a definite number of steps, until they make contact with the terminals of the line wanted. The latter switch has a capacity of 200 lines.

Before taking up the exact mechanical construction and electrical operation of these three types of switches, and to assist the understanding of the working of the system, a description of the general operating features is given, followed by a discussion of the general design features underlying the system.

GENERAL OPERATING FEATURES OF THE FULL AUTOMATIC SYSTEM.

The subscriber of a full automatic exchange desiring to be connected with another subscriber removes his telephone from the hook of his C.B. sub–set and operates the number sender, which is a number setting mechanism placed on the set. Having set up the number, the waiting subscriber hears a short buzz when ringing begins ; if the line is busy, he hears a long buzz. After having finished the conversation, he hangs up the receiver causing the connection to be automatically cleared.

In FIG. 10 is shown a diagrammatic view of the connection between two such subscribers.

The removal of the receiver of sub-set (A) causes the brushes of the line finder (LF) to rotate, until they have connected with the terminals of the calling line.

The line finder next connects with an idle register, which is now ready to receive the impulses sent out by the sender, as it is operated by the subscriber.

This readiness to receive impulses is indicated by a tone and is advantageous to the subscriber at an extension set, by indicating to him that the person at the main set has switched through.

The subscriber in operating his sender, sends out for each digit a set of impulses corresponding with the digit. Each set of impulses is received by the register and stored and translated.

As soon as a set of impulses has been received, the register (R) begins to build up the connection. The first set of impulses from the register causes that brush of the first group switch (1.GS) to be chosen and released, which will sweep over the level of terminals connected to the second group of switches having access to the group of 2000 lines where the wanted line is located. Next, the brush sweeps over the terminals, seeking an idle junction which, when found extends the connection to a second group switch.

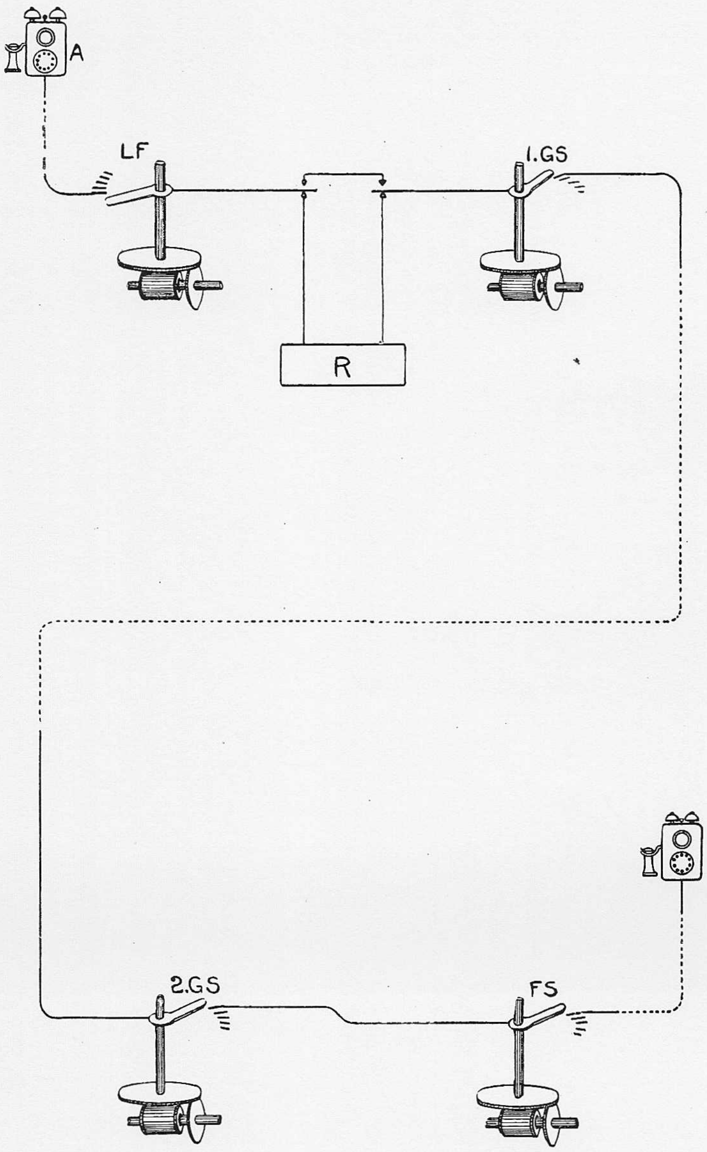


Fig. 10.

The second set of impulses from the register causes that brush in the second group switch (2.GS) to be chosen and released, which will sweep over the terminals connected to the final switches, having access to the 200 lines where the wanted line is located. Next, the brush sweeps over the terminals, seeking an idle junction which, when found, extends the connection to a final switch.

The third set of impulses from the register causes the proper brush in the final switch (FS) to be chosen and released, and the fourth set of impulses from the register will cause the chosen brush to be moved forward until it stands on the terminals of the wanted line.

Now the register disconnects itself and is ready to serve another call, while the conductor from the line finder to the first group switch is connected through by closing the upper contacts.

In the meantime, the final switch has tested the line, and applied ringing current if it be free. The ringing current is cut off automatically, as soon as the called subscriber answers.

In case the line is found busy, ringing current is not applied but a busy tone connected.

As it is not uncommon for the called main set to connect the call through to the extension set by throwing a key, thereby for a moment again opening the circuit, the system is arranged preferably so that the called subscriber cannot initiate clearing. A calling subscriber cannot, however, block the line of the called subscriber, because restoring the receiver will cause a lamp to light, notifying the mechanic in charge that there is a connection up, cleared out only one way, that needs attention. When the above condition does not obtain, the system can be readily constructed to clear from either substation.

The calling subscriber restoring his receiver, initiates the clearing of the connection or the returning to normal of the switches ; at this time, the conversation is registered automatically. The line of the subscriber is cleared immediately, so that he may send a second call as soon as the characteristic tone tells him that a register is connected.

GENERAL OPERATING FEATURES OF THE SEMI-AUTOMATIC SYSTEM.

The subscriber of a semi-automatic exchange desiring to be connected with another subscriber, removes his telephone from the hook of the usual C.B. sub-set and awaits the reply of the telephone operator who takes the number. The operator, while repeating the number to the subscriber, depresses corresponding digit keys arranged before her on the desk, whereupon the switching mechanisms automatically establish the connection. Four lamps associated with the connection circuit allow the operator to follow the connection and assist the subscriber when required. After conversation both subscribers return their telephones, causing the two supervisory lamps to glow before the operator. To release the connection she presses a key associated with the lamps.

In FIG. 11 is shown a diagrammatic view of the connection between two subscribers connected to a semi-automatic exchange.

The removal of the receiver of the sub-set (A) causes the brushes of a line finder (1.LF) to rotate until they have connected with the calling line. The brushes of a second line finder (2.LF) next rotate until they have found the terminals connected with the brushes of the first line finder. The conductors between the brushes of the line finder and group switch form the « connection circuit ».

The call, having arrived at an operator's position, lights one of the four

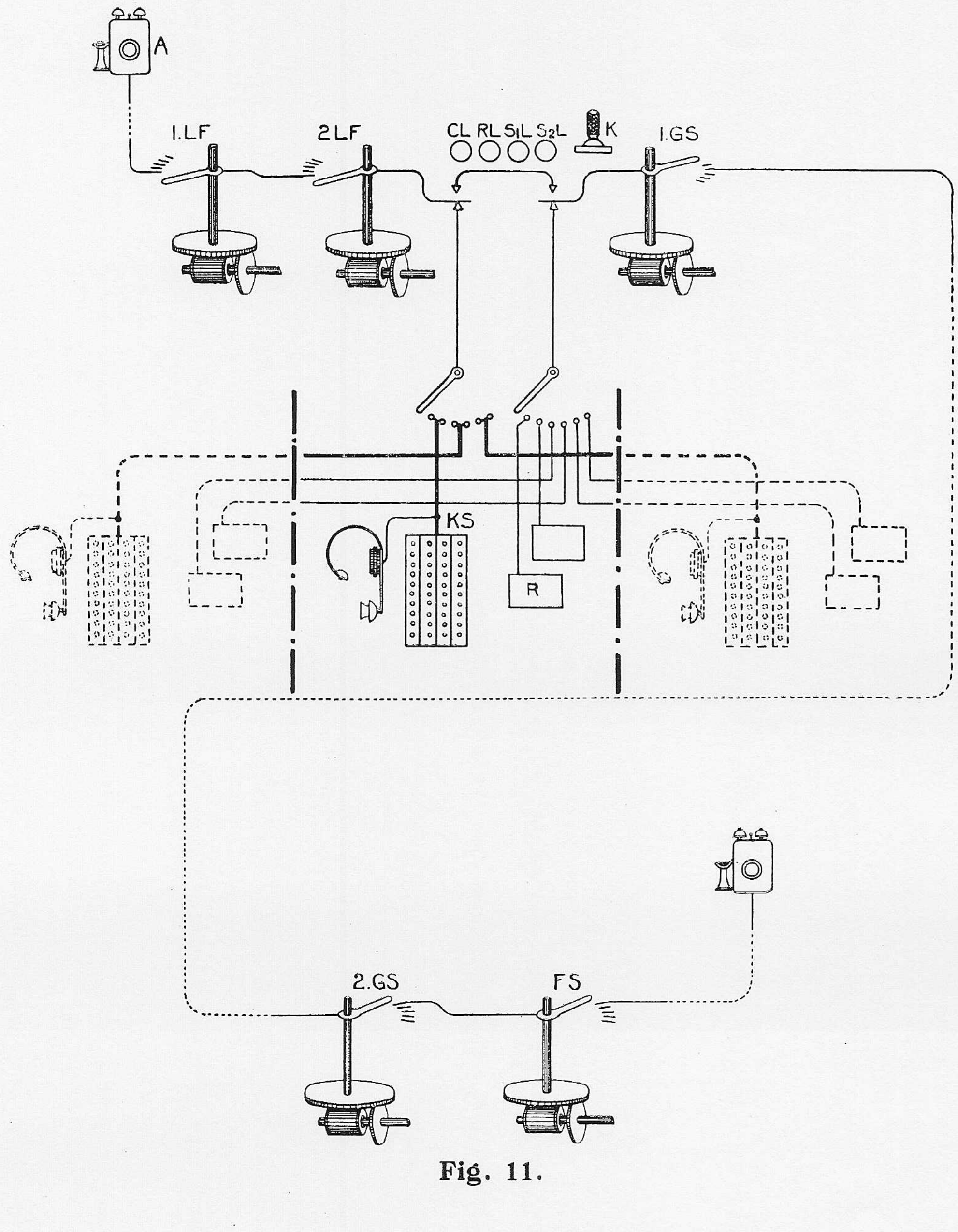


Fig. 11.

lamps (CL) placed before the operator and associated with the « connection circuit ». At the same time, the operator's telephone set is automatically connected to the line as also her key-set (KS) and an idle register (R).

Having received the number, the operator depresses the keys of the key-set (KS) corresponding with the number requested. This causes the register spindles to take corresponding positions after which the key-set is disconnected.

The register (R) is now in a position to build up the desired connection.

As in the case of the full automatic System, the register successively controls the first group switch, the second group switch and the final switch until the terminals of the line wanted are reached.

The register is now disconnected and ready to serve another call, while the conductor from the line finder to the group switch is connected through.

In the meantime, the final switch has tested the line, and applied ringing current if it be free. The ringing current is cut off as soon as the called subscriber answers. While ringing current is being applied to the line, the red lamp before the operator, marked RL, remains lighted ; when the subscriber answers, the red lamp is extinguished.

In case the line is found busy, ringing current is not applied, but instead a buzz tone and a rotating commutator are connected to the line causing the supervisory lamp (S2L) to flash for the purpose of advising the operator that the line is busy.

When finished with the conversation, both subscribers restore their telephones, lighting the supervisory lamps (S1L and S2L) as in the Common Battery System, whereupon the operator depresses the key lever (K) to initiate the clearing out. The key lever (K) thrown in a second direction, connects the operator's head set to the connection circuit.

The method of supervising a connection has been retained from the manual Common Battery System because it gives a number of important advantages.

It is found that, by individualizing operator's responsibility, operators exercise greater care in establishing a connection than in a non-supervised system, where the complaining subscriber on a re-call usually gets a new operator knowing nothing of the previous call.

On account of this individual service, all irregular calls are handled in a manner more satisfactory to the subscriber.

Among such irregular calls are all those for which a subscriber for any reason needs the help of the exchange to assist him in his difficulty. In case a wrong number is obtained, the operator who established the original connection, is the one best able to correct the error, having at the same time an opportunity of determining whether the apparatus made the error. In case the subscriber cannot understand the various tones connected in an automatic system, the operator is there to help him. If the line be out of order or the number be changed, the operator can assist the subscriber by advising him of the trouble in one case, and by connecting him at once with the information operator in the other.

Besides such operating advantages, supervision permits registering only satisfactory calls, as is done in the Common Battery System. The registration takes place while the operator presses the clearing key (K).

Another important advantage of supervision, lies in the means it furnishes for locking the switches in their operated position in case of a faulty operation of the apparatus. Having noted from the behaviour of the lamps or having been advised by the subscriber,that the apparatus has not worked properly,the operator throws the lever key (K) in a second direction, while depressing a master key. This clears the subscriber, connecting him at once to a new connection circuit ; at the same time, it locks all of the machines in their operated position. The trouble-man, once he is advised, can now inspect the faulty machines and readily determine from their operated positions where the fault is to be found. Any piece of apparatus which has been the cause of a failure is, therefore, at once brought to the attention of the trouble-man who can repair it.

The circuits are such that if, for any special traffic reason, it is desirable to omit supervision, it is readily accomplished by a simple change in wiring, following which the calling subscriber, when restoring his receiver, initiates the clear-out, as in the full automatic System. In this case, message registration also occurs automatically as already described.

In order to increase operator's loads and reduce the waiting time of subscribers, an automatic team work feature is provided. For this purpose circuits are arranged, so that a call, appearing before the operator while she is busy, will not wait until she has finished the call in hand, but will automatically be switched to the head-set of the operator either at the left, or at the right of the position, whereupon the neighbouring operator answers the call and depresses the keys on her key-set. The connection itself is supervised by the operator before whom it first appeared. Each position can thus be assisted by either of the two neighbouring positions on the throwing of a key, which permits excess calls to be received from the left or right.

Convertibility in an automatic system, making it possible to change over from semi-automatic operation to full automatic operation whenever local conditions make such a change seem desirable, is provided for in the Machine Switching System. To make this change, which can be made gradually, it is only necessary to equip the subscriber's sub-set with a sender and to replace the registers suitable for semi-automatic working, by those designed for full automatic working. The remainder of the equipment remains unchanged. All group and final switches are arranged to establish connections indiscriminately with full automatic or semi-automatic substations.

VARIOUS KINDS OF SERVICE RENDERED.

Message registration. In the full automatic Machine Switching System, the calls originated by any line are registered on a message register of a kind used generally in common battery exchanges. Only connections actually completed are registered, such registration being performed automatically during the clearing-out operation, following the restoring of the calling subscriber's receiver.

Calls for busy lines or for lines on which the called subscriber does not answer, are not registered. This is accomplished by having the sequence switch, which ordinarily connects the message register to the meter battery, pass through its metering positions at a time when the battery is not yet connected, such connection taking place later in the cycle of operation of a second sequence switch. The circuit involved will be described later.

It is usually customary not to charge calls to subscribers for information operator, chief operator and other official telephones. In the Western Electric System, connections established to such telephones are not registered.

In the semi-automatic System, message registration can be performed by supplying the message rate line with a message register of the usual type. The operator performs the registration, while pressing the key which clears the connection. As the connection is only cleared after a subscriber has had an opportunity of complaining of failure to secure the connection, the operator is in a position to charge only those calls which would be pronounced successful by the subscriber, and not to charge connections to wrong numbers, troubled lines etc. Clearing, without registration, takes place by depressing a master key, when depressing the regular clearing key.

Private branch exchange junction hunting. In all modern exchanges, it is customary to assign a series of numbers to the several telephone lines allotted to the same subscriber and usually connected to a private branch switchboard. The central office jacks connected to these lines are then marked in such a way, that an operator, receiving a call for one of the numbers in the series, will test at once other jacks connected to the same subscriber in case she finds the number busy. By this means a much larger number of calls can be handled over the lines, because of working the lines in a single group.

The Machine Switching System makes provisions for such junction hunting, as it is usually called. A series of terminals in the final switch, is reserved for each private branch exchange, exactly as one would reserve jacks in a manual exchange. A call for one of these numbers happening to be busy, whether in a full automatic or a semi-automatic exchange, will cause the final switch to test automatically the other lines in the same series, until an idle line is found, with which connection is then established in the regular manner. In case the final switch brush, in testing the lines, should find that all test busy, a regular busy report will be given to the subscriber.

As special testing relays are required for each final switch, it is customary to concentrate such private branch exchange junctions in a few groups in order to save apparatus. If it is difficult, however, to change subscribers' numbers for this concentration, it is necessary to equip all final switches with the junction testing apparatus.

Party lines. The apparatus of the Machine Switching System is also designed to give party line service up to four parties. The usual C.B. party line sets equipped for selective ringing are used. In the exchange, a terminal is provided for each party station, the scheme being on a terminal per station basis and giving each station a different number.

The final switches have special test relays which allow them to test whether the line called for is busy or idle and, if idle, what kind of ringing current is to be applied to ring the station wanted.

The method of assigning different numbers to party stations, irrespective of the numbers of the other stations connected to the same line, makes it possible to move a subscriber's station without changing the subscriber's number. It is also possible to give him later, either two party line or direct line service,if he desires, without changing his number.

Connections to information operator. A subscriber wishing to call the information operator or toll recording operator or chief operator, does so by sending in a certain number in the full automatic System or by informing the operator, who depresses certain keys in the semi-automatic System. If there are several office junctions to the information operator's position, the machine will test automatically over the series of junctions, until an idle one is found. Once a subscriber is thus connected to an operator, he is not able to clear until the operator has answered. Although the reverse could be easily performed, experience has shown it to be undesirable to make such clearing possible, as a subscriber, waiting impatiently for a reply during a period of heavy traffic, will call repeatedly the same number and thus uselessly tie up machinery that is intended for regular connections.

Connections for toll service. The problem of connecting subscribers' lines to toll lines is one that requires special treatment in nearly every case, on account of peculiar local conditions.

In either system, there are broadly two ways for establishing the connections. In the first method, the toll operator completes the toll connection directly over a subscriber's multiple jack before her, or she establishes it over an order wire junction line ending in the usual plug located before a B switching operator who completes the connection in the subscriber's multiple before her. In the second method, the operator is given a key-set, on which she registers the number wanted by depressing the corresponding keys, whereupon the connection is extended to the subscriber's line, over the usual group and final switches. Instead of the key-set, she may be given the usual finger-wheel sender.

In either system, it is possible to give any of the operating features required in ordinary manual toll line switching, according to the different requirements in various countries.

Connections with manual offices. Provisions for junction calls between manual and machine switching offices are readily made. Here again the particular manual equipment in the telephone area requires a special design of junction scheme.

For junctions from the machine switching to the manual office, a special kind of number indicator or carriage call is installed. In this service, the semi–

automatic operator or the subscriber in a full automatic System, sets up the number as usual, whereupon the connection is extended to the distant manual board over a junction line ending in a plug before a B operator. The register then controls a series of sequence switches at the distant end, which, when set, close a circuit and light a series of four lamps in a panel before the B operator, consisting of four rows of lamps of ten each, numbered 0 to 9. This indicates to the operator the number of the line wanted, whereupon she completes the connection in the subscriber's multiple before her.

All connections between the various central offices in an area, and between satellites and the neighbouring central office are made over two-wire junction lines, over which all the necessary signals are passed to establish and break down a connection. The third line conductor, usually associated with the pair of junction conductors, is not required. For junction lines in the same office running from rack to rack, three-wire junctions are usually employed to simplify the circuit. The cost of the wire involved is very low, the wire being only a few feet long.

PERFORMANCE OF SYSTEM.

Operating loads. The simplicity of operating in the semi-automatic Machine Switching System has greatly increased the number of calls that an operator can complete during the busy hour.

In the usual manual common battery system, it is customary to expect an operator to handle 230 calls during the busy hour with 0% junction calls and 170 calls with 100% junction calls, the latter being the case where all calls are sent over junctions even those for lines in the same office, there being no multiple in the A boards.

In the Machine Switching System, an operator can easily handle at least twice as many calls and, as the labour involved in connecting a call to a line in a second office is the same as connecting it to a line in the same office, there is no reduction due to the inter-office junctions.

Such loads are readily attainable after subscribers have been trained to give the number promptly, and after a suitable staff of information operators to take care of all irregular calls, has been provided.

Maintenance. The Machine Switching System has been designed both from a mechanical and electrical circuit standpoint to reduce failure of operation to a minimum. The efforts along this line have been so successful that an exchange in New York City showed, practically from the start, a failure rate of only 3 to 4 per thousand calls, which not only includes those of defective operation of machinery, but also operators' and subscribers' errors.

A careful distinction must be made between a failure and a fault. Any fault or defect of a piece of apparatus, such as a defective relay contact, might cause a large number of connection failures, before it is discovered by routine testing or accidentally by a watchful mechanic, and removed. Yet the defect, when reported, will be recorded as a single fault, when it may have been the immediate cause of a large number of failures. Subscribers, however, judge the quality of a service, not by the number of defects discovered, but by the number of failures encountered in their efforts to obtain connections. It is therefore the failure statistics which are the most significant.

The hold-over feature in the semi-automatic System, which has been described, is exceptionally effective in reducing the number of failures to that of faults, in that any piece of apparatus, which has caused a failure, is at once removed from service and prevented from interfering with other calls. Each fault, therefore, can cause only one failure.

On the other hand, any fault in the apparatus is at once detected in the semi-automatic System where each call is watched by the operator, so that routine apparatus testing becomes entirely superfluous. Routine testing at best is always inefficient through a peculiarity of all automatic machinery to develop faults which appear only occasionally, often as rarely as once in a thousand times. To locate such a fault by routine testing requires that each piece of apparatus be tested a thousand times, clearly a prohibitive testing requirement; such faults can then only be found either accidentally by an efficient mechanic or only later as the fault develops and comes oftener. In the semi-automatic System, even the rarest fault is isolated, the first time it appears, and can be removed.

High accuracy in operation must be secured, as every fault which is reported, must be located and removed, involving maintenance expense. If such faults are not removed, they increase rapidly in frequency, causing a rapid deterioration of the service, which will very soon evoke the subscribers' criticism.

A second consideration demands high accuracy in operation. As will be shown later, the number of switches provided in any group depends among other things, on the number of times per 1000 that a call reaching this group shall be delayed for want of switches. If a call is to fail only once in 1,000,000 times more switches are needed than if it may fail once in 1000 times. Therefore any percentage of call failure that a subscriber will reasonably tolerate, should not be brought about by faulty operation of mechanism which entails only useless maintenance expense, but should result from a reduction of the machines provided in any group, in a degree that can be predicted within narrow limits by the probability curves. Such reduction in machinery introduces a double economy, that of reduction of maintenance expense and that of reduction of capital expense.

A call that fails within a frequency tolerated by the subscriber may be looked on, therefore, to have a certain capital value in that it permits a reduction of machinery in a well designed system, where the exact effect on traffic of such a reduction can be accurately predicted.

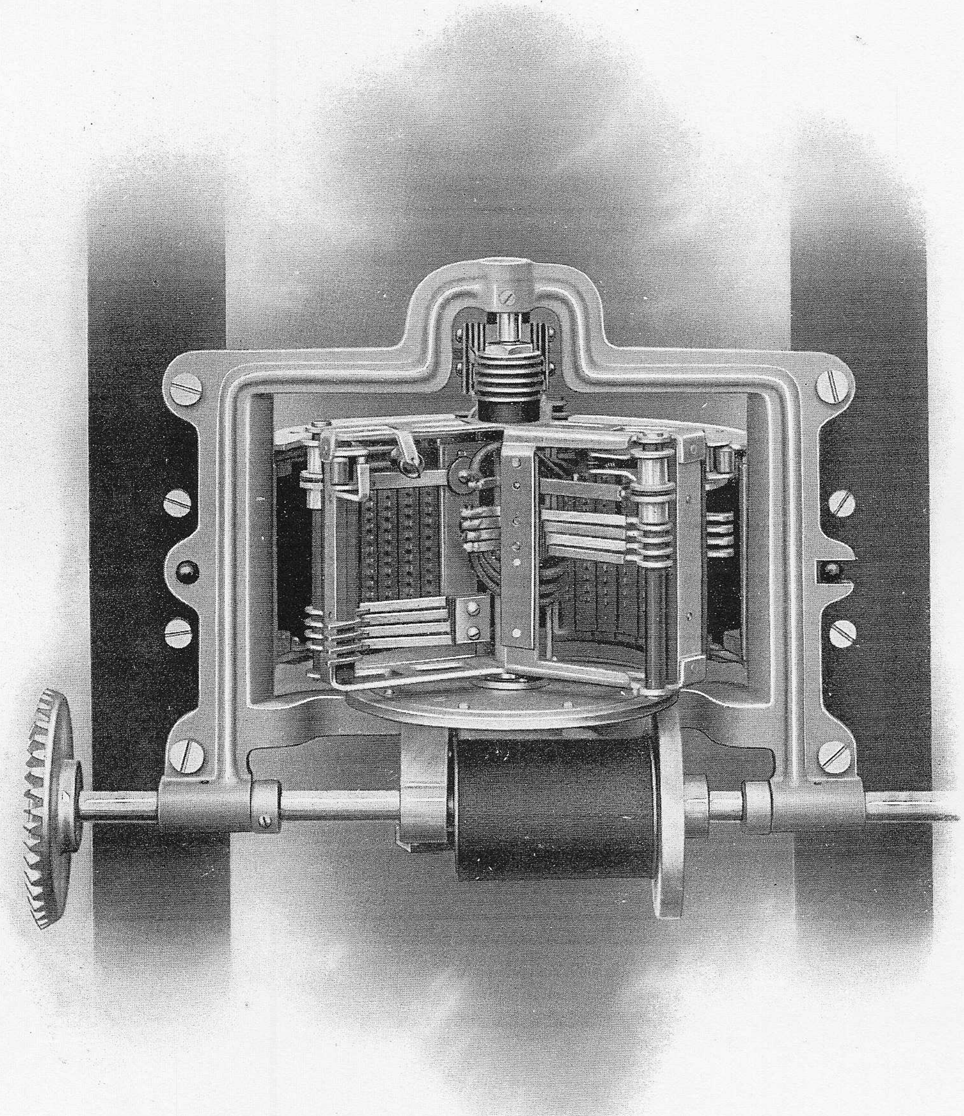


Figure 12.

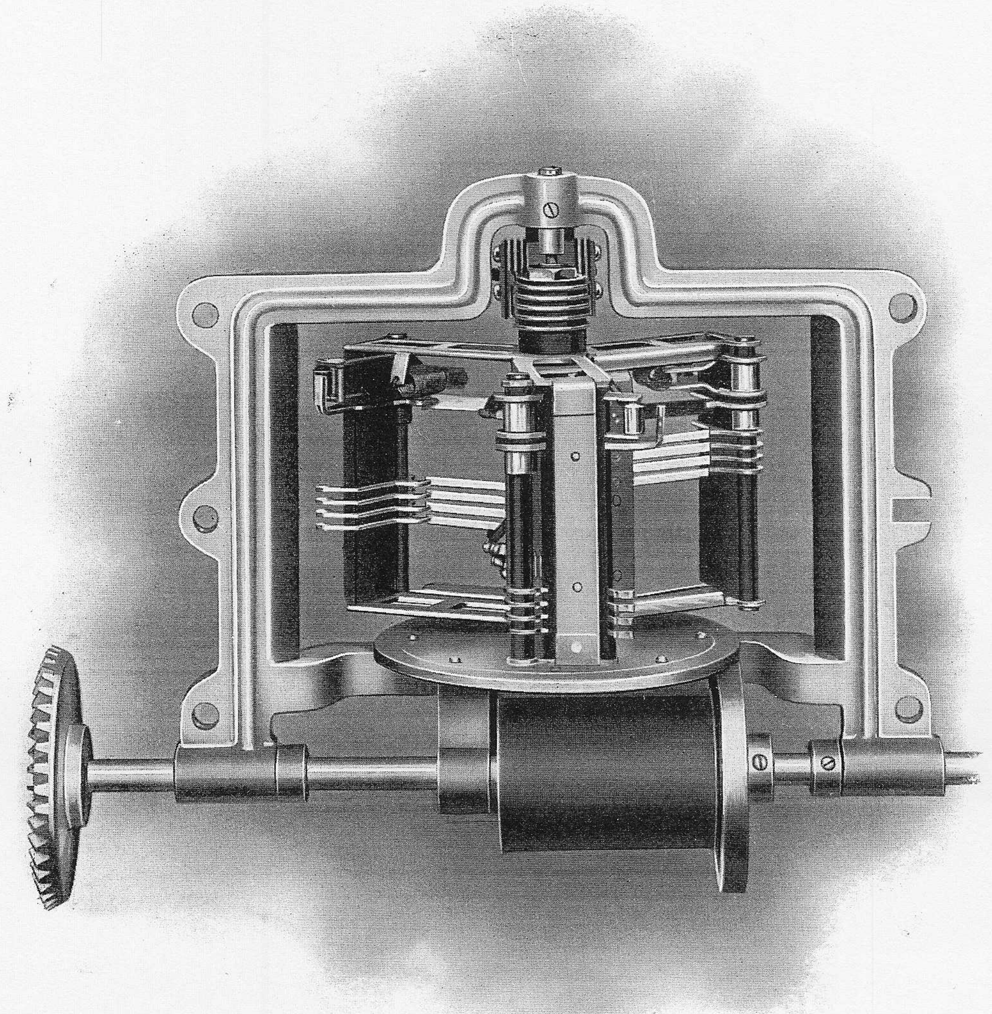


Figure 13.

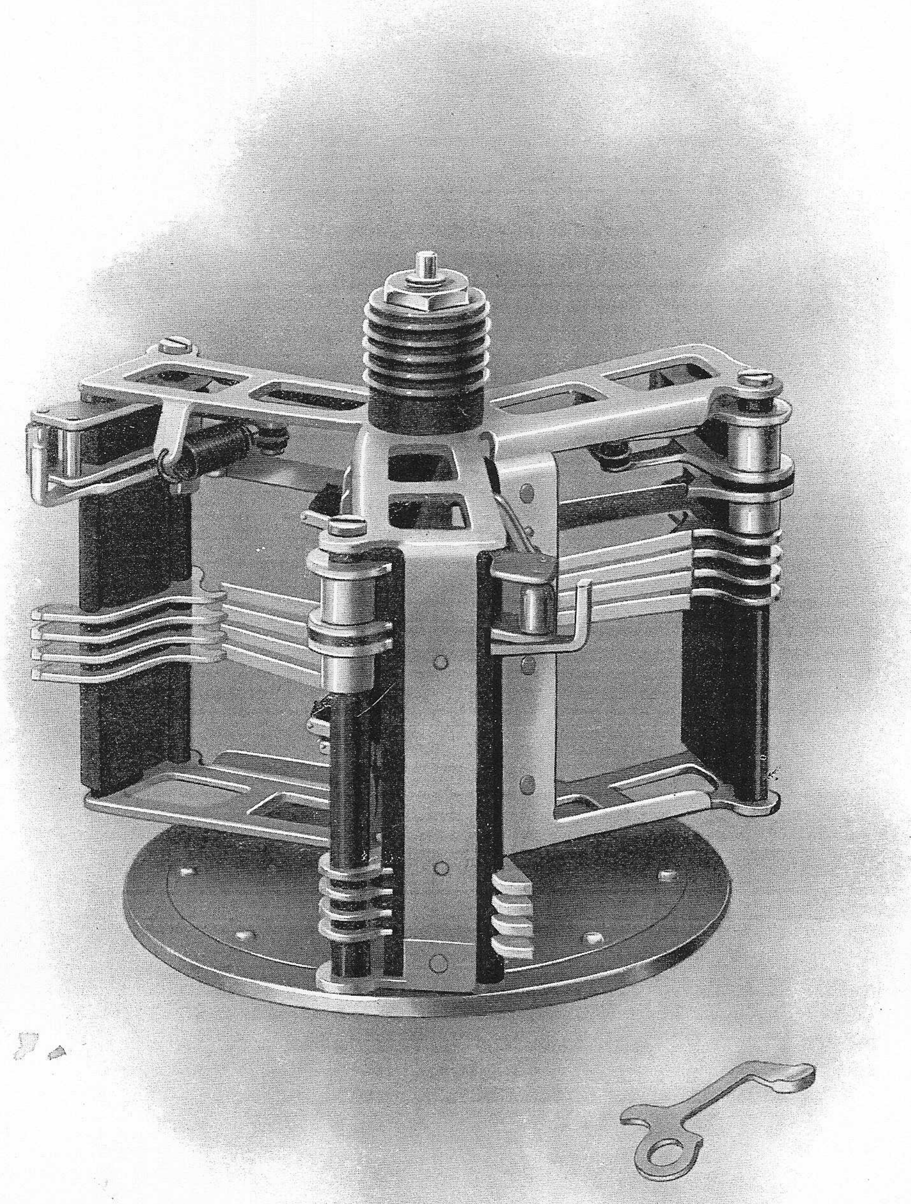


Figure 14.

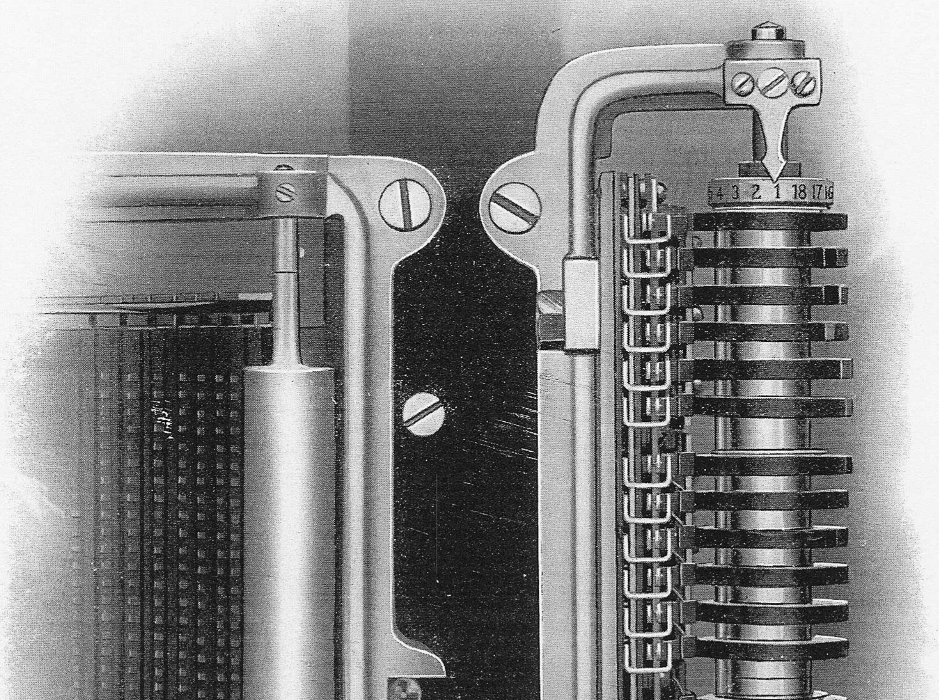


Figure 15.

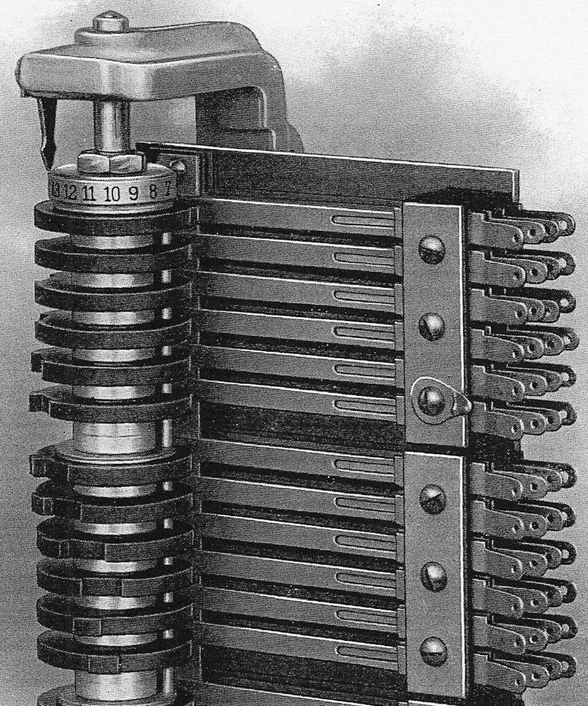


Figure 17.

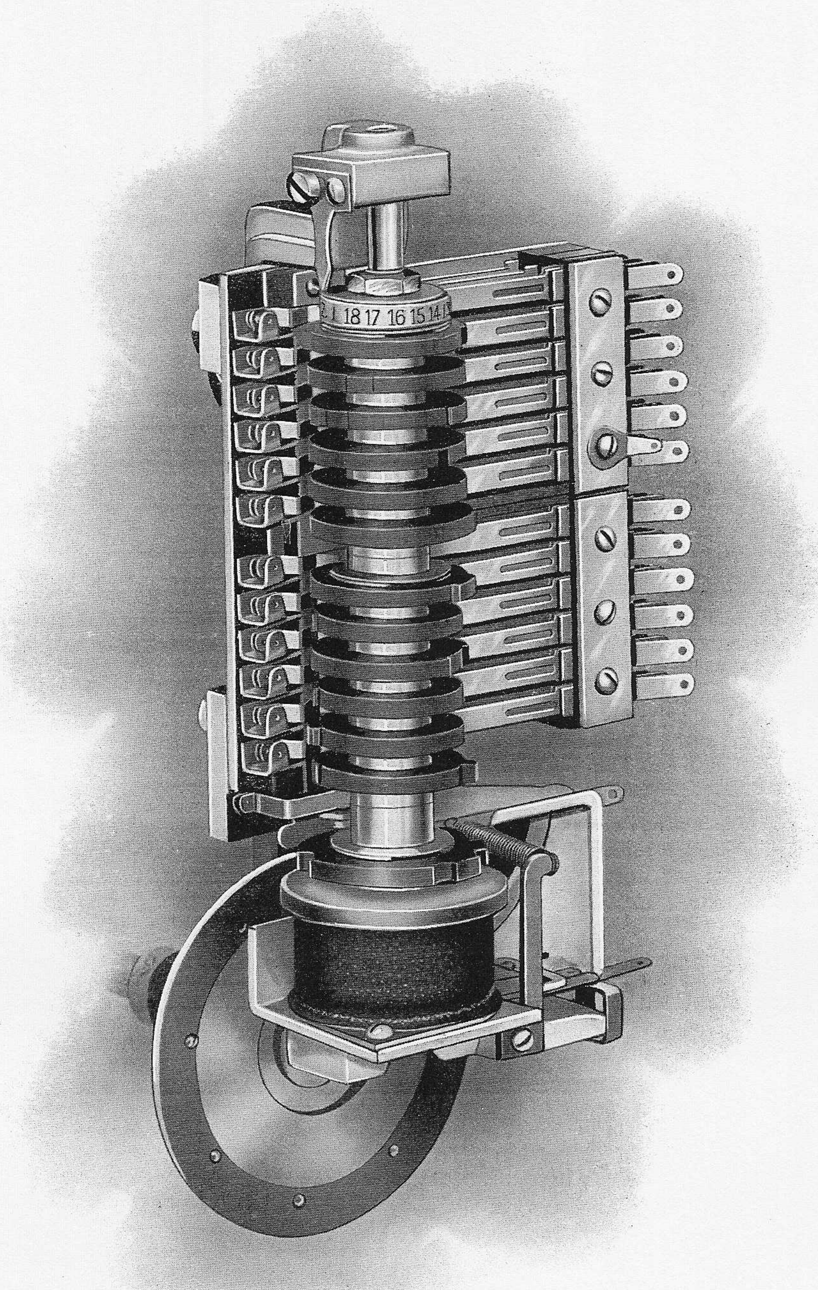


Figure 18.

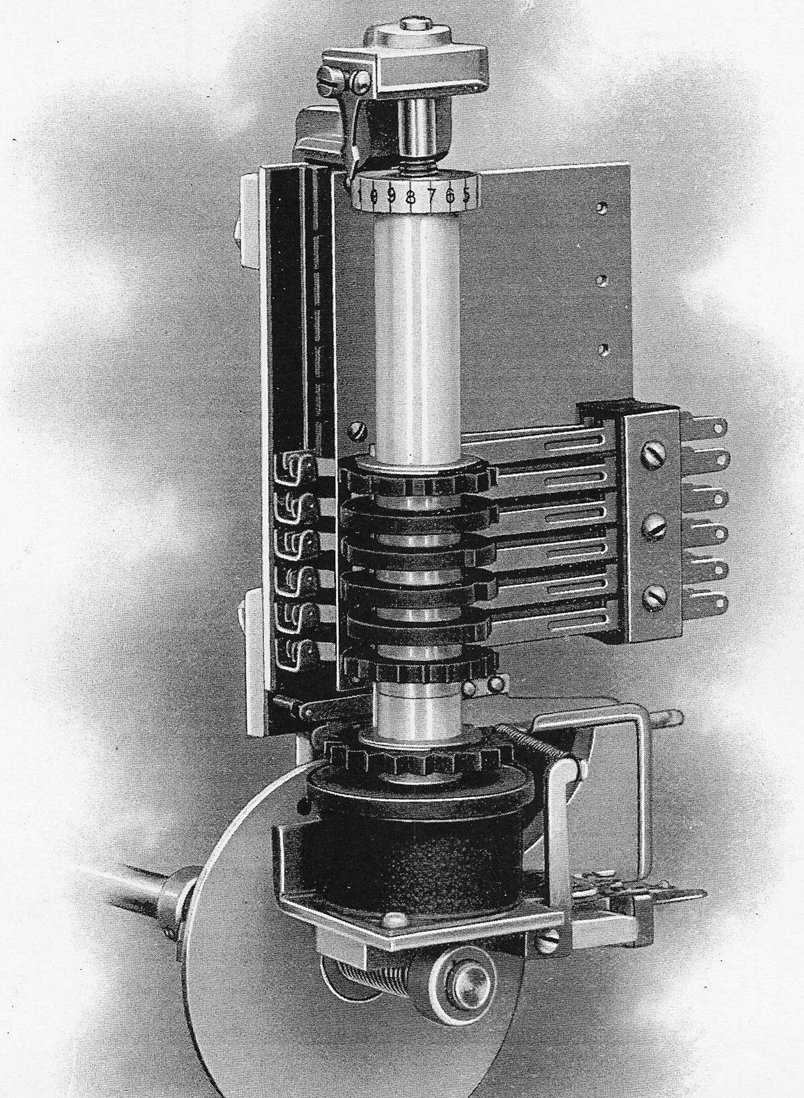


Figure 19.

GENERAL DESIGN FEATURES.

SCHEME OF MACHINE GROUPING.

The scheme for grouping machines in the Western Electric system, is best described by outlining the reasons for grouping switches in any automatic system.

For an easier understanding, it will be assumed at first, that only one connection is handled at a time, following which the case of simultaneous connections will be considered.

If it were economical to build selectors, having as many terminals as there are lines connected to the office, then each connection would require merely one selector ; but such a selector would have to be provided for each subscriber's line, manifestly a very costly plan.

In order to reduce the number of such selectors as far as possible, there is provided for each selector a switch, known as a line finder, whose brushes move to connect with a calling line, thus connecting the latter to the selector. A simple form of such a circuit is shown in a diagrammatic way in FIG. 20.

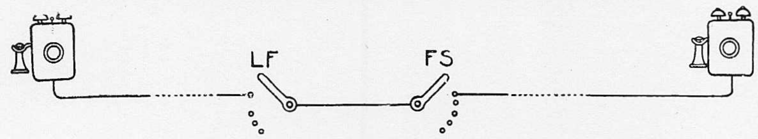


Fig. 20

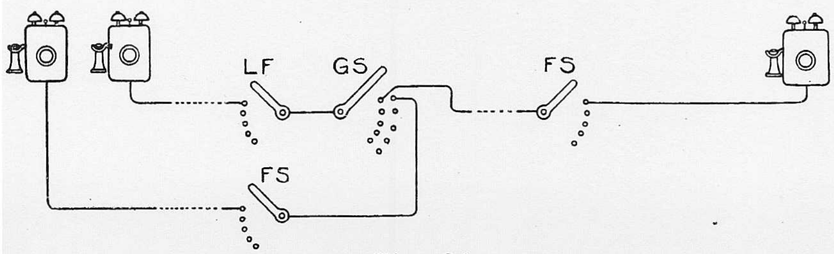


Fig. 21

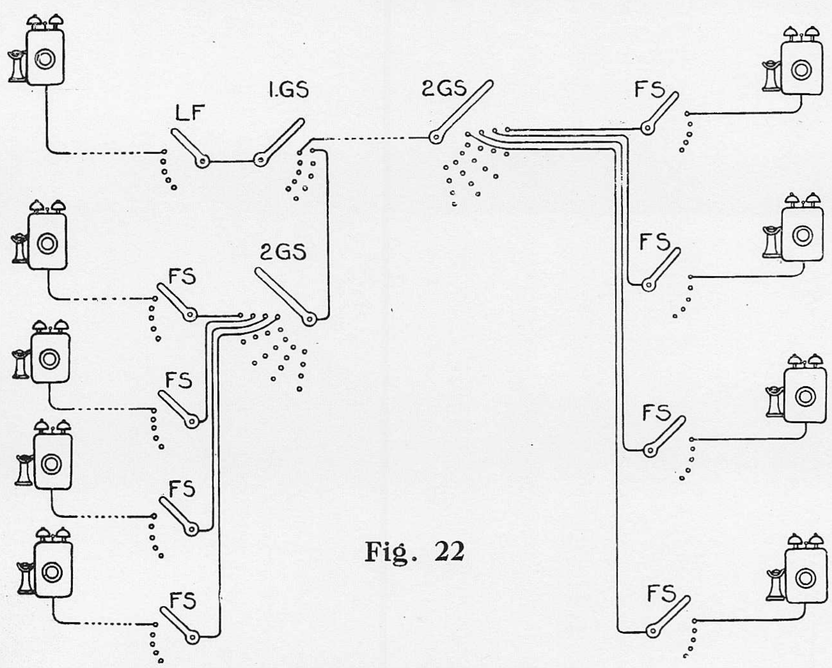


Fig. 22

The subscribers' sets are always connected, though not so shown, to the terminals of both the line finder (LF) and the final switch (FS), so that a line may both call and be called.

If there were two such offices in town instead of one, and if the final selectors or switches in each office have, as before, terminals for all the lines connected to that office, it is at once clear that the simple pair of switches mentioned above will no longer suffice, as a calling subscriber might have to be connected with a final switch in one office or the other, depending on where the wanted line is connected. To permit such switching to one office or the other, a group selector or switch must be provided with two rows of terminals. FIG. 21 shows, in a simple diagrammatic way, such a group switch (GS), whose brushes are connected to those of the line finder and whose terminals are connected to junctions, leading to the final switches either in the same office or the second office. The two terminals needed in the group switch are not placed side by side, but one over the other, the brush being provided with mechanical means for reaching either terminal as required. The group switch of FIG. 21 can be made to serve ten offices instead of two, by providing ten rows or levels of terminals. It has been found economical to use throughout the system, group switches, having such ten levels.

Final switches, having as many terminals as there are lines connected to the office, would be, however, excessively costly, and for this reason, switches having a smaller capacity, must be used and the necessary mechanism for their proper selection added. Such commercial final switches have a capacity of 100 to 200 lines. If 200 line final switches are to be used, instead of the large switches mentioned above, such a switch must be supplied for each group of 200 lines connected to the office. This at once raises the problem of connecting a call coming from Office I to that particular one of the final switches where the terminals of the line wanted are found. A group switch again serves the purpose.

Such an arrangement for two offices with 800 lines served by four final switches in each office is shown in FIG. 22. The group switch (2.GS) that was added, is permanently connected to the incoming junction line from Office I and possesses four levels of terminals, connected to the four final switches by junction lines. The conductors, connecting the terminals of a switch with the brushes of the next switch, whether running between offices or between racks in the same room, are usually called junctions. A similar second group switch (2.GS) is furnished in Office I, permitting a call for an Office I subscriber to reach that final switch, where the wanted line is connected.

If the second group switch were equipped with ten levels, as was the first group switch, it would permit connecting ten final switches and by this means provide a total capacity of 2000 lines per office. If there are ten offices connected to the ten levels of the first group switch, the capacity of the exchange area becomes 20,000 lines, and, as it is immaterial whether these ten offices are in ten buildings or concentrated in one building, because the grouping of the switches and the selection of groups remains the same, the grouping scheme is also that for a 20,000 line office.

Capacities exceeding 20,000 lines require another group switch. For an area of three offices of 20,000 lines each, a first group switch is provided with three levels connected, one to each office, in order that a call may be switched to any one of the three offices, there to be connected to the line wanted as already described. As the new first group switch has ten levels, this provides for 200,000 lines. The first and second group switches of the 20,000 line area, now become the second and third group switches, respectively.

The line finder, assumed above to have as many terminals as there are lines in the office, can be readily reduced to a commercial size of say 60 lines without introducing any group switches, as the line finder performs no selecting operation and merely seeks a calling line. Its prime function is to reduce the number of first group switches by concentrating the traffic.

In the discussion, it was assumed throughout that only one call at a time would be passed through the system. In reality, a large number of calls must be handled simultaneously, the number of such simultaneous connections depending on the number of busy hour calls originated and on the length of each connection. If calculations show, for example, that there are at least ten connections up simultaneously during the busy hour towards a given group of 200 subscribers' lines, then there must be installed ten final switches. The terminals of these switches, which are said to form a group, are all multipled together and connected to the 200 subscribers' lines. The brushes of these switches are connected to ten terminals of a level on the preceding second group switch. For heavy traffic as many as 22 final switches might be furnished.

The second group switch, introduced in Office II. (FIG. 22) has ten levels, each level connected to a final switch serving 200 lines. Any additional final switches provided in any group for the traffic, will be connected to the group switch terminals of a level,in order that the second group switch may be able to sweep its brushes over the terminals in a level to seek an idle junction towards a final switch, an operation called junction hunting. With one such second group switch, only one connection can be established towards the 2000 subscribers' lines. For the total traffic towards these lines, there must be furnished, therefore, as many second group switches as the maximum number of simultaneous connections that may be expected in the busy hour. As each additional second group switch furnished must be able to reach any final switch in the entire group for 2000 subscribers' lines, its corresponding terminals must be multipled with the terminals of the second group switch mentioned. In other words, the terminals of all second group switches, serving a group of 2000 lines, are multipled together. Such a group of second group switches is furnished for each group of 2000 subscribers' lines connected to the office.

First group switches are furnished in number equal to that of the line finders. Each level of the group switch must be connected to the second group switches having access to a particular 2000 lines. Usually any one first group switch cannot reach all of the second group switches in a group, but only 22 of them as there are only 22 terminals per level. The terminals of all first group switches, reaching these same 22 machines, are multipled together. The number of first group switches, so multipled together, depends entirely on the traffic, the number being smaller as the traffic increases.

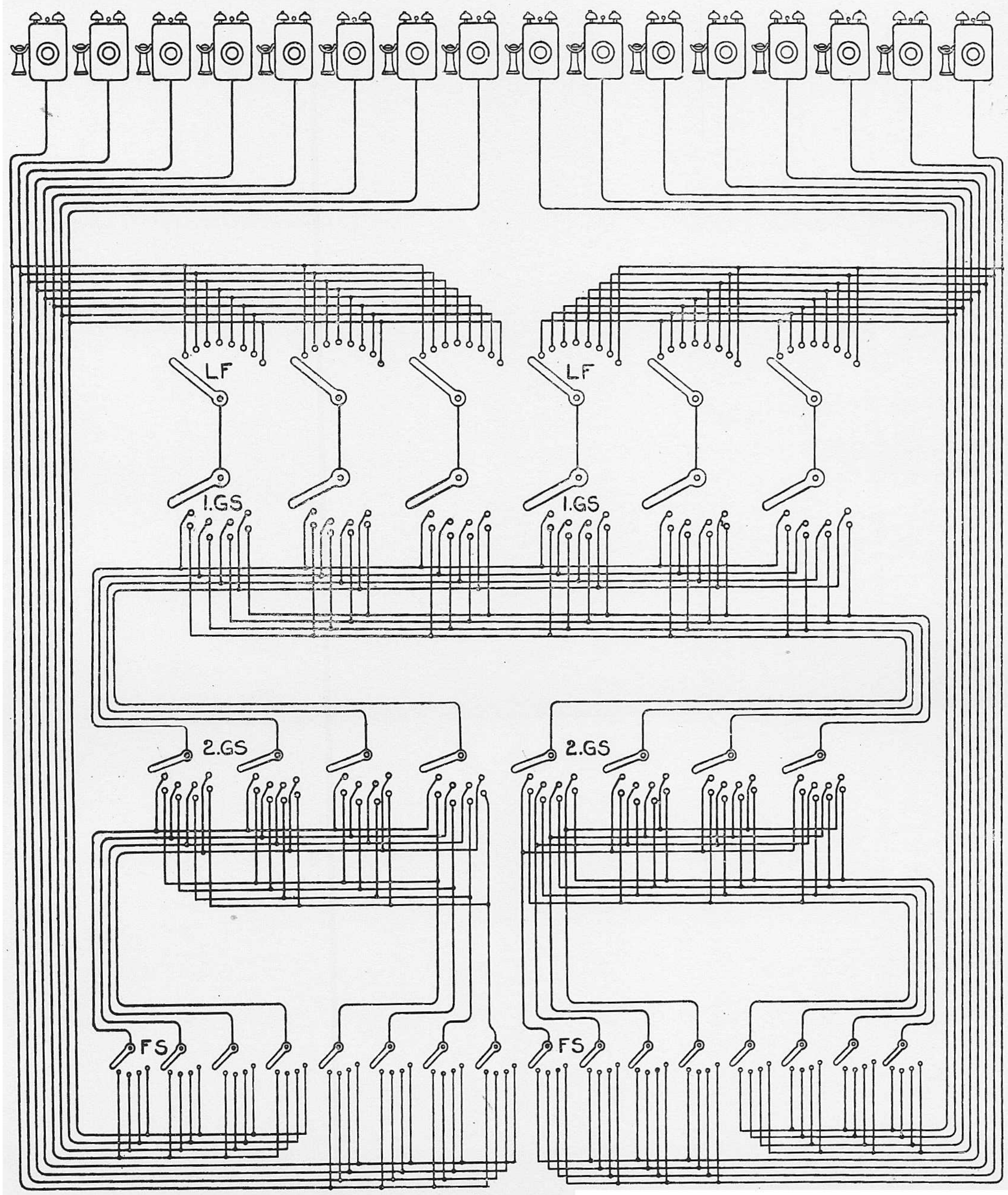


Fig. 23.

The line finders similarly are furnished in number depending on the traffic. If the subscribers' lines call very little, one line finder would be sufficient, but if they call often, a number of finders must be furnished in order that all connections required simultaneously may be served. Eight or more are often provided per 60 lines. The terminals of these are multipled together and connected to the 60 subscribers' lines, so that any finder of the eight may connect to a calling line. The brushes of the line finders are connected to the brushes of the first group switches, there being for each line finder a group switch.

A simple grouping and multipling scheme is represented in FIG. 23 where there are :—

6 8-point line finders, divided into two groups to serve 16 subscribers' lines ;

6 first group switches (8-point) equal in number to the line finders and having two levels connected to two groups of second group switches ;

8 second group switches (8-point) connected to the two levels of the first group switches, and

16 final switches (4-point) divided into four groups, each switch arranged for four subscribers' lines.

JUNCTION GROUP EFFICIENCY AND LAWS OF PROBABILITY.

In the discussion of the grouping of switches, it was mentioned that as many switches must be supplied in any group as there are connections to be established simultaneously. It is of great importance to supply the correct number of switches for such maximum traffic, as a lack of switches inevitably entails a delay or a failure to establish connections and an excess of switches involves depreciation and maintenance of costly and useless equipment.

The problem of predicting the maximum number of simultaneous connections, corresponding with a given number of calls passing at a given rate, is one that closely resembles those treated by the mathematical doctrine of probability.

Expressed mathematically, it concerns the relation existing between the total number of events in a period occurring on a chance basis, and the number of the events existing simultaneously, each event having a given duration. As switches must be provided for the total number existing simultaneously, it is the maximum number of events existing simultaneously during the period, that must be determined.

Such maxima will vary with the time of duration of each event. Maxima will increase as the time of duration increases. Maxima will also vary with the degree of accuracy or failure frequency that was premised. A given maximum will be exceeded less often than a maximum of smaller magnitude. In a switchboard, for example, it might happen only once a week that more than ten cord circuits are simultaneously in use, but it would happen only once in six months that more than 14 are in use. The larger maximum is exceeded more rarely ; in other words, the failure frequency decreases with the larger maxima.

The probability calculations investigating these relations resulted in a series of charts, which were deduced purely from the mathematical theory. The question was then raised, whether actual telephone traffic is so distributed in the ordinary telephone exchange, that it is accurately represented by the mathematical curves deduced. A careful comparison of the calculated results with those obtained from a study of actual telephone traffic under varying conditions showed that there is a close agreement.

It is not a surprise that such close agreement should be found, as American operating companies have for years used similar curves for predicting simultaneous maxima for given traffic data, upon which basis toll lines were then constructed.

Such probability curves permit the calculation not only of the number of final switches, required for 200 subscribers' lines calling at a given rate, but also of the number of switches in any group necessary to handle a given volume of traffic, which passes through in a given form of traffic division.

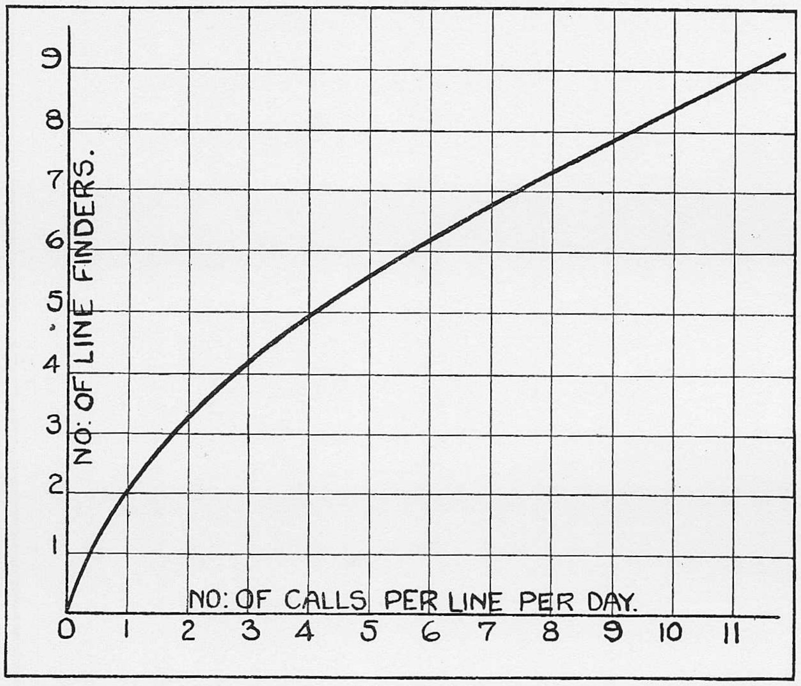


Fig. 24.

The degree of accuracy or failure frequency demanded, is fixed by the number of call delays due to lack of switches, that is to be tolerated. In the Western Electric system it is usual to assume that one call in a thousand may be delayed, this representing three calls per annum for the average subscriber. And it is to be noted that, due to the continuous junction hunting feature, such calls fail only in the sense that they are not completed without delay. In actual practice, the junction switch will find an idle junction after a few revolutions of the brush carriage, so that the delay is measurable in seconds.

By way of illustration, the Curve Fig. 24 is added to show how the number of 60 point line finders varies with the calling rate, with an average length of conversation and an accuracy of one call delayed per 1000.

Besides permitting the accurate prediction of the number of machines required in any group for a given busy hour traffic, these curves and formulae enable the investigator to study the larger problem of junction group efficiency and its effect on the economical size of machine.

To illustrate this point, Curve Fig. 26 has been drawn, showing the number of final switches required for a varying calling rate, delay frequency being one in 1000. Two curves are plotted, one for the Western Electric 200 line switch and one for a 100 line switch ; the dotted curve is made by doubling the ordinates of the latter and represents the number of switches required for 200 subscribers' lines, when 100 line switches are used. The difference is partly off-set by the somewhat increased cost of the 200 line switch, but it is not off-set entirely, so that the 200 line type comes nearer the economical type.

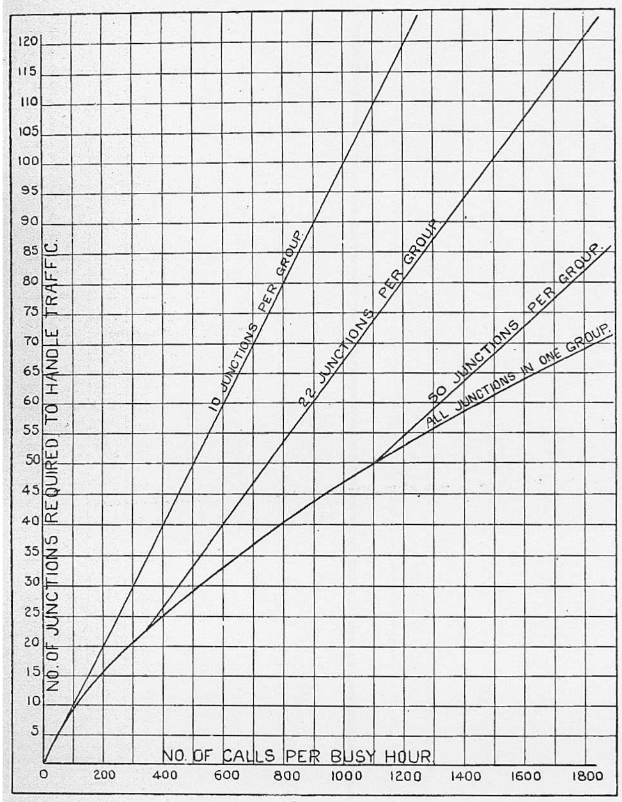


Fig. 25.

Another illustration is given in Curve Fig. 25 where are plotted the numbers of junctions required for a varying number of calls per hour, delay frequency being one in 1000. This curve is drawn for the case, first, where all the junctions are in one group, the usual case in manual junctions between offices where any operator has access to any junction; second, where the junctions are divided in groups of 22 each, which represents the usual arrangement in the Western Electric Machine Switching System as described under grouping ; third, where the junctions are divided in groups of 10 each, which is the case in the usual step by step systems ; and fourth, where the junctions are divided in groups of 50 each, which might be required, when machines are connected to very long and costly junctions, which must be kept as few as reasonably possible.

From Curve Fig. 25 the number of junctions, and therefore the number of machines, is seen to decrease as the number of terminals in a row of a group switch increases ; but as the number of terminals per row increases, the cost per machine is increased. The Western Electric group switch having 22 terminals per row comes very close to a point, where the product of the two variables is a minimum for this type of design and construction.

TRANSLATION.

As was briefly described, the study involving the balancing of the decreasing number of switches against increasing cost per switch, showed that the 200 line final switch is very near the economical point for the particular selector type on the basis of present apparatus design knowledge and practical manufacturing possibilities.

It is at once clear, that the impulses on the 10 by 10 by 10 basis sent out by the subscriber, are no longer able to control the arm of the final switch and set it on the terminal wanted, and that some apparatus is needed to convert the impulses, sent in on a decimal basis, into a series of impulses on a basis corresponding to the grouping of the terminals of the final switches. The piece of apparatus that performs this unusual function among others, is the register.

For a clearer understanding of the operation of the system, it is necessary to outline briefly the principles underlying the process of translation. The electrical and mechanical means employed by registers to perform translation will be described later.

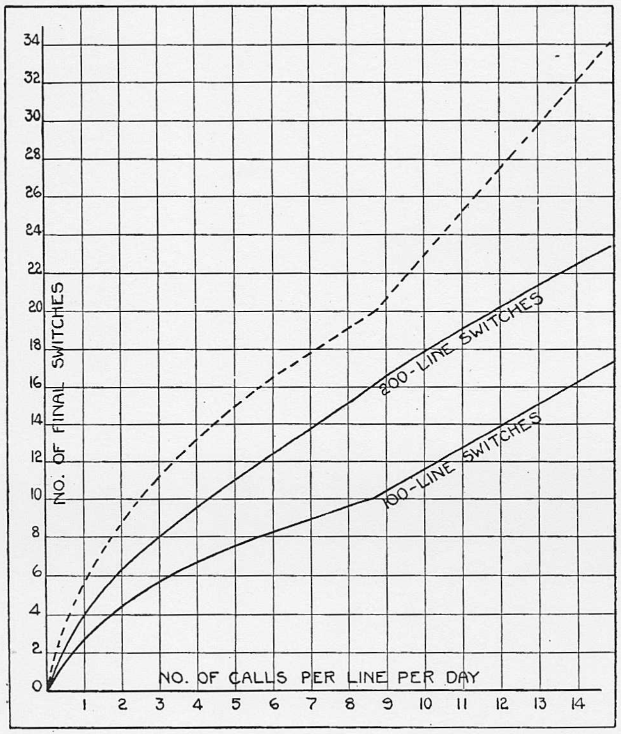


Fig. 26.

The subscriber in sending the number, produces by his sender a series of impulses corresponding to the digits of the number wanted, as follows :—

For digit :	1,	2,	3,	4,	5,	6,	7,	8,	9,	0,
Subscriber sends :	1,	2,	3,	4,	5,	6,	7,	8,	9,	10 impulses.

The assumption that the digit 0 is sent by 10 impulses, considerably simplifies the description of translation. The impulse scheme in which digit 0 is sent by 1 impulse, will be discussed later.

For simplicity of expression, it will often be stated in the following that the register sends out impulses. It is to be remembered, that the register does not control distant switches by sending out impulses ; this control is exercised by having the distant switches send back impulses towards the register, the number of which is measured off by the latter, on the reverse impulse control basis.

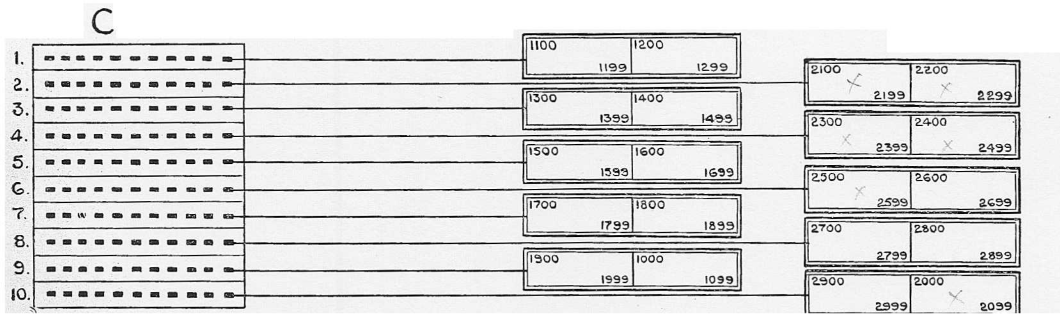
In a system with 100 line switches, whose terminal numbering is shown in FIG. 27 at A, a subscriber wishing to call N°96 sends 9-6 impulses, of which the nine impulses will step the brush of the final switch to the ninth level, and the six

A

1.	11	12	13	14	15	16	17	18	19	10
2.	21	22	23	24	25	26	27	28	29	20
3.	31	32	33	34	35	36	37	38	39	30
4.	41	42	43	44	45	46	47	48	49	40
5.	51	52	53	54	55	56	57	58	59	50
6.	61	62	63	64	65	66	67	68	69	60
7.	71	72	73	74	75	76	77	78	79	70
8.	81	82	83	84	85	86	87	88	89	80
9.	91	92	93	94	95	96	97	98	99	90
10.	01	02	03	04	05	06	07	08	09	00

B

1.	111	112	113	114	115	116	117	118	119	110	211	212	213	214	215	216	217	218	219	210
2.	121	122	123	124	125	126	127	128	129	120	221	222	223	224	225	226	227	228	229	220
3.	131	132	133	134	135	136	137	138	139	130	231	232	233	234	235	236	237	238	239	230
4.	141	142	143	144	145	146	147	148	149	140	241	242	243	244	245	246	247	248	249	240
5.	151	152	153	154	155	156	157	158	159	150	251	252	253	254	255	256	257	258	259	250
6.	161	162	163	164	165	166	167	168	169	160	261	262	263	264	265	266	267	268	269	260
7.	171	172	173	174	175	176	177	178	179	170	271	272	273	274	275	276	277	278	279	270
8.	181	182	183	184	185	186	187	188	189	180	281	282	283	284	285	286	287	288	289	280
9.	191	192	193	194	195	196	197	198	199	190	291	292	293	294	295	296	297	298	299	290
10.	101	102	103	104	105	106	107	108	109	100	201	202	203	204	205	206	207	208	209	200



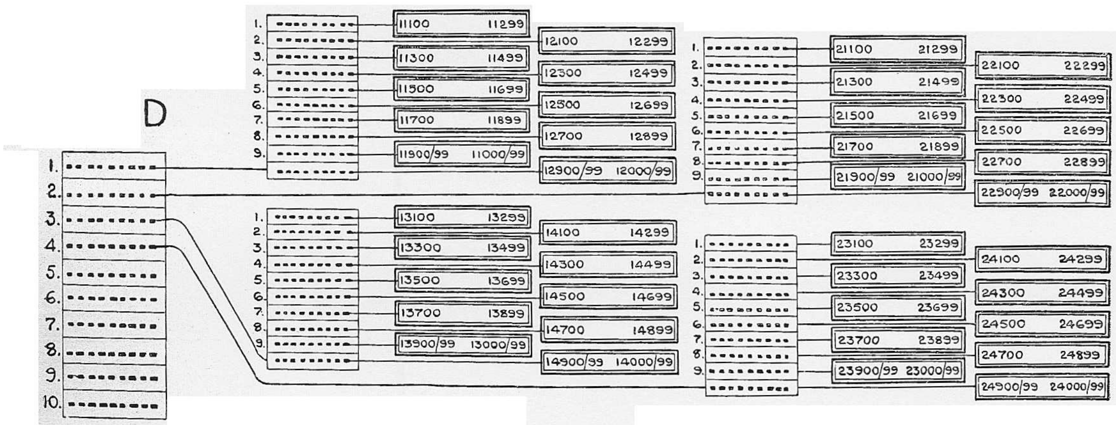


Fig. 27.

step the brush over six steps to terminal 96. Wishing to call N° 396, he sends 3 - 9 - 6 impulses, of which the three moves the brush of the group switch to the third level, while the 9 and 6 as before control the final switch. Wishing to call N° 2396, he sends 2 - 3 - 9 - 6 impulses, whereupon the 2 impulses move the brush of the first group switch to the second level, while, as before, the 3 impulses control the brush of the second group switch, and the 9 and 6 impulses control the brush of the final switch.

For the system with 200-line switches, the numbering of a terminal arc is shown in FIG. 27 at B. A glance at the numbering plan indicates that these impulses on a decimal basis, no longer suffice to direct the brushes and that modifications must be made ; such modifications involve the process of translation. The translation required, may be readily determined by an inspection of the arrangement of the terminal numbers, shown in the figure.

To avoid confusion in the description, the series of impulses that is sent out last by the register, will hereafter be called that of the «a» place, that sent out next to the last, that of the «b» place, that sent out third last, that of the «c» place etc. ; the a, b, and c places corresponding with the units, tens, hundreds etc of decimal notation.

The series sent out in the a place, directs the brush of the final switch and is always equal to the digit received in the units place, except that 10 impulses must be added, when the hundreds are even. For example, referring to the numbered arc B for 200 lines, the terminal 196 is reached by stepping the brush 6 steps over, once the proper level has been reached, but to reach 296, the brush must make 16 steps or an additional 10 when the hundreds are even (200, 400, 600, etc.) The register must determine, therefore, whether the hundreds digit is odd or even, and if even, it must send out an additional 10 impulses in the a place.

The series sent out in the b place, is always equal to the digit in the tens place of the number wanted. This series directs the brush in selecting the proper level. For example, if 196 were wanted, there would be needed 9 impulses in the b place to direct the brush of the switch to the ninth level.

The series sent out in the c place, is made up in a special way following a simple rule. This will be readily determined by referring to the numbering plan C, which shows at the left the ten levels of a group switch, whose brushes are to be directed by the impulses in the c place to one of the ten levels. These ten levels are connected by trunks with ten final switches at the right having terminals numbered in the units and tens place like B, it being assumed that the capacity is 2000 lines (Nos. 1000 to 2999). A study of the arrangement shows that:

1. The odd numbered levels (1, 3, 5 etc) have access to the odd numbered hundreds of the same magnitude when the thousands are odd ; therefore, to call 1396, 3 impulses (equal to the hundreds digit) are sent in the c place ;

2. The odd numbered levels also have access to the next higher (even) hundreds ; therefore, to call 1496, 3 impulses (equal to the hundreds digit (4),

less one, when the hundreds are even) must be sent in the c place ;

3. The even numbered levels have access to the same odd hundreds as those of the previous level but in the next even thousand; therefore, to call 2396, 4 impulses (equal to the hundreds digit (3), plus one, as the thousands are even) must be sent in the c place ;

4. These even numbered levels also have access to the next higher (even) hundreds in the same thousand ; therefore, to call 2496, 4 impulses (equal to hundreds digit (4), minus one as the hundreds are even, and plus one as the thousands are even) are sent in the c place.

It follows from the above, that the series sent out in the c place is always equal to the digit in the hundreds place of the number wanted, except that one impulse is deducted when the hundreds are even, and except that one impulse is added when the thousands are even.

The series sent out in the d place is made up like that of the c place, the principle being to send impulses equal to the original thousands digit received, minus one if this be even and plus one if the ten thousands digit received be even. The reason for this will be clear, on inspecting the numbering plan D to the left of FIG. 27, showing the terminal arcs of a first group switch whose terminals are connected by junction lines (only four shown) with the brushes of second group switches (only four arcs are shown). The latter again are connected by junction lines with the brushes of the final switches (four groups of ten each are shown) whose terminal numberings are given. Here again, the register must test the thousands and ten thousands digit impulses received, for odd or even and add or subtract an impulse as required as explained in connection with the c place.

Similarly the series sent out in the e place is made up by taking the digit in the ten thousands place and modifying it as described for the d place ; and so for the f place, if the system has this capacity.

This briefly outlines the fundamental principles involved in the translation process. There are other ways possible for numbering the 200 terminals in the final switch, as also for connecting the levels in a group switch.

In the Western Electric System, it has been found preferable at times to follow the scheme of placing 0 at the beginning of the digit series, so that in the semi-automatic System the impulses would be sent as follows :—

For digit :	0,	1,	2,	3,	4,	5,	6,	7,	8,	9,
Operator sends :	1,	2,	3,	4,	5,	6,	7,	8,	9,	10 impulses.

The numbering of the switch arcs then becomes that shown in FIG. 28. The scheme of translation required for this impulse scheme, is made up on the basis already discussed and will be found to be the following :

The impulses in the a place are equal to the impulses sent for units digit, plus 10 impulses when the hundreds digit is odd (100, 300, 500, etc.) ;

The impulses in the b place are equal to the impulses sent for the tens digit ;

The impulses in the c place are equal to the impulses sent for the hundreds digit, but minus one when the hundreds digit is odd and plus one when the thousands digit is odd ;

The impulses in the d place are equal to the number of impulses sent for the digit in the thousands place, but minus one when the thousands digit is odd, and plus one when the ten thousands digit is odd, etc.

To take an example, the subscriber wishing N° 2396, the operator presses keys 2 - 3 - 9 - 6, which sends 3 - 4 - 10 - 7 impulses into the register.

B

1.	000	001	002	003	004	005	006	007	008	009	100	101	102	103	104	105	106	107	108	109
2.	010	011	012	013	014	015	016	017	018	019	110	111	112	113	114	115	116	117	118	119
3.	020	021	022	023	024	025	026	027	028	029	120	121	122	123	124	125	126	127	128	129
4.	030	031	032	033	034	035	036	037	038	039	130	131	132	133	134	135	136	137	138	139
5.	040	041	042	043	044	045	046	047	048	049	140	141	142	143	144	145	146	147	148	149
6.	050	051	052	053	054	055	056	057	058	059	150	151	152	153	154	155	156	157	158	159
7.	060	061	062	063	064	065	066	067	068	069	160	161	162	163	164	165	166	167	168	169
8.	070	071	072	073	074	075	076	077	078	079	170	171	172	173	174	175	176	177	178	179
9.	080	081	082	083	084	085	086	087	088	089	180	181	182	183	184	185	186	187	188	189
10.	090	091	092	093	094	095	096	097	098	099	190	191	192	193	194	195	196	197	198	199

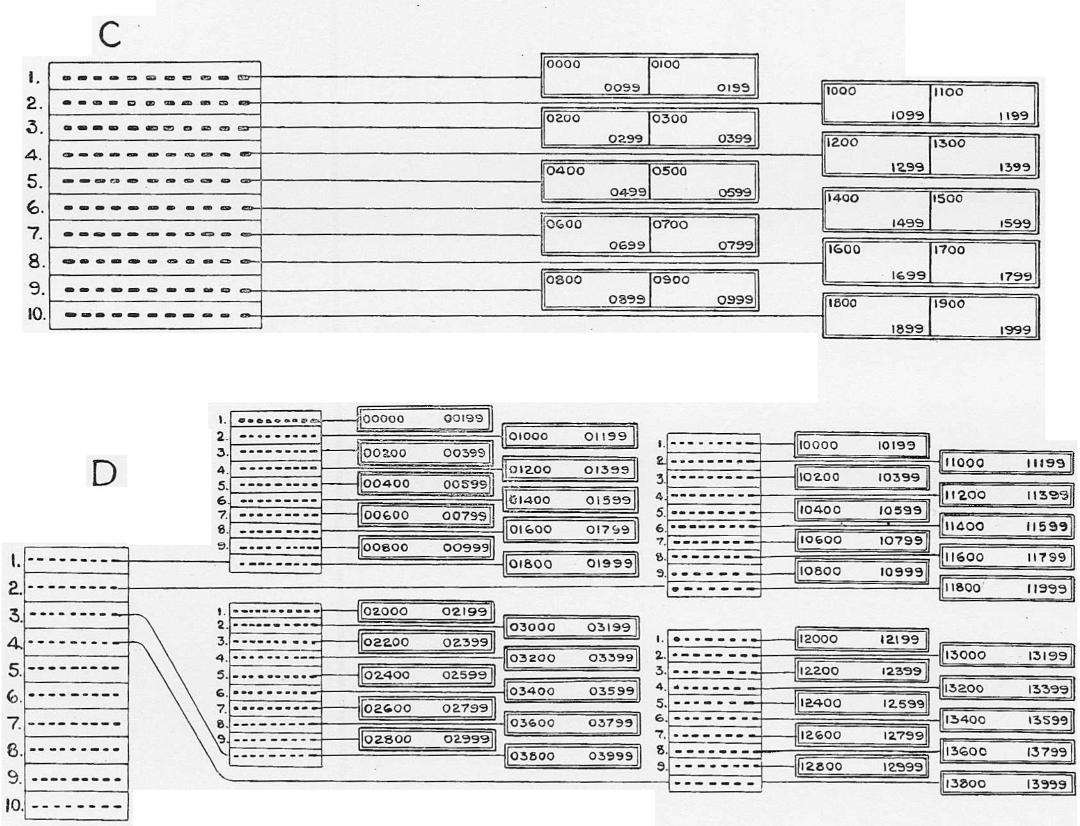


Fig. 28.

The translated series to reach N° 2396 will then be 3 - 3 - 10 - 17 and is obtained as follows :—

In the d place, 3 impulses are sent equal to the impulses in the thousands place (3) ; as the thousands digit (2) is even, no impulse is subtracted, and as the ten thousands digit (0) is even, no impulse is added ;

In the c place, 3 impulses equal to the impulses in the hundreds place (4) minus 1 as the hundreds digit (3) is odd; as the thousands digit (2) is even, no impulse is added ;

In the b place, 10 impulses are sent equal to the impulses in the tens place.

In the a place, 17 impulses are sent equal to the impulses in the units place (7) plus 10 as the hundreds digit is odd (3).

The impulses in the full automatic System on this basis would be sent, for reasons given in the description of register operation, on the complementary basis, as follows :

For digit :	0,	1,	2,	3,	4,	5,	6,	7,	8,	9,	
Finger-wheel sends :	10,	9,	8,	7,	6,	5,	4,	3,	2,	1	impulses ;
But register allows :	1,	2,	3,	4,	5,	6,	7,	8,	9,	10	impulses

to be taken out. The translation scheme is then that outlined for the semi-automatic System.

REGISTERS.

In the Machine Switching System the register stands at the center of an extensive and elaborate scheme of control.

The control of the switches instead of being exercised directly by the sender operated by the subscriber, is transferred to the register located in the central office. The control is in this way exercised more accurately and better timed. The subscriber merely sends the number ; the register receives the number, translates it, and allows the new series of impulses to be taken out just as fast as the switches can receive them and no faster. A switch that moves slowly, is as well served as a fast one.

The register does not wait until all of the impulses have been received from the substation sender before beginning to send out impulses, but sends out each set immediately after it has been received.

The register, having sent a series of impulses, waits until the group switch has found an idle junction and has connected the register to the next group switch ; it only begins to control the next set of impulses when the next switch to be controlled is ready. If all the junctions happen to be busy, it will wait, while the group switch carriage continues to revolve, hunting an idle junction, and only when found it continues to control. Calls are at such times merely delayed and do not fail.

The register allows, therefore, successful junction hunting over large junction groups, such as 50, if required for very costly junction lines.

Removing switches from the subscriber's control, opened the way for building massive, rigid, power-driven switches that can be operated at their best speeds and are independent of rapid substation senders.

On the other hand, impulses sent by the subscriber are accurately received by the register, a light, fast and sensitive piece of apparatus, that responds accurately to the rapid substation sender.

A time interval for junction hunting not being necessary between series of impulses sent in, the sender may be operated successively as fast as desired without causing an error.

Having two registers at her disposition, the operator in the semi-automatic System has before her only a single key-set. Any number depressed is promptly taken up by the register, whereupon the key-set is released.

The register, in performing translation, allows an economical size of final switch, such as one for 200 lines, to be used in the system. Such switches involve a smaller plant expenditure for a given capacity and traffic.

The operation of translation permits such special features, as suppressing a series of impulses, when this is required, or converting the name on a depressed office key into a series of impulses that will select the correct office.

Translation can effect not only a re-arrangement of impulses, but it can alter the electrical character of an impulse, and of the change over impulse, so that one kind of an automatic system can be arranged to operate with another type widely different.

POWER DRIVE.

The characteristic mechanical feature of the Machine Switching System is power drive. Through its agency, the force, necessary for moving the mobile parts of the switches, is taken directly from shafting coupled to a central, reliable commercial electric motor, instead of being produced locally by stepping electromagnets.

Power drive allows the application of any amount of power needed for moving a brush carriage or switch spindle, without affecting the selecting speed. With stepping magnets, it is found that the power is limited, as increasing the magnet to increase the power, results also in slowing up seriously the stepping speed of the magnet.

These larger driving forces have greatly influenced the design of the switches, allowing rigidity, massiveness and stability to become cardinal features.

Firm, reliable contacts are readily obtainable, as all the power needed to produce these, can be supplied independently of any magnets.

Sufficient power can be supplied, through its agency, to set the heavy brush carriages rapidly into motion. Once in motion, they are driven with a smooth, even and continuous action, avoiding all vibrations, hammering and the incident heavy wear.

High speeds may be given to all moving parts ; in fact, such speeds are limited only by the accuracy required in stopping the brushes. These high speeds permit junction hunting over large groups.

The wearing margins may be greatly increased and all adjusting springs, cams, screws, etc. eliminated, as any power needed for the increased motion of parts involved for permitting self–adjustment for wear, is available and applicable.

Power drive permits the use of a simple form of circuit for reverse impulse control, described elsewhere, which secures a high degree of accuracy in selection.

Reserve motors are provided and readily switched in when required. Such reserve motors can be operated from the battery, so as to make the exchange independent of the outside power during periods of breakdown.

During hours of light traffic, a portion of the shafting may be stopped. At night all the shafting may be stopped; an automatic device starts up the shafting, when a call is received.

The shafting revolves at a very low speed (31 revolutions per minute), so that it is practicable to design bearings that are subject to very little wear, reducing maintenance to a minimum.

The power required to operate the shafting is very small. A 2 HP motor is more than able to operate the switches in a 10,000 line office.

REVERSE IMPULSE CONTROL.

The usual method for controlling selectors, the direct impulse control method, involves the opening of the circuit at the sending end of a line a definite number of times, causing a series of impulses, each of which drives the selector brush at the distant end, one step forward. The undesirable feature in this control lies in that the selector, which is usually a rather heavy mechanism, is expected to follow the light mechanism at the sending end. A single failure to respond, results in a wrong connection. To eliminate such failures the reverse impulse control method was developed and introduced in the Western Electric System.

Selection, in this improved method, is performed by closing the circuit of the line at the sending end, which causes the distant selector brush to revolve contacting with terminal after terminal. For each terminal the selector sends back an impulse, which steps the sending mechanism one step towards normal. This goes on until the sending mechanism reaches normal, when it opens the circuit and stops the selector brush carriage. If the sending mechanism had been displaced six steps from normal, the brush of the selector would now make contact with the sixth terminal.

The operation is perhaps better described by referring to FIG. 29, which shows a simplified diagrammatic circuit. The complete operation will be described in connection with FIGS. 50 and 51 showing actual circuits.

At the sending end A, there is a simple form of sending mechanism, a power driven register spindle. The spindle is rotated by enregizing the electromagnet RU, which attracts to the iron disc of the spindle S2 the iron disc S1 on

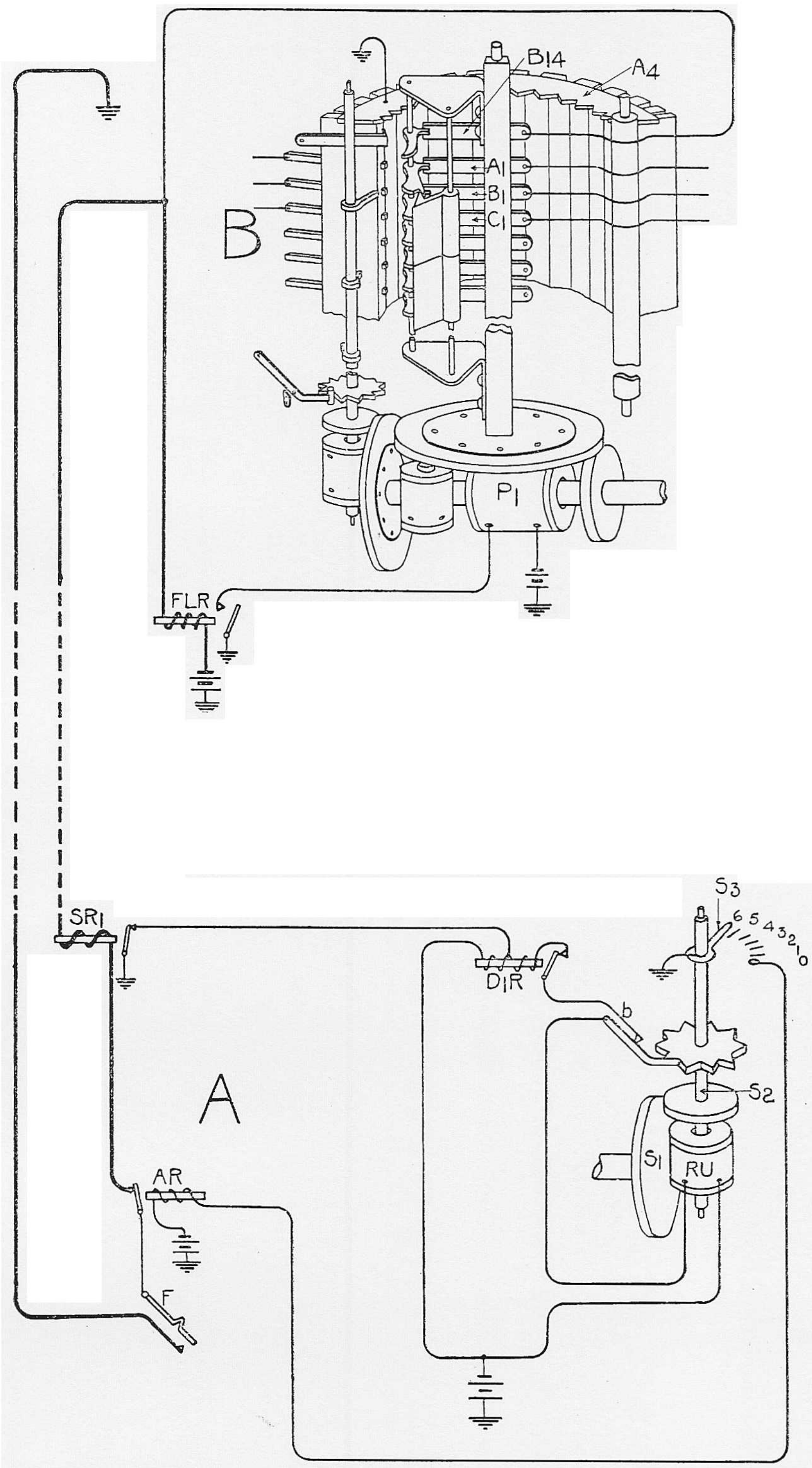


Fig. 29.

the rotating shaft. The spindle carries an arm S3, which can be displaced from normal any number of steps up to ten. In its zero position it closes a contact in a circuit towards a cut-off relay AR. The power winding is connected with the differential relay D1R over a contact b, which is opened and closed, as the spindle is moved from position to position. The differential relay D1R merely serves to prevent the spindle from taking more than one step, when once in motion.

At the distant or receiving end B, is shown a selector with a brush carriage, on which is mounted a brush B14 making intermittent contact with the earthed toothed rack A4. The teeth of this are spaced between the vertical rows of terminals, so that the brush B14 is earthed when the brushes A1, B1 and C1 stand between two sets of terminals and is insulated when the brushes stand on a set of terminals.

The sending and receiving apparatus are connected by the so-called fundamental circuit, drawn in heavy lines, which always contains at one end the selecting relay SR1, the back contact of the cut-off relay AR and a spring F to close the circuit when selection is to begin, and always contains at the other end the line relay FLR and a battery.

The electrical operation is best described by assuming that the selector brushes are to make contact with the sixth set of terminals. To do this, the arm S3 is at first set to position 6, and then spring F is closed, which completes the fundamental circuit, energizing relays SR1 and FLR, with which selection begins. At the same time two springs (not shown) close the two differential circuits of relay D1R, the left hand winding being closed before spring F is closed.

The brush carriage begins to rotate continuously, due to the magnet P1 of the magnetic clutch being energized over the front contact of the energized relay FLR until the sixth set of terminals is reached. In rotating, the brushes A1, B1 and C1 will make contact successively with each set of terminals in a level, while the brush B14 is earthed successively as the brushes pass from terminal to terminal.

The register spindle takes its first step, just before the brushes A1, B1 and C1 reach the first set of terminals, because of the first earthing of the brush B14 on the rack A4. This earthing de-energizes the selecting relay SR1, so that current flows over its back contact to earth in two circuits : through the power winding of RU and the right hand winding of relay D1R ; and through the left hand winding D1R. The two differential windings balance each other, so that the armature of relay D1R is not attracted, but the power winding RU of the spindle is energized and sets the spindle in motion. As it moves from position 6 to 5, the spring contact b is opened, so that the relay D1R is now energized by the left hand winding, attracting its armature and opening the circuit towards the power magnet RU, which stops the spindle centered in position 5 by a special means not shown. In this position contact b is again closed.

When the brushes A1, B1 and C1 reach the first set of terminals, the brushes B14 will be again insulated and thus relay SR1 is re-energized ; whereupon the relay D1R releases, completing the two differential circuits and preparing the spindle to take its next step.

The register spindle takes its second step just before the brushes A1, B1 and C1 reach the second set of terminals, following the second earthing of the brush B14 on the rack A4, which as before, de-energizes SR1 and energizes the magnet RU.

Thus the register spindle takes each additional step, as the brushes are passing to the next set of terminals ; until the spindle has completed its sixth step, which closes the circuit of the relay AR. The latter is operated, opens the fundamental circuit and initiates the stopping of the brush carriage.

The brush carriage, however, is not stopped immediately, as relay FLR continues to get current over the earthed spring B14 until the brushes stand on the terminals, when the brush B14 will be insulated, de-energizing relay FLR and opening the circuit of the power magnet P1, which stops the carriage.

The brushes now stand on the sixth set of terminals and stop there, as the sending mechanism, having made six steps, has reached normal and opened the fundamental circuit.

In discussing the various selecting operations in connection with circuits, there will be found in each case the characteristic fundamental circuit with its line relay at one end controlling the power magnet, and with its selecting relay and contact of the cut-off relay at the other.

The method of controlling switches by reverse impulses presents important advantages. It takes place entirely over a metallic circuit with no grounds at the sending end. The sending or controlling mechanism does not take its step until the brush is taking its next step, so that, if the brush is slow, the mechanism will wait. The impulses that perform the selecting are sent out by the switch towards the sending end ; for this reason no steps can be lost due to the sending mechanism being light, while the brush carriage is heavy and performs work such as closing firm contacts. The brush carriage is not stopped until it has reached the terminals wanted, even though the light sending mechanism has opened the controlling circuit. And finally, it permits the application of power drive in a simple effective manner, to move the relatively heavy brush carriage.

SEQUENCE SWITCH AND RELAY CONTROL.

The general method for building up circuits progressively through a cycle, deserves comment. The exact process for performing this electrically, will be presented in connection with actual circuits.

The sequence switch is at the centre of the system of control. At least one is provided for each line finder, group switch, final switch and register, whose successive motions it initiates and controls. It performs this function by establishing in its various positions successively and in proper sequence, a series of circuits. Of these positions, there are 18, and it passes, in its cyclic motion from position to position, until normal is again reached. In each position in which it stops, it establishes several circuits which remain, until some apparatus in the circuit has operated, performed its function and caused an impulse to be sent to the sequence switch power magnet. The spindle turns into its next position, thereby breaking up the existing circuit and establishing a new one.

Very often two sequence switches control each other, so that one, having performed its function, steps into the next position, thereby sending the second switch into its next position.

In the case of a premature disconnect, circuits are usually established, so that the sequence switch will pass a number of intermediate positions, until it

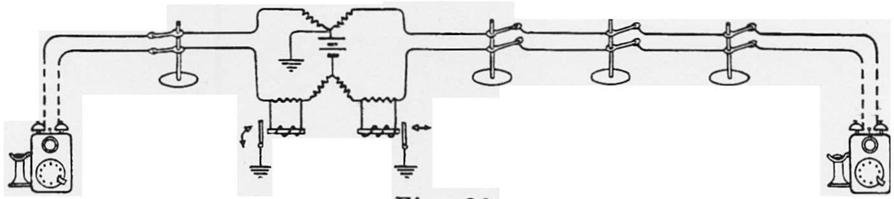


Fig. 30

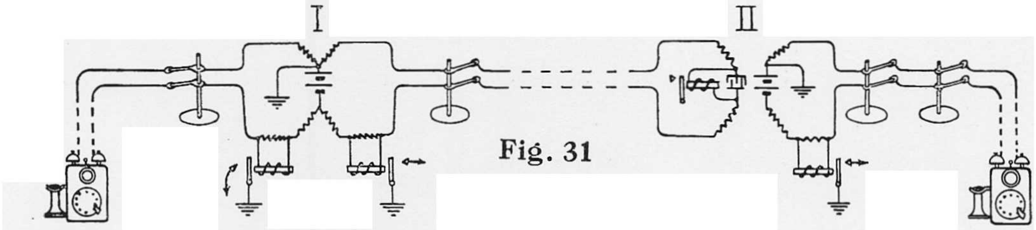


Fig. 31

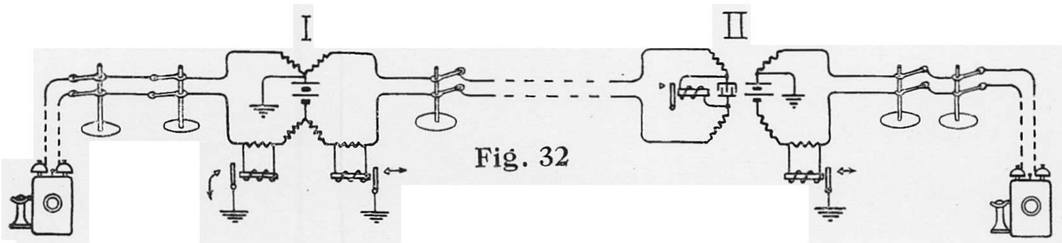


Fig. 32

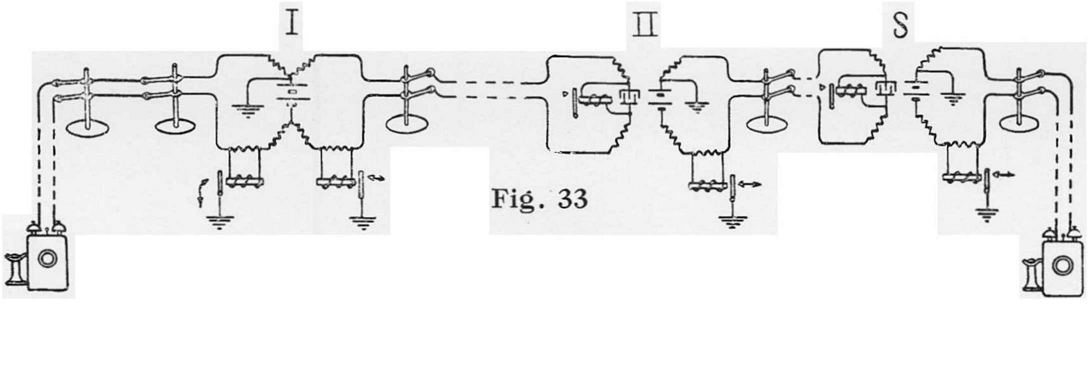


Fig. 33

reaches a position connecting a piece of apparatus which is off-normal, as for example, the carriage of the group switch. Here it stops and applies power to the carriage. When the latter reaches normal, power is cut off and at the same time the sequence switch takes its last step to normal.

Though a sequence switch can pass from one position to another in one eighteenth of a second, it is, nevertheless, not fast enough to perform such a function as the cutting off of the power from a switch. Here relays must be used, being very much faster. The relay, in performing the function, also starts off the sequence switch, which now opens permanently the circuit opened by the relay and moves into the next position closing a new circuit.

TRANSMISSION CIRCUITS.

All transmission circuits established by the switches, will be found, following standard Western Electric practice, to be free from all bridges and grounds and to utilize repeating coils and a 24 volt battery. Retardation coils for battery feed can be provided, when required.

Typical circuits are shown :

FIG. 30 for a full automatic System in a single office ;
FIG. 31 for a full automatic System in two offices ;
FIG. 32 for a semi-automatic System in two offices ;
FIG. 33 for a semi-automatic System in two offices and a satellite (S).

For toll connections the practice varies, as already stated. The standard 48 volt transmission can be given, whether manual switching operators before multiple jacks are employed, or whether a machine plant is provided for toll connections.

If it is desired for special reasons, transmission circuits can be provided using 48 volts and retardation coils instead of repeating coils, for supplying current to the substation transmitters.

The junction between offices is, under certain conditions, entirely cleared from battery and ground during conversation, and differs from that of the circuits mentioned above, in which battery and ground remain, following manual junction working practice.

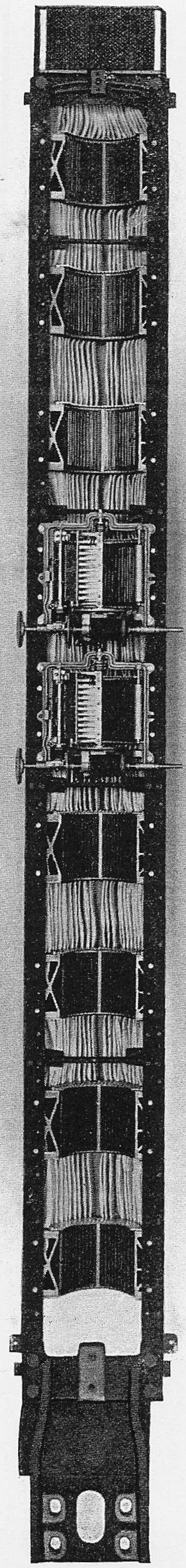


Fig. 34·

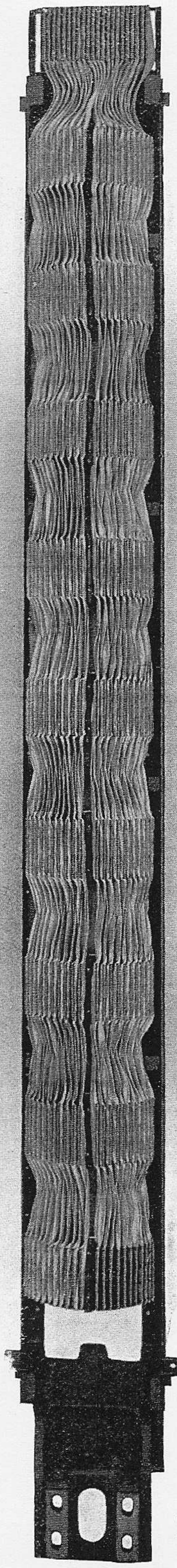


Fig. 35.

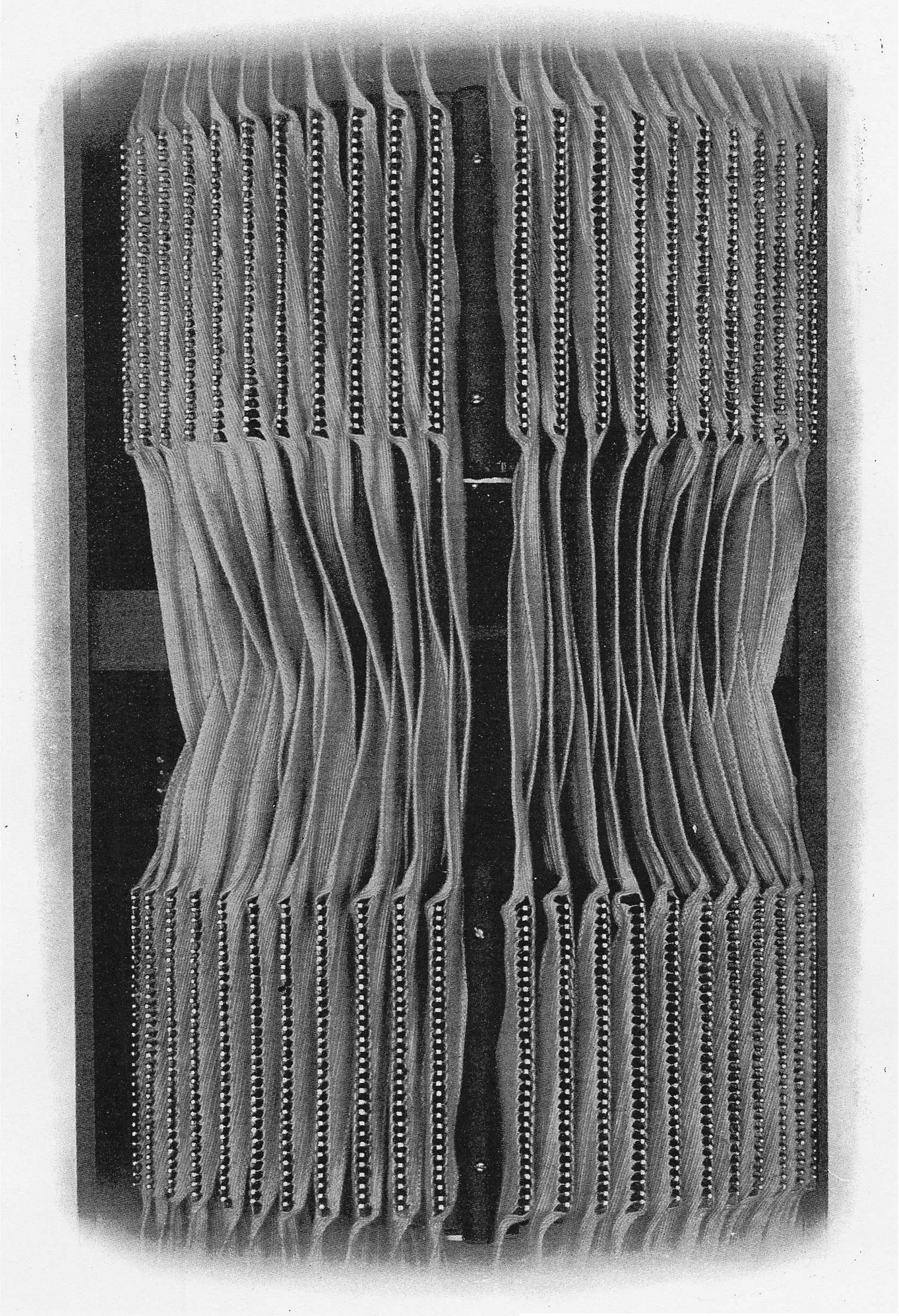


Figure 36.

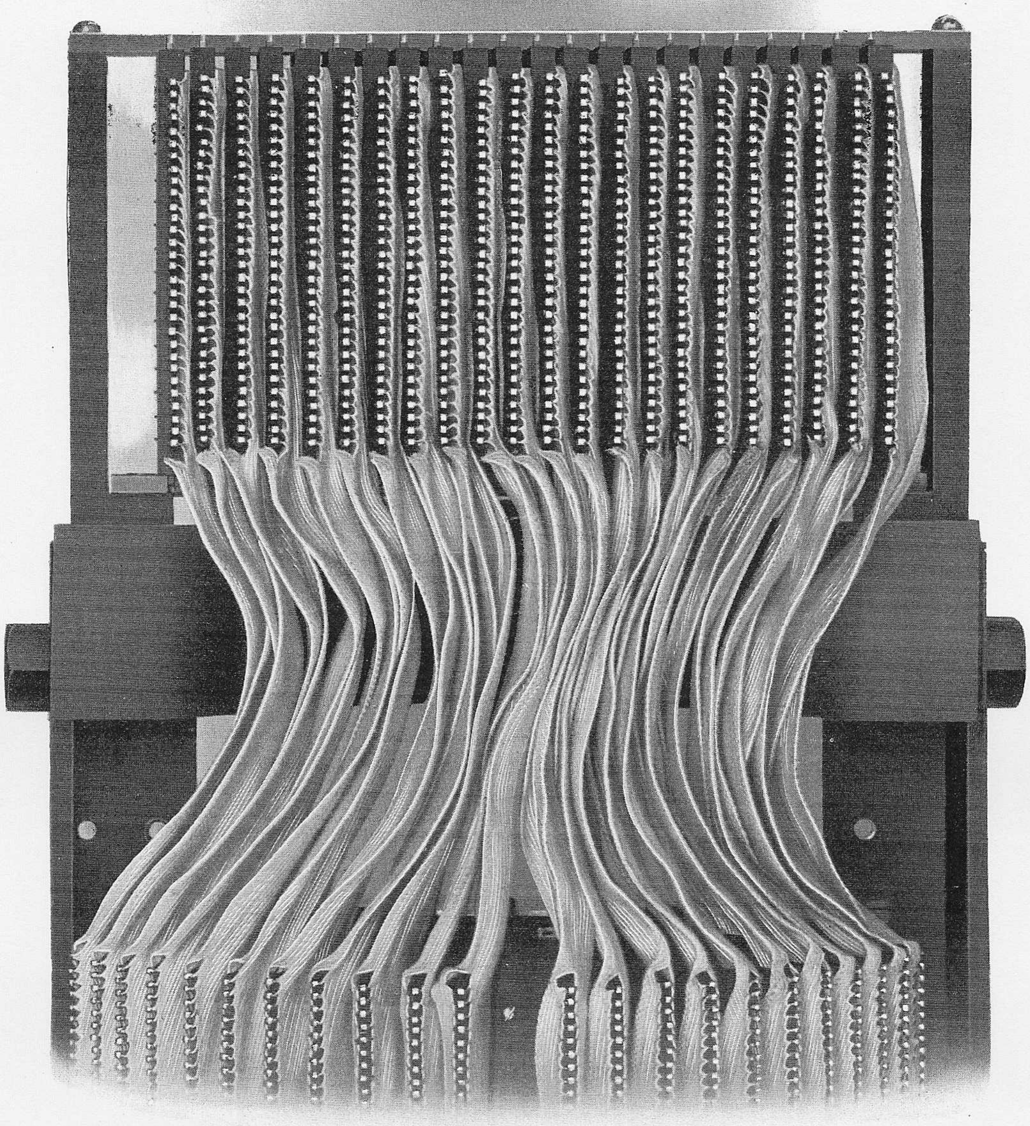


Figure 37.

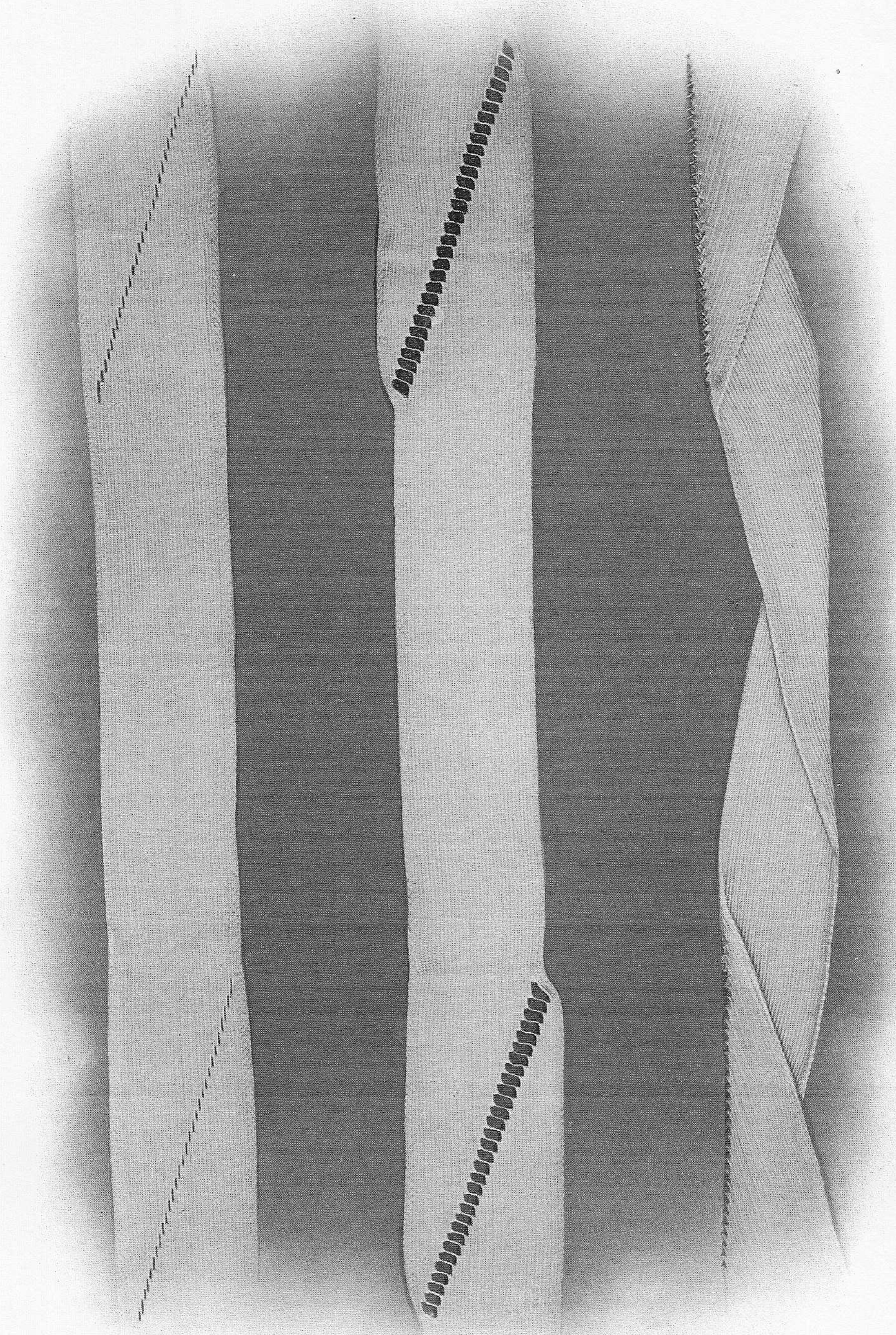


Figure 38.

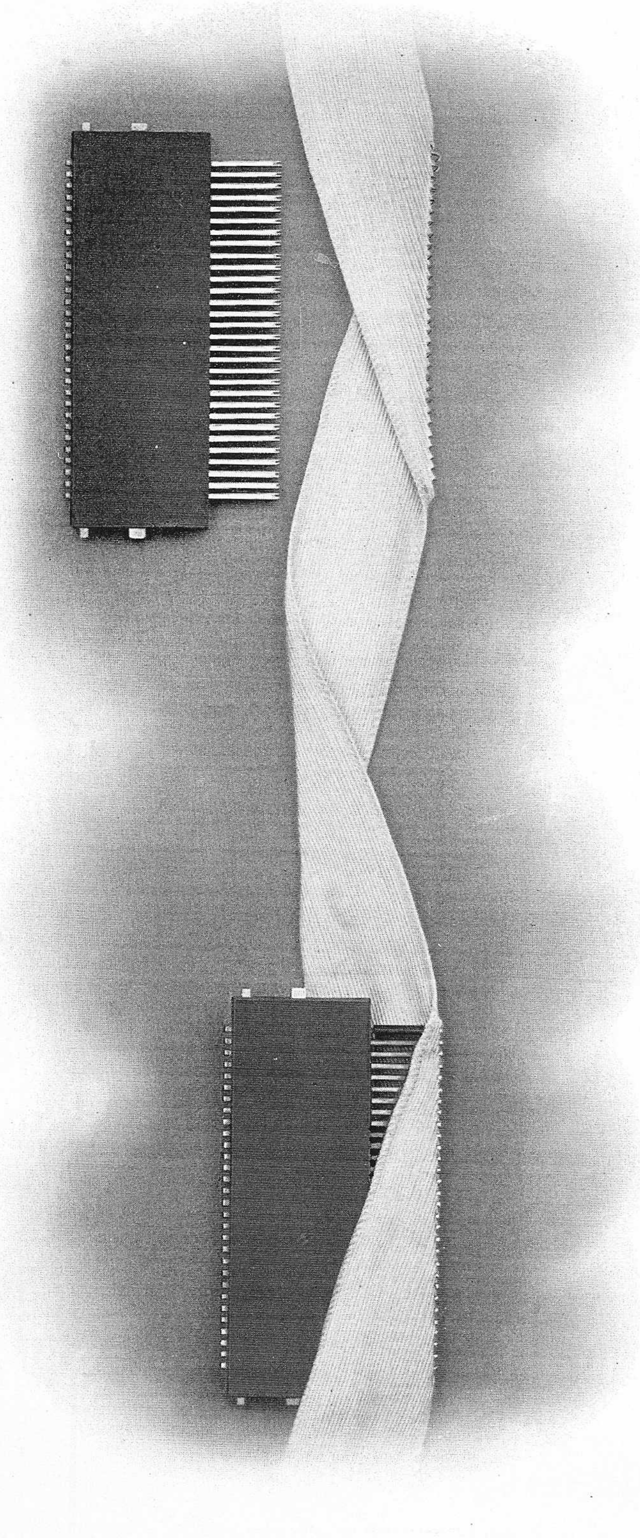


Figure 39.

Figure 40.

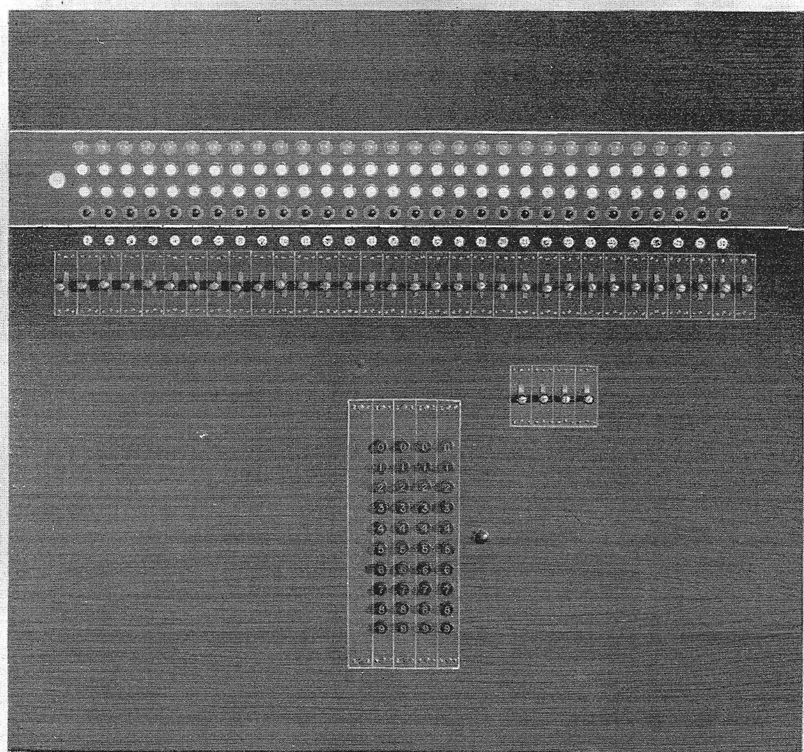


Figure 41.

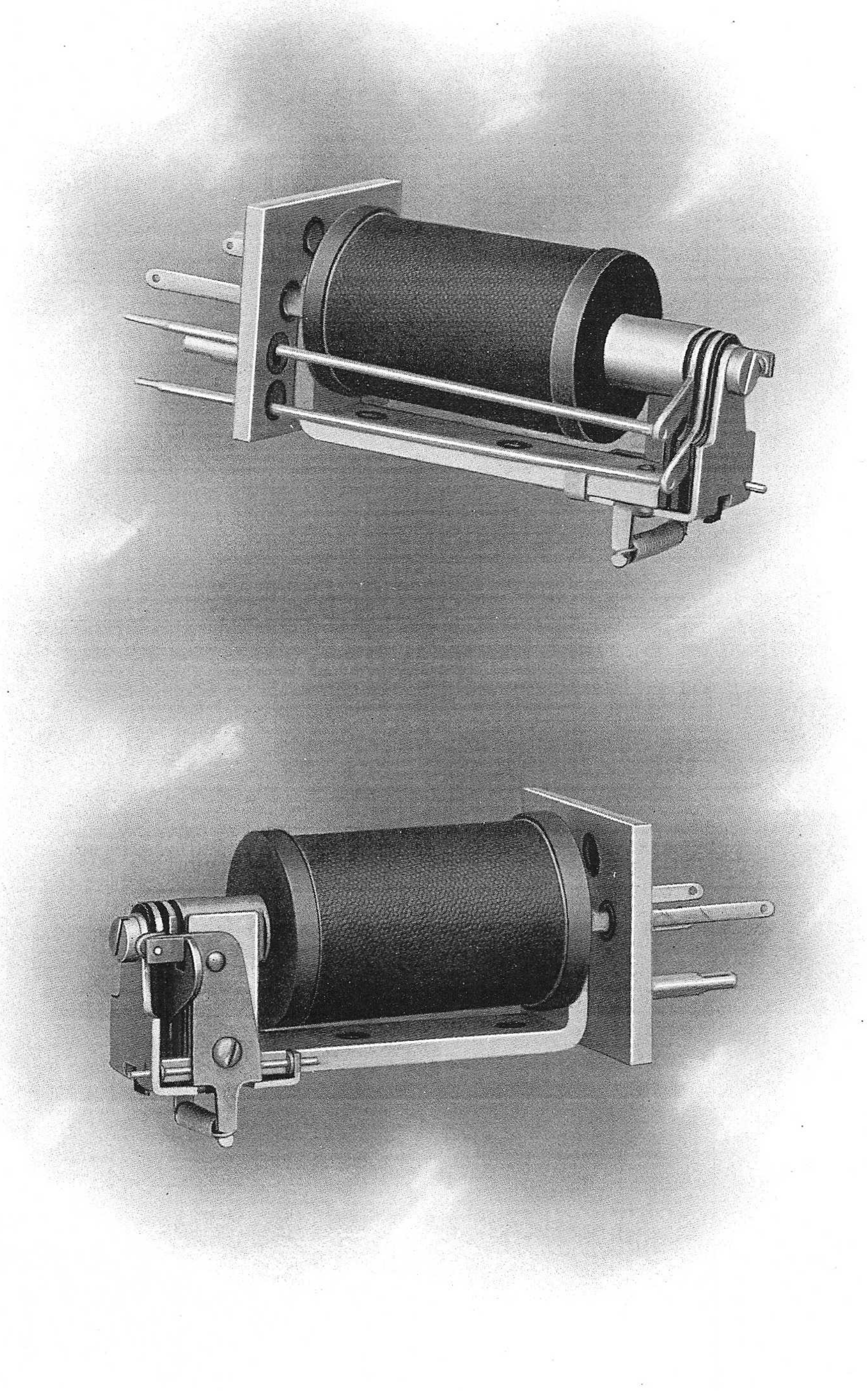


Figure 42.

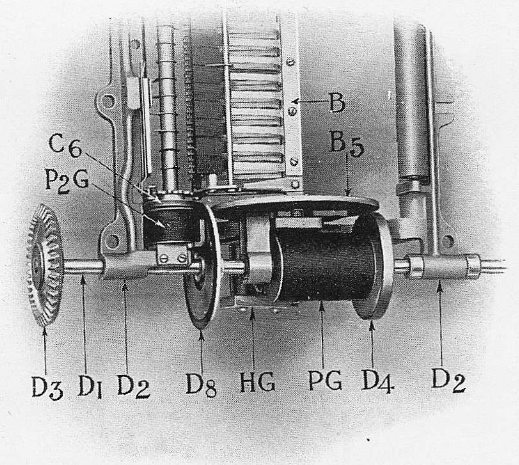
MECHANICAL AND ELECTRICAL APPARATUS FEATURES.

Regular Common Battery apparatus not described. Much of the apparatus used in the Western Electric Machine Switching System is of the type used for many years in the standard Common Battery System. It is not believed necessary here to describe such apparatus ; so that only the new types of switching machines will be taken up which were developed for the system.

MAGNETIC POWER CLUTCH.

Since power drive plays an important part in the operation of the system, and was largely instrumental in determining the lines of switch design and the character of circuits, the mechanical means, employed in transmitting to the mobile parts of the switching apparatus, the power necessary to move them, will be discussed first.

The power needed is taken from a commercial motor, and is brought to the switches by a system of simple shafting, interconnected by bevel gears as shown in the frontispiece. There is provided for each switch, as shown on page 67, a short shaft D1 held in bearings D2 and coupled to the vertical power shaft by a bevel gear D3. This shaft revolves constantly at the very slow rate of 31 revolutions per minute.



MAGNETIC POWER CLUTCH (SEE FIG. 9.)

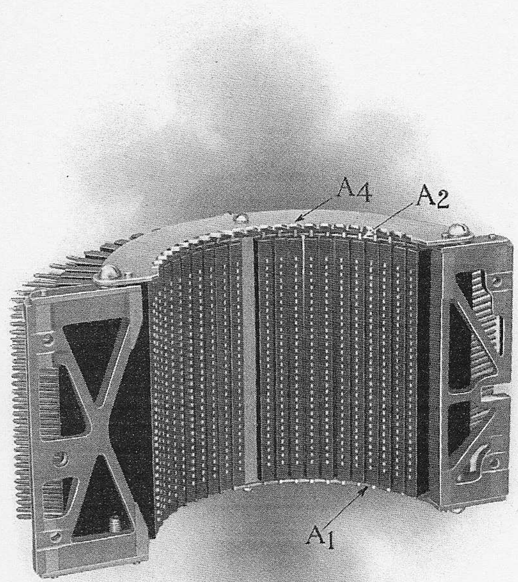
To transmit the power to the movable parts of the switches, a very simple and effective form of magnetic clutch is made use of. It consists of an iron disc fixed on the rotating shaft, and a second iron disc fixed by a diaphragm on the shaft of the movable part ; an electro-magnet, when energized, firmly holds together the edges of the two discs, placed at right angles, and thus forces the second disc to revolve with the first.

For the brush carriage, the disc D4 is fixed on the revolving shaft D1 and the second disc B5 is fastened by a diaphragm to the shaft B of the carriage. To rotate the carriage, the fixed electro-magnet PG is energized and attracts the edges of the two discs, whereupon the disc B5 revolves with the disc D4. When the circuit of the electro-magnet PG is opened, the disc B5 is released, and the carriage stops. To prevent the inertia of the brush carriage carrying the brushes beyond the terminals, a holding magnet HG is arranged to be energized the instant the power circuit is opened and so to bring the carriage to an immediate stand-still.

For the trip spindle, the disc D8 with its diaphragm is fastened to the shaft D1, while the spindle itself carries the second disc C6. When the fixed power magnet P2G is energized, the first disc is drawn against the second and transmits motion to the spindle. The inertia of the spindle is small, so that the roller spring and the power cam are sufficient to hold the spindle in an operated position.

For the sequence switch, shown on page 74, like the trip spindle, the disc D11 is fixed to the shaft by a diaphragm, while the spindle carries the second iron disc G5. To rotate the spindle, the fixed electro-magnet R2 is energized, attracting the first disc against the second. To stop the spindle, the circuit of the power magnet R2 is merely opened.

The magnetic clutch is made of a few simple parts which do not require adjustment ; they are subject to little wear, and that self-adjusted. The clutch and release are almost instantaneous and thus suitable for fast selective operations. Any power needed for closing firm contacts, is readily transmitted without slipping.



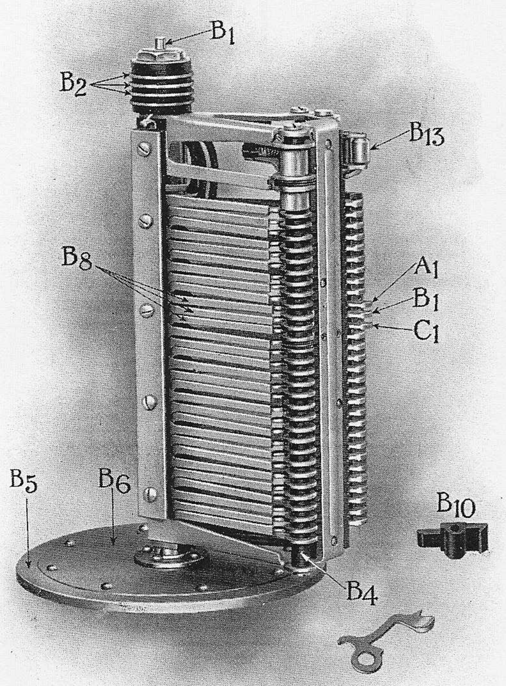
SELECTOR TERMINAL ARC (SEE FIG. 2).

SELECTORS.

The selector is shown in FIG. 1, with the brush carriage in its normal position.

The selector is made up of two portions, the terminal arc (FIGS. 2 and 3) and the brush frame (FIG. 8), which are mounted on the opposite sides of two vertical steel bars. Two steel pins fastened in the steel bars engage a hole and slot in each frame and arc, so that high accuracy in the alignment of brushes and terminals is insured.

The terminal arc, shown on page 68, consists of a number of terminal plates (FIG. 39). The plates are made of electrose with the terminals moulded in place, electrose being a material which is specially reliable and insures high insulation. The terminals are of phosphor bronze with the grain presented on end to the brushes, furnishing mechanically and electrically the best contact surface of any available material. The terminal plates, 22 in number for the group switch (20 for a final switch) are assembled in a frame. The lugs at the ends of the plates enter the steel segments A2 at the top and bottom of the frame, and hold the plates securely in a correct and unchanging position. When assembled, there are 30 rows of terminals with 22 per row for the group switch. These 30 rows form ten so-called levels of three rows each. Three terminals under each other form one line, either subscriber or junction.



SELECTOR BRUSH CARRIAGE (SEE FIG. 4).

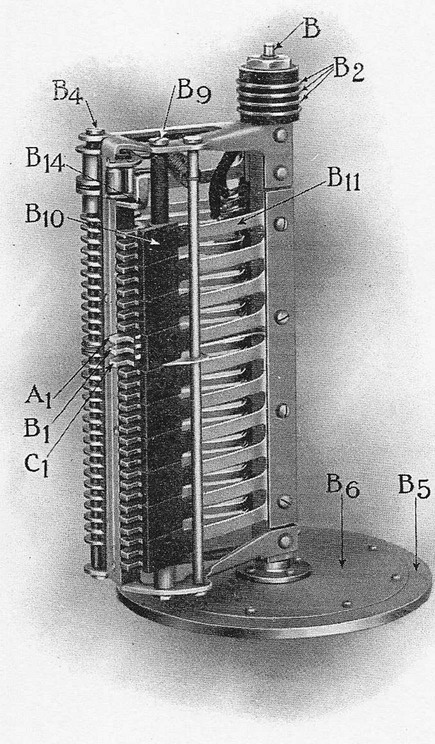
The brush frame in FIG. 8 contains two movable members, the brush carriage (FIGS. 4 and 5) and the brush chooser (FIG. 6.)

The brush carriage, pages 69 and 70, carries ten sets of brushes, with three brushes per set. The thirty brushes, of which a single one is shown to the right comprising a long arm with the contact surface and a short arm, are strung on a rod B4 and have their contact ends (the long arm) forced outwardly by three comb springs B8 pressing on the short arm. These contact ends are held normally inward by ten ebonite latches B10, strung on a second rod B9 and pressed against the brushes by the comb spring B11. By pulling a latch outwardly, three brushes are released, as at A1, B1 and C1 and are projected sufficiently to make contact with the terminals in the arc, though not so far as to cross two terminals together in passing from terminal to terminal. The three comb springs B8 make electrical contact with the corresponding terminals in each set, and are wired to the three collector rings B2 on the shaft B1. By this means all ten sets of brushes are connected in multiple.

The brush carriage also carries a roller B13 mounted on a lever arm and engaging the teeth on the toothed rack A4 for mechanical centering. A second lever arm B14 makes contact with the teeth of the toothed rack A4 ; the arm, however, does not touch the rack when standing between two teeth.

The iron diaphragm disc B6, to which is rivetted an iron disc B5, forms part of the magnetic clutch.

The brush chooser, shown on page **71**, possesses a pivotted trip spindle C1, (FIG. 7 shows this part separately), on which are mounted ten teeth, arranged spirally about the shaft and on levels with the ten ebonite latches B10. A tooth in position will project sufficiently to pull back a latch, as the brush carriage passes, and release a set of brushes ; the ten teeth serve for releasing any one of ten sets of brushes. A power cam C3 carried by the spindle, has eleven notches, one for each tooth and one for normal ; it engages a roller contact spring C4.



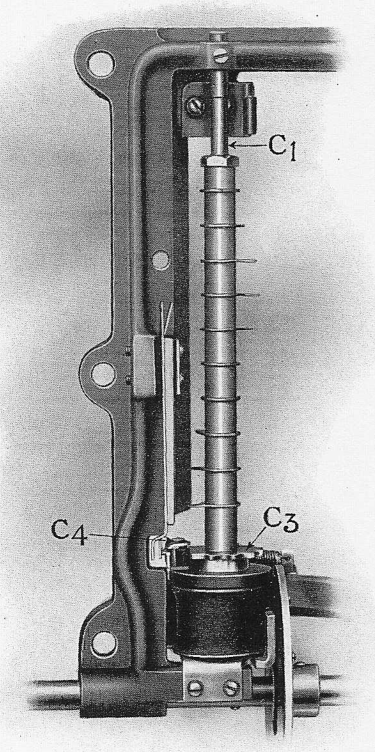
SELECTOR BRUSH CARRIAGE (SEE FIG. 5).

The group switch, serving to connect a junction line with another one extending to one of a distant group of switches, performs this function, first, by tripping that one of the ten multiple sets of brushes, which will sweep over the proper level of terminals, and second, by rotating the released set of brushes over the terminals, until a set connected to an idle junction line is found. The first operation is known as brush choosing, the second as junction hunting.

To perform brush choosing, the trip spindle is moved under the control of the register through a number of positions, say four, when the fourth tooth is in position to trip a set of brushes. In moving to the fourth position, it sends out four impulses towards the distant register, which stops the rotation. The brush carriage next begins to move and in passing the trip spindle, causes the fourth latch to be pulled back by the fourth tooth. The fourth set of brushes, now released, is ready to sweep over the fourth level of terminals, while the other nine sets of brushes, not released, move by their respective rows of terminals without contacting.

The brush carriage continues to move until an idle set of terminals is found, when the circuit for the power magnet is opened and the brush carriage stops. To center the brushes squarely on the terminals, the brushes are not stopped until the brush B14 stands insulated between two teeth of the toothed rack.

The brush carriage is returned to normal, after conversation is finished, by closing the circuit of the power magnet, which again applies power to the brush carriage. The released brushes are passed over a roller shown at the right of FIG. 8, after the last set of terminals has been passed, which forces the brushes back to be relatched. In reaching normal, the spring B14 makes contact with a metal finger screwed to the top of the selector frame as shown just above C1, in figure on page 71. This closes a relay circuit and opens the power circuit.



BRUSH CHOOSER OF SELECTOR (SEE FIG. 6).

The brush spindle is returned to normal, after it has released the desired brushes, by being driven through the remaining positions until normal is reached, where the power spring finds a deeper notch in the power cam which allows it to open the power circuit.

The selector described above is that used for group switch purposes. The type, used for final switch, is in every way identical with the group switch, except that it has only 200 sets of terminals (10 levels and 20 per level) and that there is provided a special form of local contact, operated by the toothed rack. The final switch does not perform junction hunting, but must move its brushes across the terminals until a definite terminal, connected with the line wanted, is reached. Each terminal passed operates the local contact, which operations are counted off by the register. When the desired number of steps has been taken, the register cuts off the power and the brush carriage stops.

The following features of the selector merit mention.

The selector is massively built to ensure stability of alignment of parts and to avoid any changes in the inter–action of parts.

The design is such that all wear is adjusted automatically, so that neither adjusting springs, cams nor screws of any kind are provided. If the parts are properly made the selector, when assembled, will be in adjustment ready to operate.

The use of 10 brushes, instead of a single brush, avoids the necessity of sliding the shaft, always a cause of an excessive wear of parts, as it eliminates the complicated mechanism required for producing such a sliding movement. It guarantees, furthermore, that, as the brush carriage does not move along its axis, the brushes will always be in alignment with the terminals.

By simply loosening two screws in the top of the selector frame the brush carriage or the trip spindle is readily removed for repairs.

The revolution of the brush carriage being in one direction, permits continuous junction hunting, in which the brush carriage, failing to find an idle junction, will continue to revolve and repeatedly test the 22 terminals in a row, until an idle junction terminal is found.

The collector rings on the brush carriage eliminate flexible cords with their attendant cord failures.

The surfaces of the contacts are arranged vertically so that dust cannot collect.

The material used for the brushes and terminals, and the method of disposing the long grain in the brush to rub over the end of the grain in the terminal, secures freedom from wear and abrasion, while ensuring a low resistance and sure contact.

All terminal contacts in a level are passed over, because of the complete revolution made by the brush carriage after each connection in returning to normal. As a result, all contacts wear evenly and are regularly cleaned, so that terminals toward the end of the level, which are rarely used for connections, will always be bright and ready to make a good contact when required.

Very firm contact pressures are obtainable by strong springs,as the resulting friction of resistance is readily overcome by the power available due to power drive.

On this account, the brushes may be given considerable motion when rubbed up on a contact, providing for a very heavy wear of the material without affecting adjustment.

A broad contact surface of the brushes always assures contact with the corresponding terminal, even with a slight change in alignment, resulting from wear in the bearings after years of service.

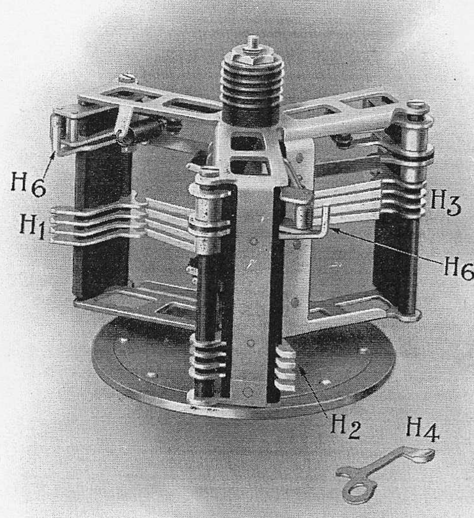
The selector switch is equally well adapted to a large variety of purposes in a telephone system, as all circuit shifting mechanisms, required to control the motion of the selector, have been removed and centered in the sequence switch, leaving the selector mechanically very simple.

LINE FINDER.

The line finder is shown in FIG. 12. This, like the group switch, has a terminal arc and a brush frame with a brush carriage shown in FIG. 13.

The terminal arc subtends an angle of 120° and has three levels of terminals of 20 each, suitable for connecting 60 subscribers' lines. Each level is made up of four rows of terminals.

The brush carriage, shown on page 73, has a three-arm frame with three sets of brushes H1, H2 and H3 of four brushes each. One of the brush punchings is shown at H4. The three sets of brushes are spaced at 120° around the shaft, are displaced along the axis to be in the same planes with the three levels of terminals and are connected in multiple. No latching device is required for the brushes, nor is there a brush chooser. There is no home position, the carriage remaining in the position where it was last used. There is, however, a toothed rack at the top of the terminal arc and a contact lever H6, carried by the shaft of the carriage. This serves to center the brushes squarely on the terminals. The brush carriage is rotated by the power shaft, over a magnetic clutch, like that of the group switch.



BRUSH CARRIAGE OF LINE FINDER (SEE FIG. 14).

The general operation of the line finder is as follows :—

When it is required to connect the brushes to a calling line, the power magnet of the magnetic clutch is energized, causing the brush carriage to rotate. One set of brushes after the other now sweeps over the corresponding levels of terminals until the brushes touch the terminals of the calling line, when the current in the power magnet is cut off and the carriage stops. The brushes are now in electrical connection with the line and extend the calling line to a second line finder or a register as provided.

The mechanical and electrical advantages of the construction are broadly the same as for the selector. By its use, it is possible to concentrate the traffic to relatively few circuits, thereby greatly reducing the apparatus that would otherwise be required for each subscriber's line. It performs the same function that does the operator when she inserts the answering plug of a cord circuit into the jack of a calling line.

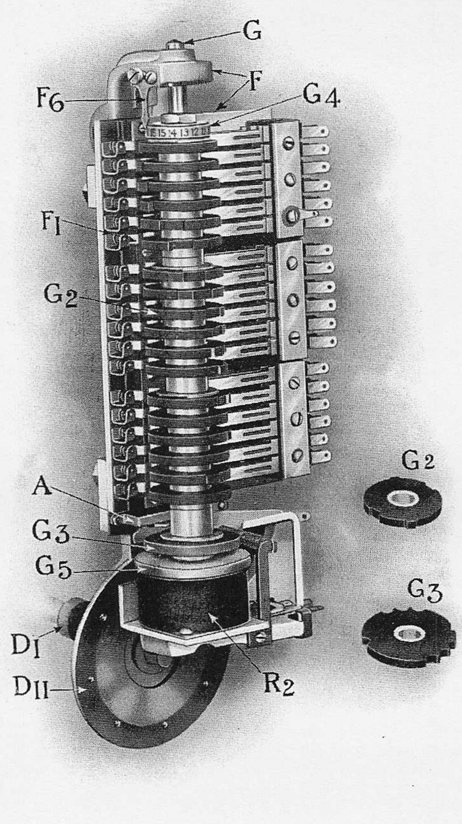
CABLE AND CABLING.

The switches in a group are mounted on bays, consisting of two heavy angle irons fastened top and bottom to heavy castings for rigidity, as is seen in FIGS. 34 and 35.

The terminal plates belonging to the same line conductors thus lie one above the other and are connected in multiple by means of a special form of ribbon cable.

The ribbon cable, shown in FIG. 38. consists of 30 wires, placed side by side and held together by weaving, so that the wires are insulated from each other. The weaving, which is done in a loom, exposes the wires in bare spots, which lie diagonally across the cable and on centers, equal to those on which the terminals to be cabled are spaced. In order to perform the cabling operation, the bare spots are enlarged, as shown in the second view of the cable and then bent back, as shown in the third. The bare spots on the wires, are now placed on the ends of the terminals, the spacings coinciding, and, by means of a simple soldering operation, the terminals are connected with the wires at the bare spots. The completely cabled terminal plate is shown in FIG. 39. When these terminals are assembled in the arcs, they present the appearance of FIG. 35 for an entire bay. As is clearly seen from FIG. 36. each soldered terminal remains at all times visible and permits inspection and repairs, where needed, without touching or disturbing a single wire of the multiple cabling. The upper ends of the cables are connected to terminal plates, FIG. 37, which are fastened in a rack shown at the top of the bay; these connecting racks are then multipled across from bay to bay for the entire group.

On account of the low capacity between conductors, it is possible to place the wires side by side without twisting and without introducing cross-talk. When connecting up a considerable number of machines,



SEQUENCE SWITCH (SEE FIG. 16.)

the wires of the cable can be connected in transposed relation by means of the connecting rack at the top which eliminates any cross-talk.

SEQUENCE SWITCH.

The sequence switch is shown in FIG. 15 mounted in position next to the switch whose motions it controls and again in FIGS. 16 and 17. A type of switch used with the line finder is represented in FIG. 18.

The switch, shown on page 74, is made up of a frame F carrying a series of contact springs, a spindle G and the magnetic clutch which drives the spindle.

The spindle G carries a series of ebonite cams G2 and an ebonite power cam G3. A typical type of cam and a power cam are shown to the right. The cams are cut depending on the contact requirements of the circuit. The spindle carries furthermore a disc G4, numbered 1 to 18, and a pointer F6 serving to indicate in which of the 18 positions the spindle is stopped at the moment.

The frame F carries a series of springs, each consisting of a lever spring F1 and a left and right contact spring. Each lever spring presses against a cam, and, depending on whether it stands in a notch or on a projection, will make a contact to the right or the left ; or it may remain insulated in the middle between two springs when there is neither notch nor projection. A spring A engages the power cam G3 and opens its contact when the spring drops into a notch.

The operation of the switch is as follows :—

The spindle stands normally in position 1, in which certain contacts will be closed due to the projections and notches of the cams.

When it is desired to shift the circuit, current is sent to the electro-magnet R2 which attracts the iron disc D11 mounted on the permanently rotating shaft D1 against the iron disc G5 and rotates the spindle. When rotation has commenced, contact A is closed, maintaining the electro-magnet R2 energized. The spindle will continue to move until the next notch is reached on the power cam G3, into which the roller of spring A falls, opening the circuit of the electro-magnet R2 and thereby releasing the magnetic clutch. While the switch has passed from the first to the next position, certain contacts have been opened and others closed, thus establishing new circuits.

When the particular function of the circuit just established has been accomplished, an impulse is again sent into the electro-magnet R2 causing the spindle G to revolve as before, until it arrives in its next position, determined by the next notch on the power cam G3. Thus a series of circuits is established in proper sequence over its contacts, as required for the operation of the system.

The particular features of the sequence switch, which deserve attention, are the following :—

The whole construction is very massive, securing unchanging alignment of mechanical parts and permitting the application of considerable power without distorting the parts.

A sequence switch, contrary to a relay, requires no electric power to hold contacts closed ; electric power is required only to step the spindle from one position to the next.

By means of its cams, a contact may be closed and opened repeatedly during a single revolution or cycle of the spindle, thus permitting a relay, for example, to be introduced repeatedly into various combinations of circuits, as required.

As the spindle is driven at a uniform speed, it is possible to make passing contacts of a predetermined duration.

The arrangement of cams permits one contact to be closed before or after another, as required for the circuit operation.

The contacts are vertically arranged and of platinum. The application of power drive allows these contacts to be made very firm and secure.

By loosening a screw a spindle may be readily removed and replaced.

The numbered disc and pointer show in which position the apparatus stopped, and thereby give an accurate indication to the mechanic as to the nature of the fault.

REGISTER

The register shown in Fig. 19 resembles in many ways a sequence switch, the main difference being the arrangement of contacts and cams. It has 20 positions, but a cycle of operation is performed in 10 positions or in one half revolution. The spindle revolves only in one direction.

The number sent in by a subscriber, is said to be registered when the spindle turns through a number of positions equal to the number of impulses sent. In the full automatic System, this number is usually one that is complementary to the digit (10 steps for digit 0, 9 steps for digit 1, 8 for 2, 7 for 3, etc.) so that the register spindle in being moved forward to normal through the remaining positions, will send out a number of impulses equal to the original digit sent in.

The means employed by the register for translating impulses are best explained in connection with the circuit.

The selecting relay used in connection with the register is shown in Fig. 42. It is also used in other portions of the circuits where its permanency of adjustment secures accurate and reliable working.

OPERATOR'S EQUIPMENT.

The desks furnished for operators in the semi-automatic System are shown in FIG. 40, while FIG. 41 shows a top view of the keyboard.

The keyboard is equipped with 30 sets of lamps for 30 « connecting circuits », each set consisting of a calling lamp, a ringing lamp and two supervisory lamps. A two-position key is associated with each lamp and serves, thrown in one direction, for listening in on an existing connection, and thrown in the other for releasing a connection with simultaneous message registration, but only when a subscriber has restored his receiver.

The key-set, used for recording the number of the line wanted, consists of four strips of plunger keys each numbered from 0 to 9. A fifth strip of keys is usually provided, bearing the names of the various offices in the exchange area.

To the right, are placed four master keys, which serve respectively, for forced release with the receiver off the hook ; for permitting clearing without registration ; for the hold-over of faulty apparatus that failed to establish a connection ; and for releasing keys in case an operator wishes to correct an error in depressing.

The operator uses the usual head telephone and breast transmitter, which is connected automatically to a connection circuit when a call appears. The keys used to receive excess incoming calls from the neighbouring positions for helping out, are placed to the right and left of the row of listening keys.

SUBSTATION NUMBER SENDER.

In the full automatic system, a mechanism is mounted on the subscriber's set, which allows him to establish his own connections. One form of this mechanism, known as the finger-wheel, is shown in Fig. 43 ; there is a second view with the cover plate removed to display the internal mechanism.

It consists of a finger disc with 10 holes arranged over a plate marked 0 to 9. This disc is mounted on a shaft and held against a stop by a spiral spring. When displaced from normal, the disc returns under the tension of the spiral spring, but does so at a predetermined and constant speed under the influence of a governor. A special loose disc at the center is so fitted that the finger disc may be moved forward as quickly as desired, the governor being disconnected.

The finger disc carries a series of small teeth and one large tooth which operate in passing a contact lever ; the contact lever opens a contact, included in the line circuit, but only on the return movement of the finger disc.

To call a number, the subscriber inserts his finger in the hole of the disc, corresponding to the digit wanted, pulls the disc to the stop and releases it. The disc returns to normal and, in so doing, opens the line circuit a corresponding number of times, these short interruptions always being followed by a long one, to mark the change-over.

Some views Figs. 44, 45 and 46 of wall and desk sets with finger wheels mounted, are shown. A set suitable for the semi-automatic System is readily converted into one suitable for the full automatic System by adding the finger-wheel.


3
4
5
6
2
7
1
8
0
9
REMOVE
RECEIVER
BEFORE CALLING
PULL DIAL AROUND
TO STOP & LET GO
No.

Figure 43.

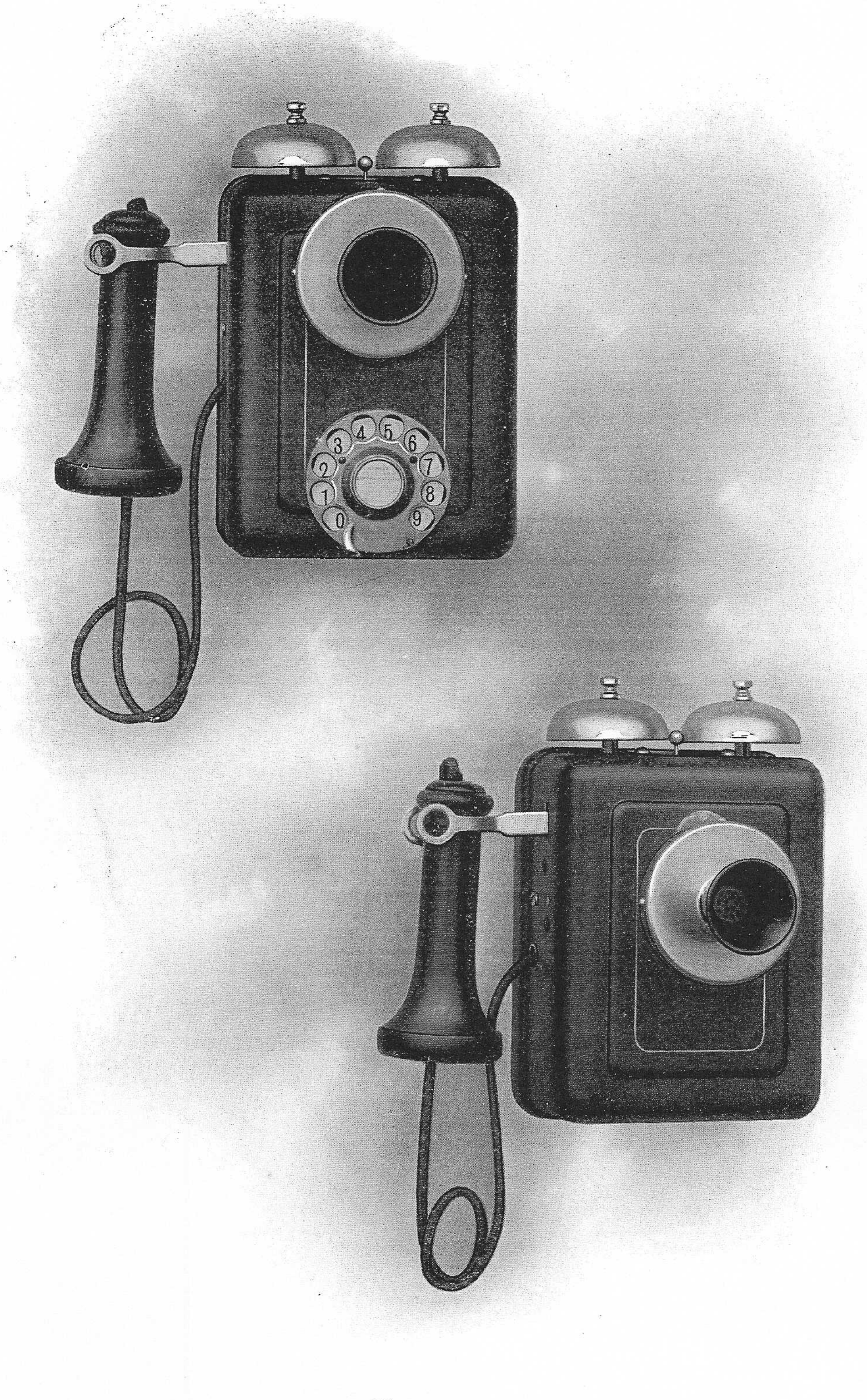


Figure 44.

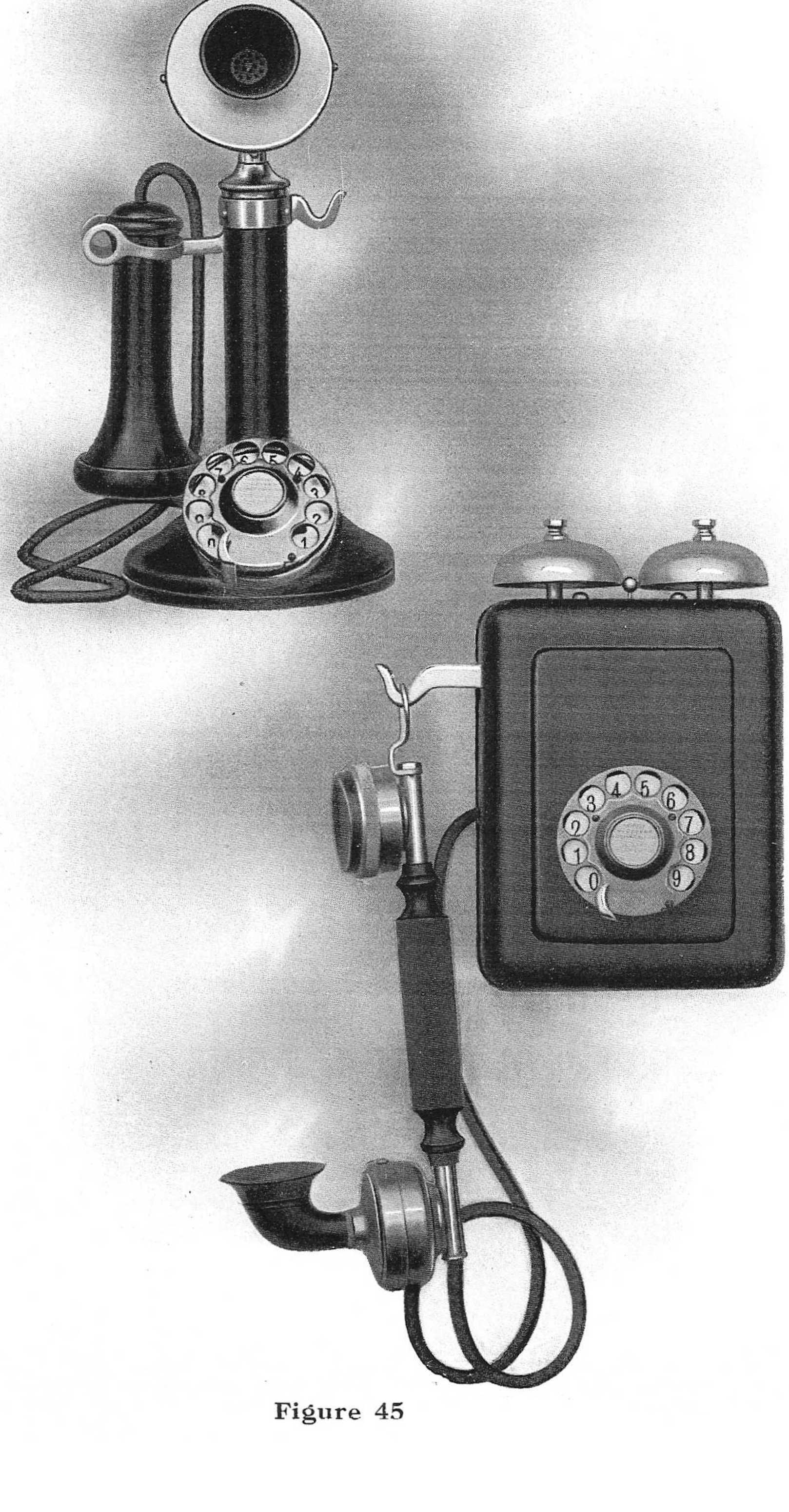


Figure 45

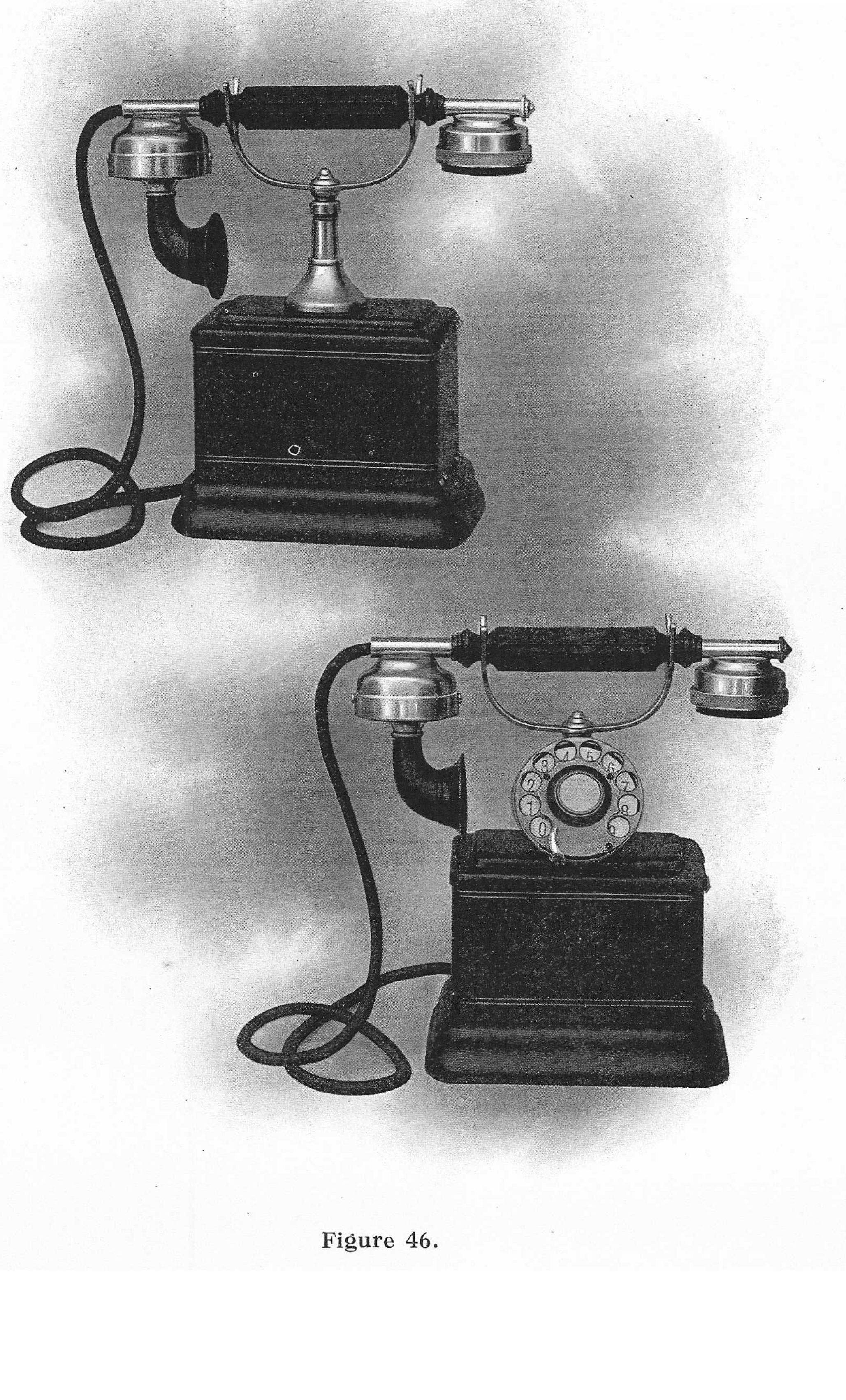


Figure 46.

DESCRIPTION OF THE CHARACTERISTIC CIRCUITS.

A general description has been given for both the full automatic and semi-automatic System, showing the order in which switches and register are taken into use. In the selection and control of such switches there appear a number of characteristic circuit operations, which will be described. These operations will be analyzed into their elements where required for a readier understanding.

FULL AUTOMATIC SYSTEM CIRCUITS.

The circuit elements of the full automatic System will be described first and then those elements of the semi-automatic System taken up wherein they differ.

Subscriber calls and line finder connects to his line (Fig. 47). In removing his telephone, the subscriber, as in a Common Battery system, operates a line relay LR, which in turn energizes a starting relay CR, common to the group of line finders. The latter energizes the clutch magnets PF of a number of line finders, whose brush carriages begin to rotate.

These rotating brush carriages seek for the calling line and, when one of them finds it, the particular brush carriage stops. This is accomplished by testing, and involves three operations ; making the test terminal of the line test unchoosable, stopping the brush carriage and centering the brushes.

To prevent other line finders from connecting to the line after one has found it, the terminal D must be made unchoosable as promptly as possible. The line relay, in closing its contact, sends current through the 200 ohm and 600 ohm resistances, so that the terminal D will possess about 36 volts potential against earth. The brush D1 in touching the terminal D of the calling line completes the circuit of the test relay GT1R, which closes over its front contact a 15 ohm winding in parallel with the 800 ohm winding and so immediately reduces the potential of terminal D to only a few volts. The 800 ohm test windings of other line finders still rotating will fail to find enough potential to be energized and will therefore not stop their respective brush carriages.

The brush carriage stops, when the second test relay GT2R is energized over the front contact of relay GT1R and opens the circuit of power magnet PF.

To ensure that the brushes A1, B1, C1 and D1 will stand squarely on the terminals, the test relay GT2R is, however, not energized until all the brushes are so centered. This is attained by means of the interrupter FINT, consisting of a toothed rack H5 and a brush H6. Before the brushes reach the terminals, the brush H6 touches the rack H5 and short-circuits the relay GT2R. When the brushes stand squarely on the terminals, the brush H6 stands insulated between two teeth, opens the short circuit around the relay GT2R and allows the relay

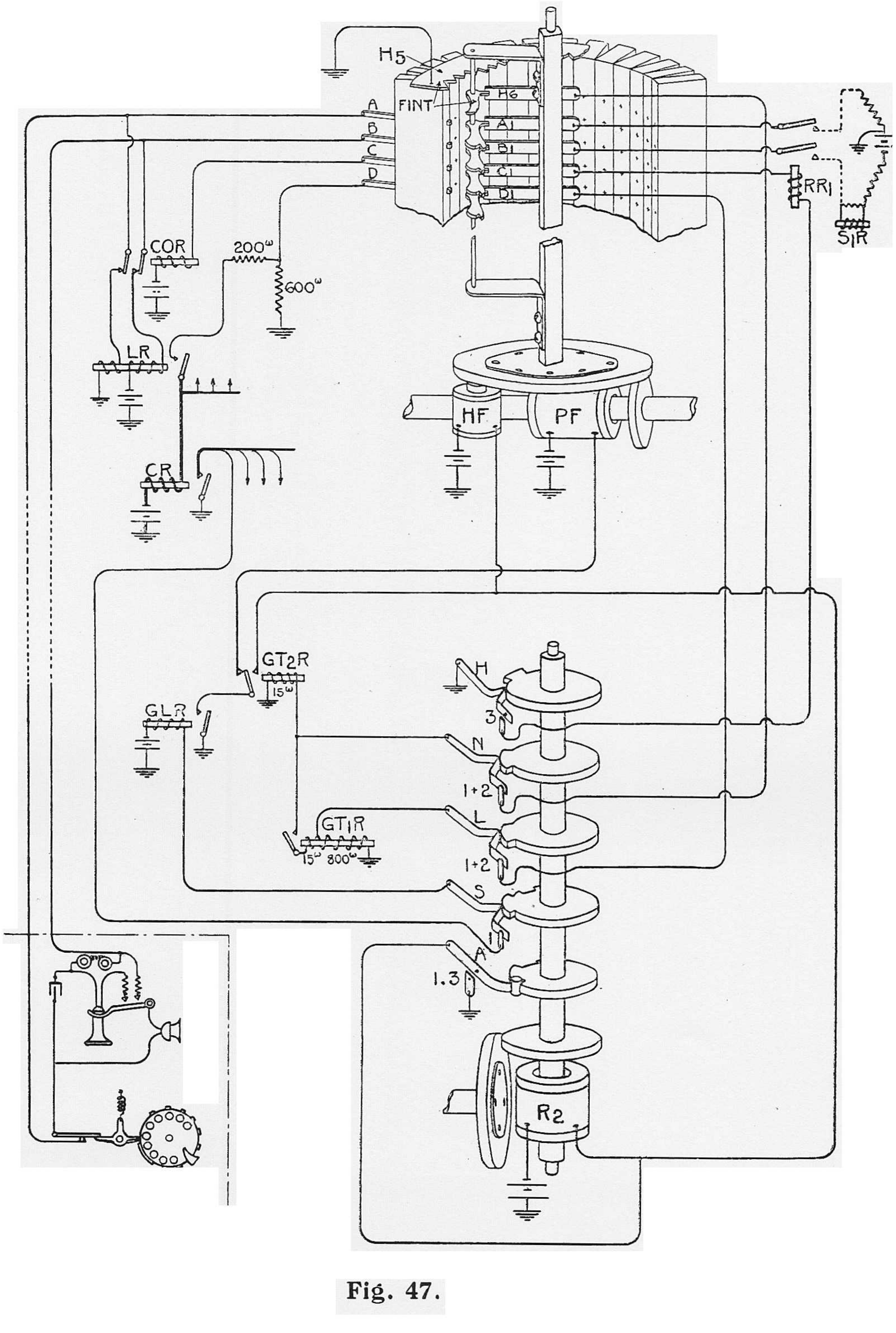

H5
FINT
A
B
C
D
H6
A1
B1
C1
D1
RR1
S1R
COR
200ω
600ω
LR
CR
HF
PF
GT2R
15ω
GLR
H
3
N
1+2
L
1+2
GT1R
15ω
800ω
S
1
A
1.3
R2

Fig. 47.

to operate and stop the brush carriage. This brush centering method is used in all line finders and group switches.

To prevent the inertia of the moving brush carriage carrying it beyond the terminals, A, B, C and D when stopping, the holding magnet HF is energized over the front contact of relay GT2R the instant the power is cut off the magnet PF.

The brush carriage of the line finder having stopped and made contact with the calling line, the function of the existing set of circuits controlled by the sequence switch R2 is accomplished and may be broken up, while the next set must be established. This is done by placing the winding of the power magnet R2 of the sequence switch in parallel with the holding magnet HF, so that when the latter is energized by relay GT2R, it will also close the circuit for the magnet R2. This electro-magnet operates the magnetic clutch, causing the spindle to rotate. As it leaves position 1, the power spring A is connected to earth and will hold the power circuit closed,until it drops into the next notch in the power cam, which is in position 3. Position 2 is passed in this case to secure the necessary working margins for the apparatus. The spindle stops, closing certain contacts and opening others, substituting in fact the next set of circuits for the set no longer needed. This next set of circuits concerns selecting an idle register.

There are associated with each connection circuit between a line finder and a group switch, three sequence switches : R2 mentioned above, R1 and R3 to be mentioned later.

The other line finders, which failed to find the calling line, were left rotating. They are stopped by releasing the starting relay CR ; this follows the energizing of relay COR brought about by closing the contact spring H in position 3 of the sequence switch. The relay RR1 is also operated connecting the line to the « connection circuit » with its repeating coil. The circuit connecting a line finder and group switch is called a « connection circuit » ; it corresponds to a cord circuit in a manual switchboard.

The springs of the sequence switches in the following circuit drawings, will not be shown near their respective cams, as was done in Fig. 47, the drawings being much simplified by showing them in their circuit position. The springs will be drawn like spring F, for example, in Fig. 48 and each spring will be lettered. The numbers near the contact show in which positions of the sequence switch the particular contact is closed. The marking : 3+5, means closed in positions 3 to 5. The electro-magnet of the sequence switch to be easily recognized is always marked R with a number or letter suffix. The power spring, always marked A, holds the electro-magnet circuit closed once the spindle has started to rotate until the next notch is reached in the power cam. The numbers near the spring A indicate in this case the positions in which the spindle will stop, until driven into the next position as determined by the notches of the star wheel. When there are two sequence switches shown on the same drawing, as in Fig. 48, the springs belonging to each will be enclosed by a dash and dot line to avoid confusion.

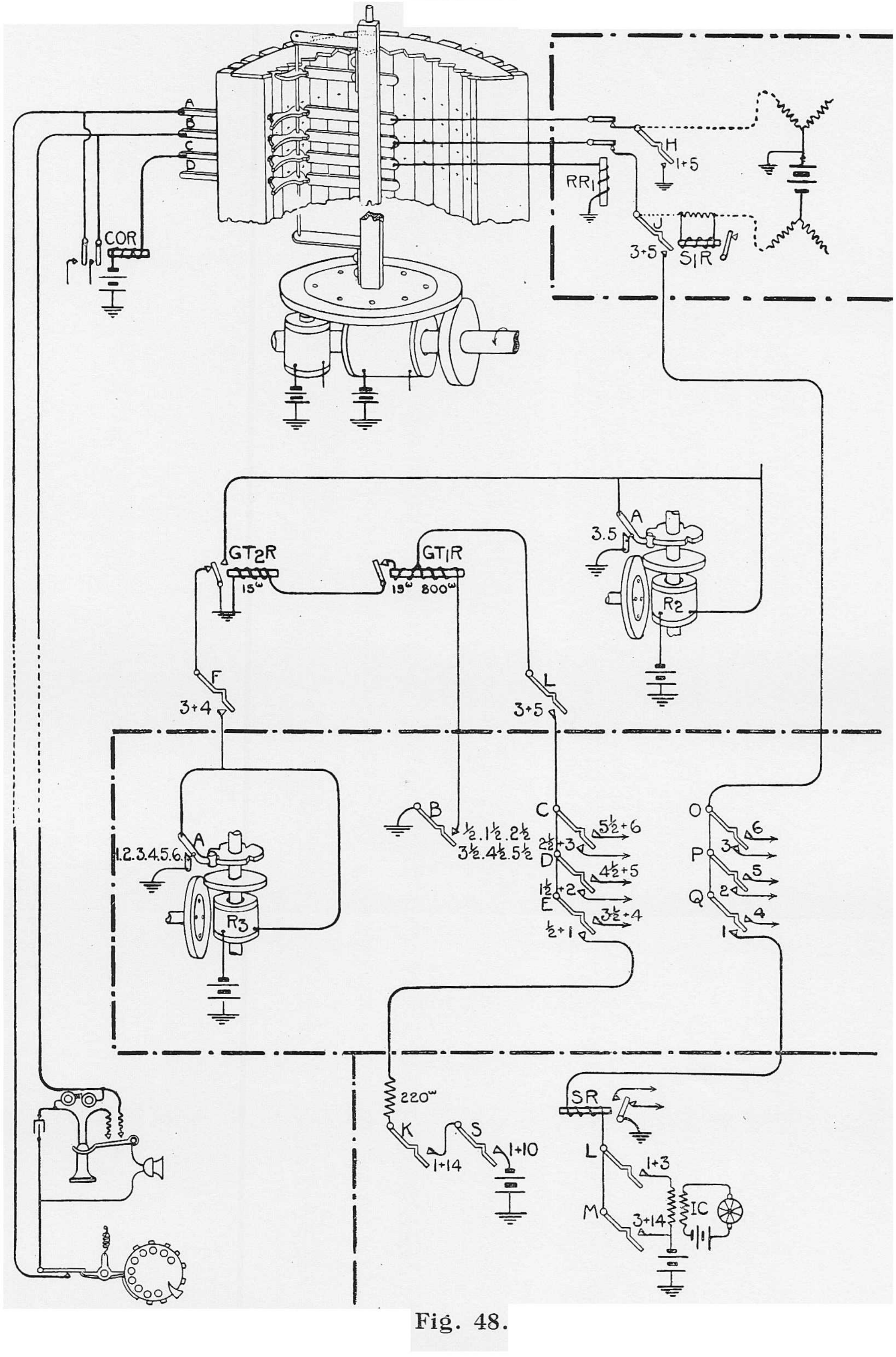

A
B
C
D
H
1+5
RR1
3+5
S1R
COR
GT2R
GT1R
15ω
15ω
800ω
A
3.5
R2
F
3+4
L
3+5
A
1.2.3.4.5.6.
R3
B
½.1½.2½
3½.4½.5½
C
5½+6
2½+3
D
4½+5
1½+2
E
3½+4
½+1
O
6
P
3
5
Q
2
4
1
220ω
K
1+14
S
1+10
SR
L
1+3
M
3+14
IC

Fig. 48.

In many cases, the sequence switch, when moving into its next position, passes over a number of intermediate positions. This is done often to secure necessary working margins for apparatus. Again, intermediate positions are reserved for special purposes such as premature release which are not described.

Line is connected with an idle register (Fig. 48). Each one of a number of connection circuits has an opportunity of testing six registers to pick an idle one. For this purpose, a second sequence switch R3 is provided for each connection circuit. This switch begins to rotate as soon as the line finder has connected to a line, receiving current for its power magnet over spring F (closed in position 3 of R2) and back contact of relay GT2R. While the spindle of R3 rotates, it successively tests the six registers, by closing successively the six contacts of springs C, D, E and repeatedly the contact of spring B.

An idle register is characterized by having closed its spring contacts K and S shown for register N° 1. The other five registers, not shown, have similar contacts.

Register N° 1 is assumed to be idle and will be connected to the connection circuit, for which purposes, sequence switch R3 must stop in position 1. This is accomplished by a circuit closed over battery springs S, K, E, L, relay GT1R and spring B ; this circuit energizes first the test relay GT1R and then the relay GT2R which latter, in opening its back contact, cuts off current from the power magnet R3 and stops its spindle. The register is quickly made busy by placing the low resistance windings of relays GT1R and GT2R in shunt with the 800 ohm winding of relay GT1R to reduce the potential.

The impulses from the subscriber's finger-wheel will be received by the selecting relay SR, which forms a part of the register and which is now connected over spring Q to the connection circuit.

To permit the subscriber to free his line promptly, the relay RR1 is placed in the circuits during the entire connection, in such a way that restoring the receiver at once de-energizes the relay and opens the subscriber's line. On an immediate recall, a new line finder and register are thus able to connect at once to the line.

The circuit set up by sequence switch R2 in position 3, having accomplished its purpose, the switch R2 must be driven into the next position 5. This is done over the front contact of the energized relay GT2R.

It is interesting to note in passing, that the relays GT1R and GT2R have been used a second time, due to the switching facility of the sequence switch. These relays will be found again in other circuits to be built up.

Subscriber sends the number of the line desired (Fig. 49). To advise the subscriber that the register is ready to receive the number, a buzz IC is connected to the line simultaneously with selecting relay SR. This provision permits a subscriber at an extension station to know when the main set has cut through to the central office.

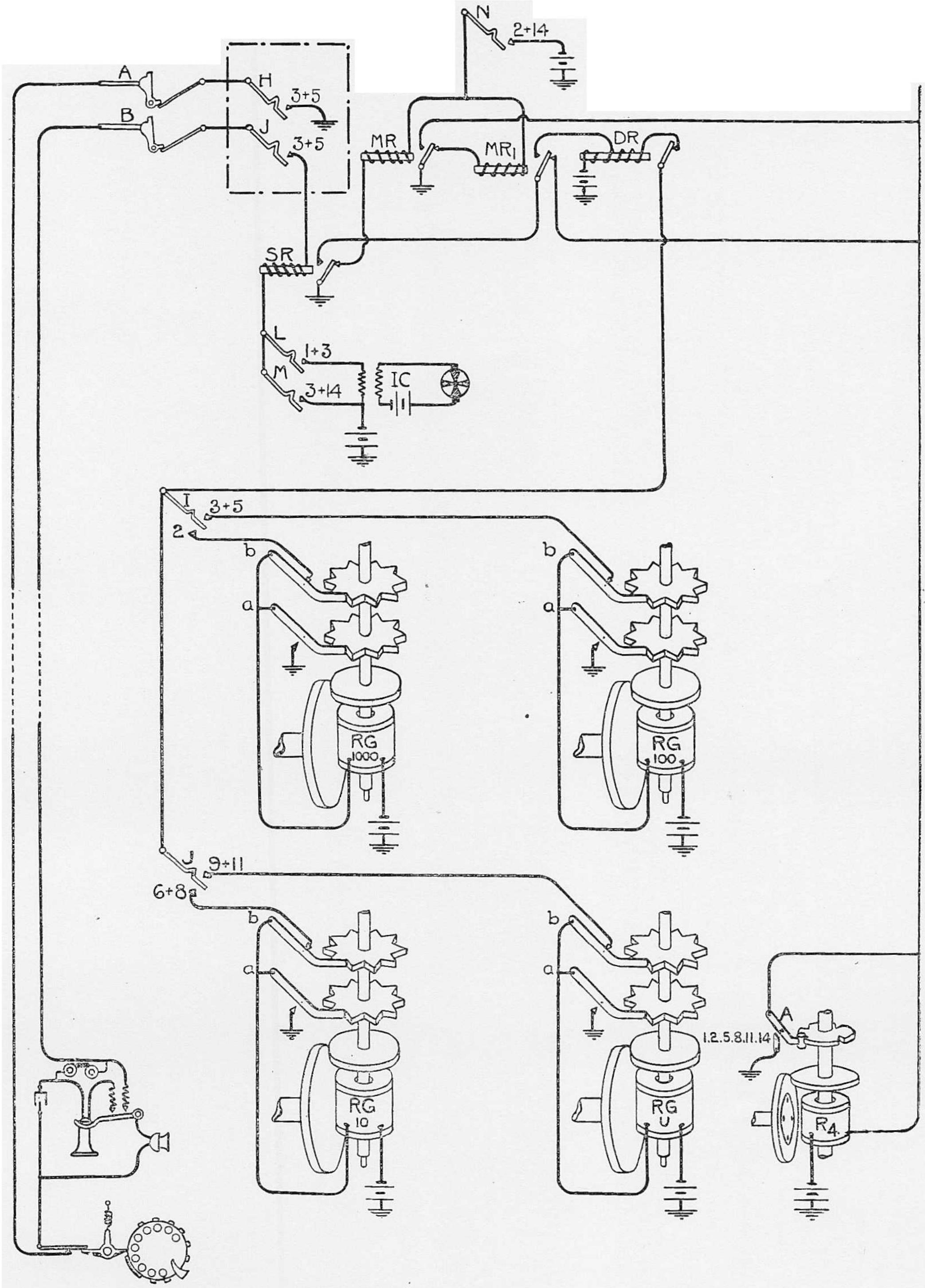

N
2+14
A
B
H
J
3+5
3+5
MR
MR1
DR
SR
L
M
1+3
3+14
IC
I
3+5
2
b
a
RG
1000
RG
100
J
9+11
6+8
RG
10
RG
U
A
1.2.5.8.11.14
R4

Fig. 49.

The subscriber obtains the desired connection by sending in the digits that make up the number, for each digit inserting his finger into the proper hole of the finger-wheel and pulling it to the stop. Each pull sends in a series of impulses. It will be assumed for convenience that a finger-wheel is used though registers permit any type of sender to be employed.

The finger-wheel is so arranged, for reasons to be given later, that impulses are sent on the complementary basis as follows :

For digit :	0,	1,	2,	3,	4,	5,	6,	7,	8,	9,	
Finger-wheel sends :	10,	9,	8,	7,	6,	5,	4,	3,	2,	1	impulses.

The impulses are separated by very short interruptions. The first impulse is due to the closed circuit of the substation when calling.

When the last of a series of impulses is transmitted, there is a change-over interruption, which is somewhat longer than the short interruption. This operates the change-over by connecting the second register spindle to the line to receive the impulses for the second digit.

Each series of impulses for each digit is received by a register spindle, there being a spindle for each digit. In the present instance, it is assumed the exchange has a capacity of 2000 lines, so that there will be four digit numbers, requiring four register spindles.

The four spindles and the sequence switch that controls them, are shown in Fig. 49.

The first impulse due to the connection to the closed subscriber's line circuit, energizes fast selecting relay SR. This drives sequence switch R4 into position 2 in which the first or 1000's register spindle is connected to the receiving circuit over spring 1. The relay MR is slow acting and operates only when the relay SR has closed its back contact a definite length of time.

The first impulse also moves this register spindle one step forward, which is accomplished by means of the differential relay DR. In position 2 of R4, the spring N closes its contact, which energizes relay MR1 and connects the front contact of the relay SR to the differential windings of relay DR. Current will now flow to earth over two differential circuits, one the left-hand differential winding of relay DR, and the other, a circuit including the power winding of the 1000's spindle and the right-hand winding of relay DR. The two windings of the relay DR are so proportioned, that they will neutralize each other and not pull up the armature ; but the power winding of the 1000's register spindle is energized and drives the register spindle to position 1. In going to position 1, it opens at the spring b the circuit towards the right-hand winding of the relay DR, so that the left-hand winding can now energize the relay DR and attract its armature. The circuit momentarily opened by spring b, is now opened permanently over the back contact of relay DR ; and consequently the 1000's spindle will stop in position 1. The differential relay DR in this way prevents the spindle, once energized, from taking more than one step.

Other steps are taken by the 1000's register spindle, one for each impulse following a short interruption. Each interruption releases the fast selecting relay SR, which opens its front contact and releases the differential relay DR. The latter in closing its back contact re-establishes the two differential circuits. Each impulse re-energizes the relay SR, which closes its front contact and energizes the spindle magnet, making the spindle take another step. In doing so, it again opens the circuit at the spring b, energizing the relay DR.

The change-over is initiated by the long interruption produced at the end of the series of impulses, which allows the relay SR to close its back contact sufficiently long to operate the slow acting relay MR, which did not happen when the short interruptions were received. The relay MR completes the circuit for the sequence switch R4, which goes into its next position 5. Here the 1000's register spindle is disconnected from the relay DR, and the 100's register spindle is connected at the spring 1.

The hundreds impulses may now be sent in as were the thousands. After the impulses for the 100's digit have been received, relay MR is again briefly energized, moving sequence switch R4 to position 8, disconnecting the 100's spindle and connecting the 10's spindle.

The tens impulses may now be sent in. After receiving the tens impulses this spindle is cut off due to the change-over interruption and the units spindle is connected.

The units spindle receives the last set of impulses as above and is then cut-off by the last change-over interruption.

As each series of impulses is received or registered, the sequence switch R4, in going into its next position, closes a contact. This contact, not shown in the figure, closes the power circuit for a second sequence switch R5, belonging to the same register, which controls the sending operations described in connection with Fig. 51.

In case the subscriber hangs up his receiver for a premature clear-out, the relay SR will drop back its armature, permanently energizing the relay MR, and thus drive the sequence switch R4 through all of its 14 positions to normal.

Brush spindle of the group switch is controlled by register (Fig. 50). Before describing the operation of the register, the method for advancing the trip spindle of the group switch a definite number of steps on the reverse impulse method will be outlined.

The trip spindle must be moved through a definite angle, until one of its ten teeth will project and be in position to release the proper set of brushes. Such brushes, when rotated, will hunt an idle junction to a final switch. The power necessary for rotating the trip spindle is applied when the fundamental circuit is closed at the spring F at the register end, which energizes relay GLR and closes the power circuit of the sequence switch R2, sending it from position 5 to the position 6.

The trip spindle now begins to revolve under the influence of the energized power magnet P2G, receiving current over spring M closed in position 6 and over front contact of relay GLR. Before completing each step, called a step for convenience, though the motion is continuous, the interrupter INT2 earths a portion of the fundamental circuit and de-energizes relay SR1. Each time relay SR1 releases, it steps the register spindle one step towards normal. When normal is reached, relay AR is energized and opens the fundamental circuit, thus de-energizing relay GLR. The latter by opening the power circuit, stops the trip spindle P2G. At the same time it closes over its back contact the circuit to the sequence switch R2, which is moved into position 7.

The trip spindle has now stopped having taken as many steps (say 5) as were in the register and projects a tooth, which will release the fifth brush and cause it to sweep over the fifth level of terminals, seeking an idle junction to a final switch in the fifth group.

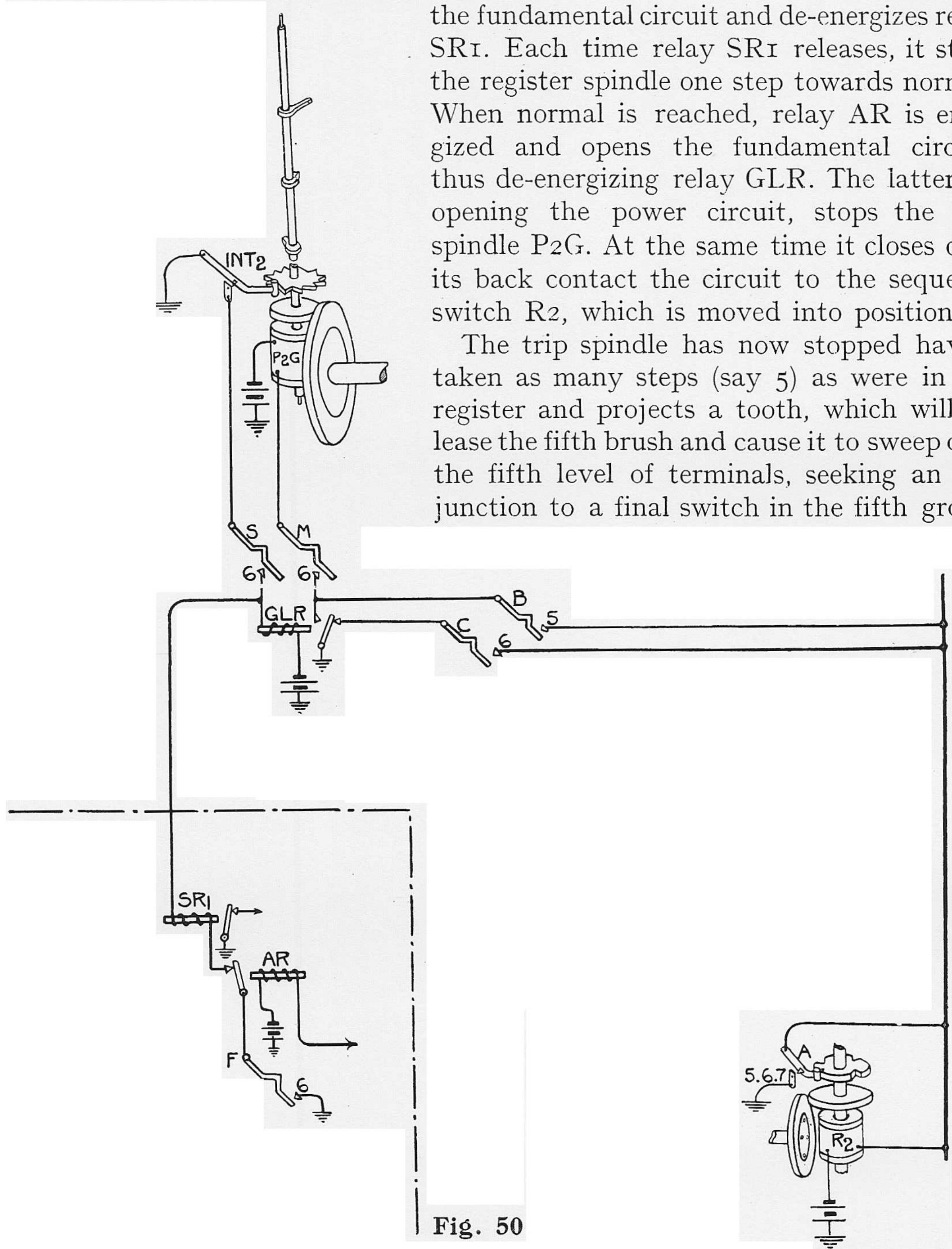


Fig. 50

Before taking up the next operation, which is the rotation of the brush carriage of the group switch, the working of the register and its operative relation with the selecting relay SR1 and the cut-off relay AR will be discussed.

Register controls the building up of the desired connection (Fig. 51). The four register spindles were set forward a number of steps, corresponding to the digits of the number of the wanted line, as described in connection with Fig. 49. These same spindles will now translate the number, and then direct and control the selectors that establish the connection wanted. Impulses are sent out as soon as each set is received.

As the register spindle revolves only in one direction, the number of steps to go to normal will be the complement of the number of impulses sent in, the spindle having ten positions. Therefore, in order that the impulses taken out of the register may correspond with the digit wanted, the impulses sent out by the finger-wheel must be on a complementary basis. The impulse scheme then becomes as shown in the following table :—

Digit :	0,	1,	2,	3,	4,	5,	6,	7,	8,	9.
Impulses sent by finger-wheel :	10,	9,	8,	7,	6,	5,	4,	3,	2,	1.
Number of steps to return register spindle to normal :	0,	1,	2,	3,	4,	5,	6,	7,	8,	9.
Extra impulse taken out of relay AR :	1,	1,	1,	1,	1,	1,	1,	1,	1,	1.
Total number of impulses taken out of register spindle and relay AR :	1,	2,	3,	4,	5,	6,	7,	8,	9,	10.

These last are the impulses required, each one being one greater in magnitude than the digit wanted.

The electrical operation is performed as follows :—

The 100's register spindle is connected to the fundamental circuit, when the sequence switch R5 is moved to position 6. The necessary impulse for this is sent by sequence switch R4 (Fig. 49) after disconnecting the 100's spindle from the substation sending circuit. In a system for 2000 lines, the 1000's register spindle is not required in sending, there being only three sets of impulses, those in the c, b and a place controlled by the 100's, 10's and units register spindle. The 1000's spindle merely serves for translating the impulses in the c place.

The trip spindle of the group switch begins to rotate, as described in connection with Fig. 50, as soon as the fundamental circuit is closed at spring F in position 6. To perform selection the 100's spindle must be set forward one step, for each step taken by the trip spindle, which is done as follows.

The sequence switch R5 in going to position 6 closes spring R in position 2. This closes the circuit of relay D1R which attracts its armature and opens the circuit towards the register spindle. As soon as the fundamental circuit is completed at the distant switch end, relay SR1 is energized and relay D1R is

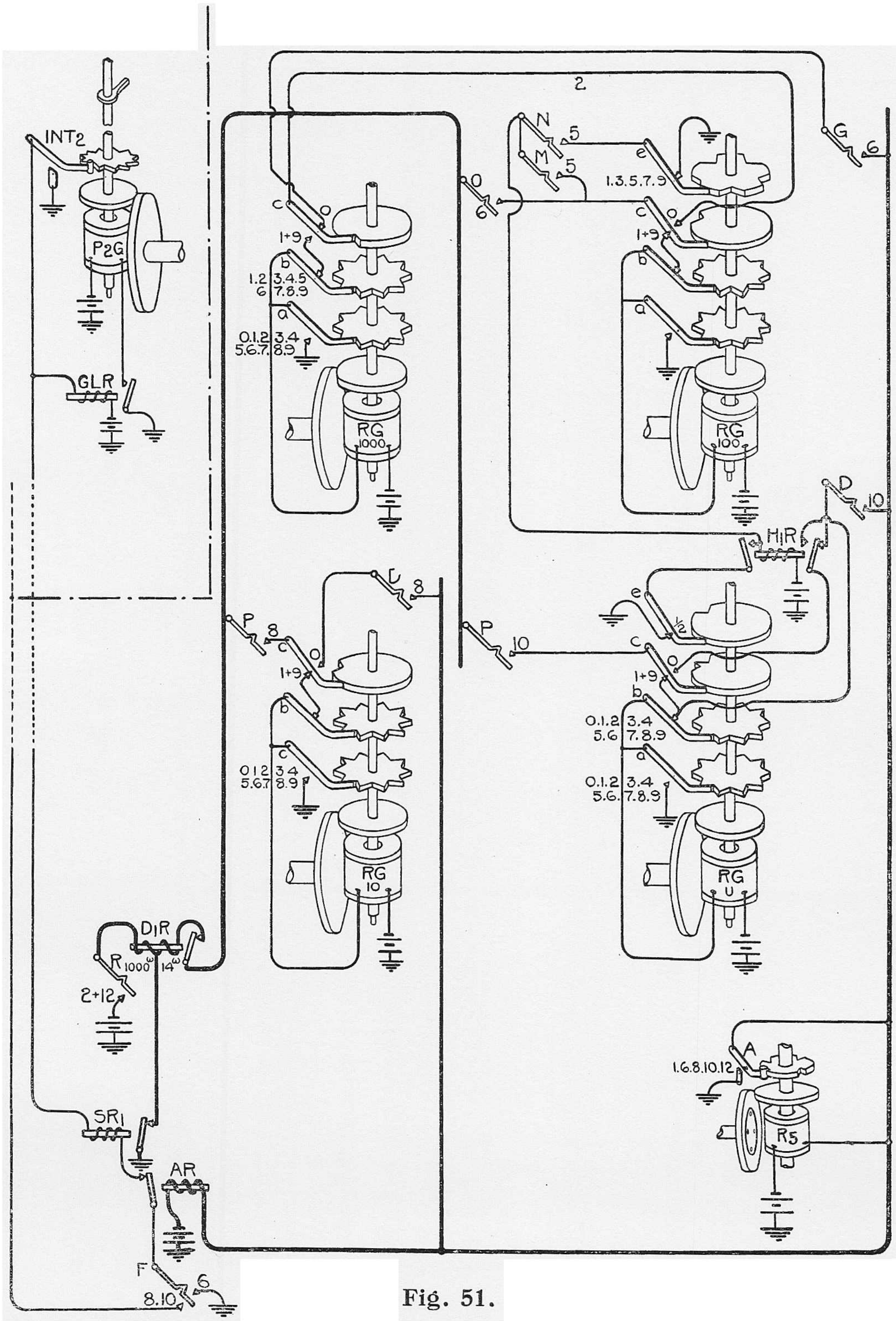

INT2
P2G
GLR
RG 1000
RG 100
RG 10
RG U
H1R
D1R
R 1000ω
14ω
2+12
SR1
AR
F
8.10
6
R5
A
1.6.8.10.12
G
6
D
10
N
M
5
5
2
O
6
P
8
P
10
1.3.5.7.9
1+9
1.2 3.4.5
6 7.8.9
0.1.2 3.4
5.6.7. 8.9
0.1.2 3.4
5.6 7.8.9
0.1.2 3.4
5.6. 7.8.9
½

Fig. 51.

de–energized, partially completing the second differential circuit.

Before the trip spindle completes the first or any additional step, it earths the fundamental circuit and releases the relay SR1, as described above. Each release of relay SR1 closes to earth over its back contact two differential circuits : that of the left-hand winding of relay D1R, and that of the right-hand winding which is in series with the power magnet of the 100's spindle over contact springs b, c and O. The two differential windings balance each other electrically and prevent relay D1R from attracting its armature ; but the power winding RG 100 is energized and moves the spindle one step. That the spindle will take only one, is brought about by a second cam on the 100's spindle, which momentarily opens spring contact b, as each step is taken. Such contact opening removes current from the right-hand winding of the relay D1R, which having current now only in the left-hand winding, is energized, and opens over its back contact the circuit towards the power magnet of the register spindle. In order that the register spindle will not stop prematurely, a power cam and power spring a is provided whose contact once closed, is not opened until the step is completed.

As the trip spindle completes the step, the relay SR1 is again operated, opens its back contact and causes the relay D1R to release its armature and to re-establish the two differential circuits.

The same action occurs for each additional step taken, until the 100's spindle is returned to normal, when a third cam operates spring c. This opens permanently the circuit towards the power magnet of the 100's spindle and closes the circuit towards the cut–off relay AR. The trip spindle takes another step, in the course of which relay SR1 is once more released, the latter now energizing the cut-off relay AR which opens the fundamental circuit. This last is the extra impulse taken out of the relay AR, spoken of above.

Translation requires, as explained, that the series in the c place be decreased by one, if the hundreds digit wanted be odd, and augmented by one, if the thousands digit wanted be odd.

An impulse is deducted, by simply advancing the spindle one step, before it is connected to the fundamental circuit. To this end, there is provided on the 100's spindle a fourth cam, having a notch in every second position and a spring e which closes its contact in these odd positions, being those when an odd hundreds digit is wanted. This contact, in closing, prepares a circuit to the magnet RG 100 over the springs M and N, which are closed momentarily in position 5 as the sequence switch R5 goes from 1 to 6. This energizes the magnet RG 100 causing it to take one step so that there is now one step less in the spindle to be taken out over the fundamental circuit, when the hundreds were odd.

An impulse is added, by taking an extra impulse out of the 1000's spindle. Let it be assumed that the subscriber pulled digit 1 on the finger-wheel (for one thousand) and that the finger–wheel sent in 9 impulses, moving 1000's spindle to position 9. Now, when the spring c of the 100's spindle cuts off the magnet

RG 100 after the spindle is returned to normal, it will switch into circuit the magnet RG 1000 over its spring c. The selecting relay SR1 in taking an impulse out of the magnet RG 1000 operates an additional time, which returns the 1000's spindle to normal and connects conductor 2 to the cut-off relay AR. After this, the relay SR1, operated the last time, takes the extra impulse out of relay AR ; the latter is energized and opens the fundamental circuit. There is thus added an impulse to the series in the c place, when the thousands are odd and only then.

If the capacity is over 2000, the 1000's spindle is controlled by a relay (not shown) so that, when the thousands are odd, the spindle will only go to the 9th position when controlling the impulses in the d place. The remaining step is taken as described above, in adding an impulse to the c place series.

The sequence switch R5, being in parallel with the relay AR, is also operated moving its spindle to position 8.

The 10's spindle is connected to the selecting circuit over the spring P closed in position 8 and is ready to measure the impulses for the b place. The fundamental circuit is also reclosed at spring F in position 8.

The brush carriage of the group switch has, in the meantime, hunted the terminal of an idle junction and extended the circuit to a final switch, whose brush chooser is placed in circuit relation with the fundamental circuit.

If the brush carriage is slow in finding an idle junction the 10's spindle, connected to the fundamental circuit, is prevented from taking a step, by the relay D1R, which remains energized over the back contact of relay SR1. This keeps the circuit open towards the magnet RG10, until the relay SR1 operates with the closing of the fundamental circuit at the switch end.

The trip spindle of the final switch revolves, when the fundamental circuit is closed at both ends, and, as before, through the intervention of the relay D1R, steps the 10's spindle back to normal. When normal is reached, one more impulse is taken out over the cut-off relay AR, which operates, opens the fundamental circuit and stops the brush chooser.

The sequence switch R5 in parallel with relay AR, is also operated and moves to position 10.

The units spindle RGU is now connected to the fundamental circuit, which has been again closed at F in position 10. In the meantime, the brush carriage of the final switch is also connected to the fundamental circuit, whose control is described in connection with Fig. 53.

The units spindle RGU is advanced one step for each step taken by the brush carriage of the final switch, and, when returned to normal, connects the relay AR over the spring c. The extra impulse is next taken out, energizing relay AR, which in turn opens the fundamental circuit and stops the brush carriage.

The operation of translation, when necessary, is simply performed in this case. It was shown in the discussion of translation that, to reach the proper terminal, 10 impulses must be added to the series in the a place, when the hundreds were odd.

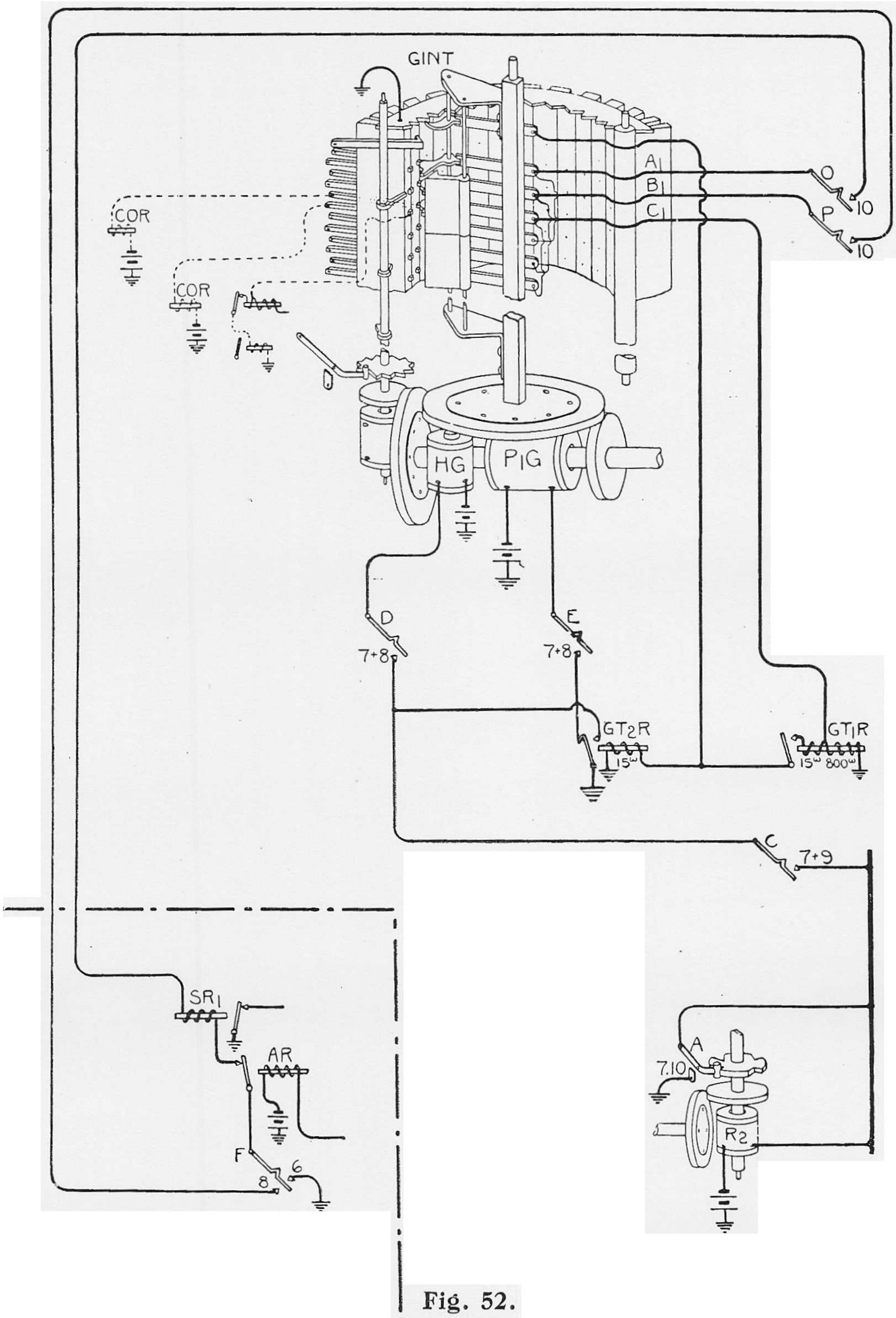

GINT
COR
COR
A1
B1
C1
O
P
10
10
HG
P1G
D
E
7+8
7+8
GT2R
15ω
GT1R
15ω 800ω
C
7+9
SR1
AR
F
8
6
A
7.10
R2

Fig. 52.

This is accomplished by means of the relay H1R, which is energized over spring N (closed momentarily in position 5) and over the spring e of the 100's spindle (closed when hundreds sent in were odd). The relay holds up over its front contact and over the spring e on the units spindle connected to earth, and it connects the springs b and c together over a second front contact. Under this condition the spring c will fail to make the switch-over to the relay AR when operated the first time the spindle reaches normal, as the relay AR is cut-off at the back contact of relay H1R. Therefore, the spindle will continue to step and take 10 more steps until normal is again reached. In taking these 10 steps, it passes position $\frac{1}{2}$, when the fourth cam allows the spring e to drop into a notch which momentarily opens the circuit and releases relay H1R. When reaching its normal position the second time, the spring c, in making the switch-over, is this time successful in substituting the relay AR for the power magnet of the units spindle in the circuit of the right-hand winding of relay D1R. When the last impulse is taken out of relay AR, it is energized, again opens the fundamental circuit, and stops the brush carriage of the final switch.

The sequence switch R5, in parallel with relay AR, is also operated, moving its spindle into position 12, which initiates the release of the register from the connection circuit, not shown, the register having performed its function.

Brush carriage revolves hunting an idle junction (Fig. 52). The trip spindle having been advanced to project the desired tooth, the brush carriage must be rotated.

The brush carriage begins to rotate under the influence of the energized power magnet, which receives current over the spring E (closed in position 7) and the back contact of relay GT2R. As the ten sets of brushes pass the trip spindle, one of the teeth will pull back the ebonite latch and thus release the particular set of brushes. In the figure only two sets are drawn, and the top tooth assumed to be in position ready to trip the top set of brushes. The brush carriage continues to revolve, with the set of brushes tripped, sweeping its brushes over the terminals of the level.

The brush carriage will only stop when an idle junction is reached. For this purpose each junction terminal is tested in passing, by the third or test brush, as it touches each terminal.

The testing is accomplished by means of the two test relays GT1R and GT2R. A busy condition of a junction line, illustrated by the first test terminal, is indicated by a very low potential of only a few volts, not enough to operate relay GT1R. The idle condition of a line, illustrated by the second terminal, is marked by full battery potential. When connected with an idle terminal, having a full potential, the test relay GT1R receives enough current to be energized and, in closing its front contact, puts a low resistance shunt around the high resistance winding, thereby making the terminal instantly busy to any other brush of a group switch that might be testing over the same level of terminals.

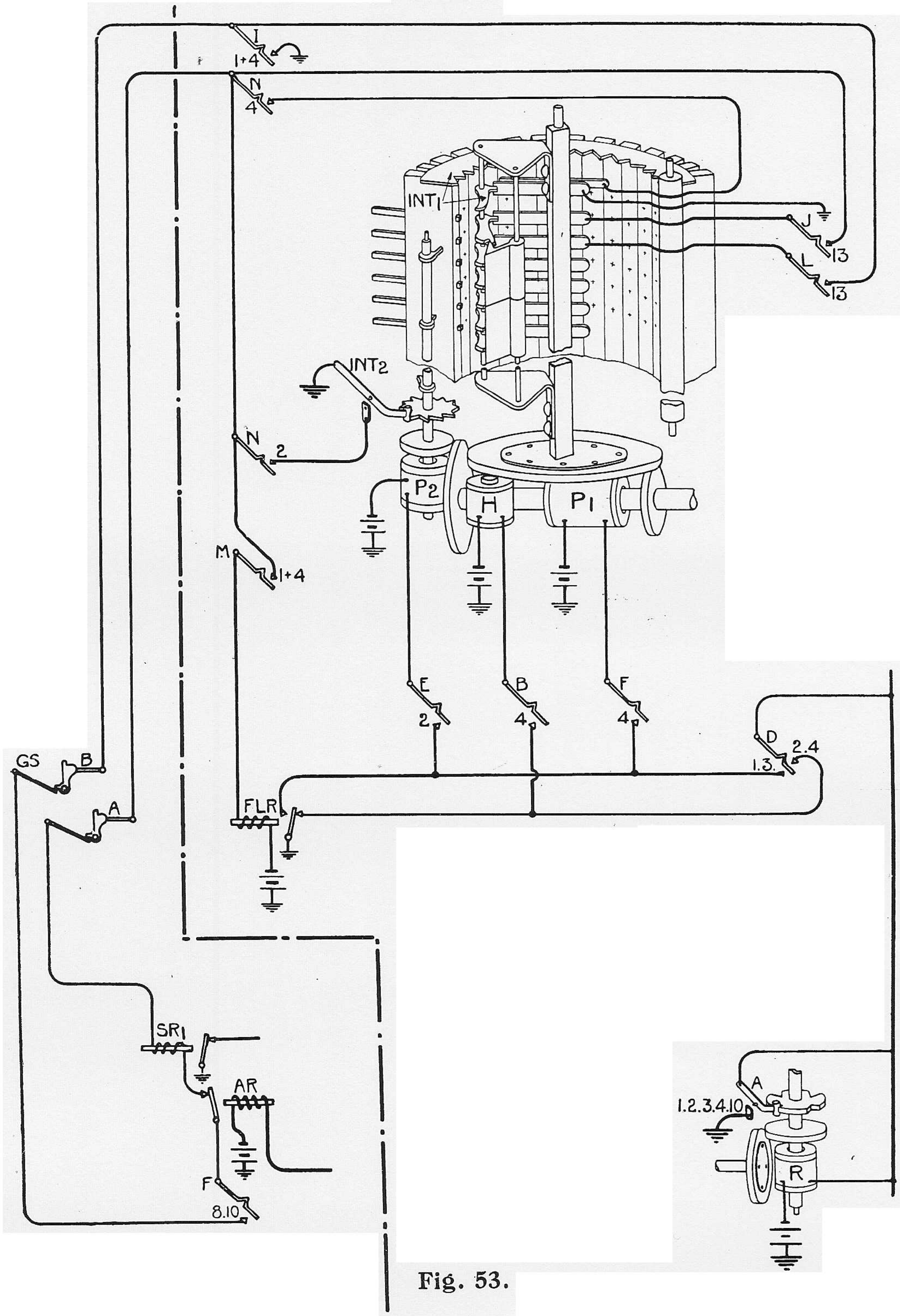

I
1+4
N
4
INT1
J
13
L
13
INT2
N
2
P2
H
P1
M
1+4
E
2
B
4
F
4
D
1.3.
2.4
GS
B
A
FLR
SR1
AR
F
8.10
A
1.2.3.4.10
R

Fig. 53.

It is to be noted that an irregularity in the testing circuit, such as a break or an open contact, will also cause the test relay GT1R to fail to respond, treating it as if it were a busy line.

The brush carriage does not stop, however, until the brushes are squarely on the terminals, which, as for the line finder, is accomplished by an interrupter GINT, which holds the relay GT2R short-circuited, until the brushes are centered. The relay GT2R, when energized, opens the power circuit of magnet P1G to stop the brush carriage, while closing the circuit of the holding magnet HG to bring it to an immediate standstill.

The sequence switch R2, whose winding is in parallel with the holding magnet HG, is also energized and moves into position 10. In this position the fundamental circuit containing the relays SR1 and AR is connected over the springs P and O and over the brushes A1 and B1 to a junction line leading to the final switch.

When the system has a capacity over 2000 lines, the fundamental circuit will be connected to a distant second group switch which will be selectively controlled as was the first group switch above described and which will then extend the fundamental circuit to the final switch, where the terminals of the wanted line are found.

Brush chooser and brush carriage of final switch are selectively controlled by the register (Fig. 53). As soon as the fundamental circuit has been completed to the final switch, relay FLR is energized, moving sequence switch R from position 1 to position 2, ready to begin the brush choosing operation.

The trip spindle of the final switch revolves in position 2 of the sequence switch, due to the energized power magnet P2 taking current over the front contact of relay FLR.

The trip spindle must be moved through a definite angle so that a tooth will project and release the proper set of brushes for the desired tens level. As described for the group switch, each step taken by the brush spindle returns the register spindle a step forward towards normal, until normal is reached, when the relay AR is energized, releasing relay FLR and stopping the spindle.

The sequence switch R will now move from position 2 to position 3, because of current received over the back contact of relay FLR and over spring D.

The register next connects the units spindle, ready to control the movement of the brush carriage, and again completes the fundamental circuit by closing spring F. Relay FLR is energized and, over its front contact closes the circuit for sequence switch R, stepping it to position 4.

The brush carriage begins to rotate because of the energized power magnet P1, finding a circuit over the front contact of relay FLR, and, when passing the trip spindle, it will have one of its sets of brushes released by the projecting tooth

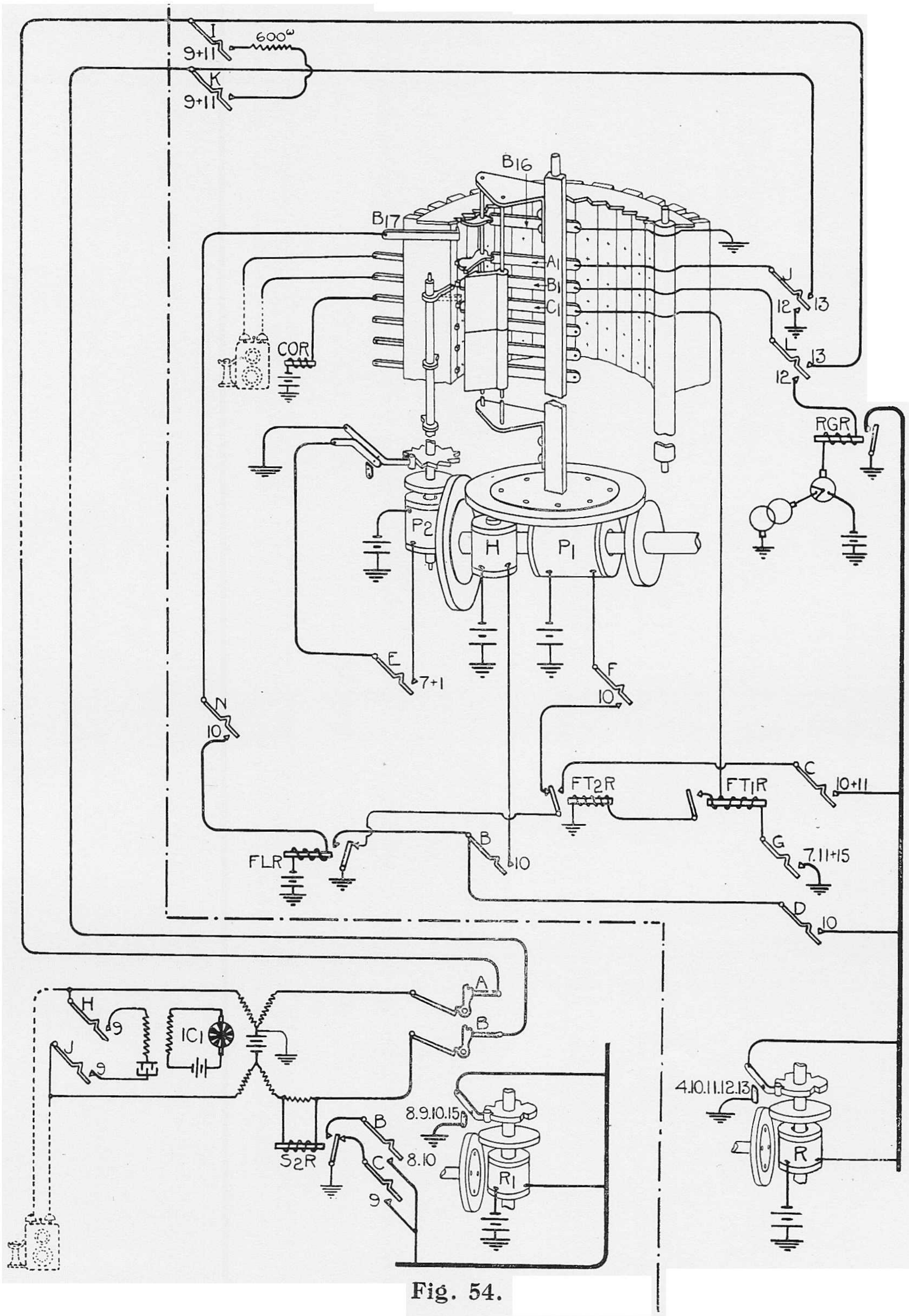

I
9+11
600ω
K
9+11
B16
B17
A1
B1
C1
COR
J
12
13
L
12
13
RGR
P2
H
P1
E
7+1
F
10
N
10
FT2R
FT1R
C
10+11
FLR
B
10
G
7.11+15
D
10
A
B
H
9
J
9
IC1
S2R
B
8.10
C
9
8.9.10.15
R1
4.10.11.12.13
R

Fig. 54.

The brush carriage must next be moved forward over a number of terminals, each passage from terminal to terminal being marked off by the interrupter INT1, by earthing the fundamental circuit over the spring N and stepping forward the units register spindle.

The brush is stopped, when the register spindle is returned to normal and therefore the required terminal has been reached, by the opening of relay AR, which releases relay FLR and de-energizes the power magnet P1.

The sequence switch R is moved from position 4 to position 10 as soon as the relay FLR in releasing completes the sequence switch circuit over its back contact.

While the sequence switch passes from position 4 to position 10, the line is tested, as will be described in connection with Fig. 54.

Line wanted is tested, rung and connected for conversation ; if busy, busy tone is applied (Fig. 54). Testing of the called line is performed, as the sequence switch R, having left position 4 (Fig. 53), closes the contact spring G in passing through position 7. A circuit is then completed for the test relay FT1R over the test brush C1, test terminal and cut-off relay to battery.

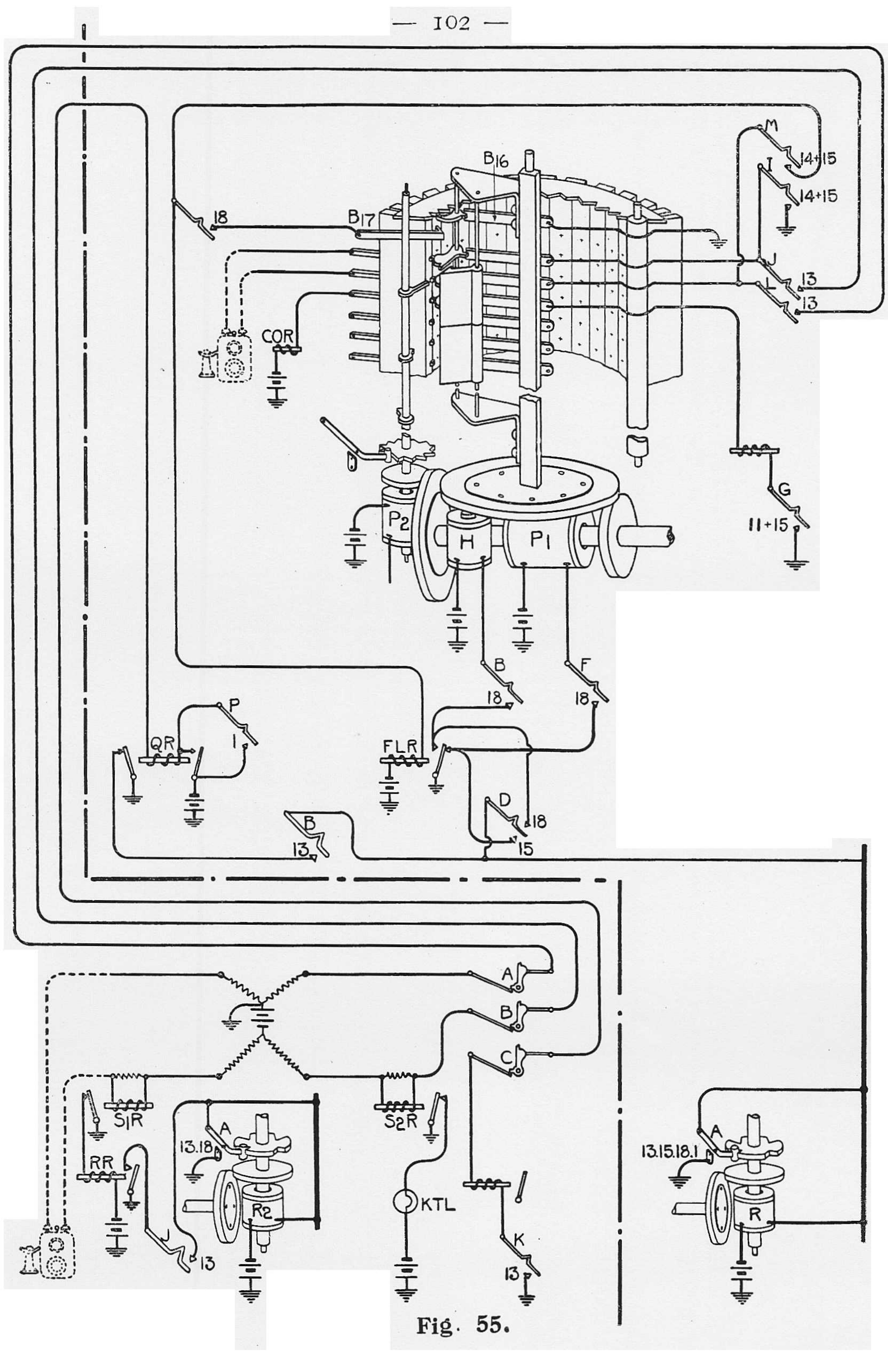
It will be assumed that the line is idle. A line that is not busy, possesses full battery potential as in the case of an idle junction line terminal, which allows the high resistance winding of relay FT1R to become energized and to close its front contact, placing a low resistance shunt in parallel with this winding and thus making the test terminal immediately busy for any other calling line.

Sequence Switch R must be moved in this case at once to position 12, the ringing position. This is done by relay FT2R, which is energized, when relay FT1R is operated, and over its front contact holds the circuit of the power magnet R closed. The sequence switch R continues to move, until the spring C is opened after leaving position 11, so that R moves to position 12.

To ring the bell of the substation wanted, alternating current is applied to the called line in position 12 over the springs J and L ; in the intervals of ringing, battery is connected, as is usual in machine ringing pratice.

To inform the calling subscriber by a short buzz that ringing has commenced, a 600 ohm resistance is bridged on the junction line over the springs I and K, while the sequence switch is passing through positions 9, 10 and 11. This resistance energizes supervisory relay S2R, which over its front contact energizes sequence switch R1, associated with the group switch. The latter moves to position 9, in which an interrupter IC1 sends tone to the waiting subscriber. But this only for an instant, as the resistance bridge is immediately after opened, causing the relay S2R to drop back and to step sequence switch R1 into position 10 removing the tone.

When the called subscriber answers the call by removing his telephone, he energizes relay RGR, which completes the power circuit for R and steps it to position 13, thereby cutting off the ringing current. Relay S2R is also energized



B16
B17
18
M
14+15
I
14+15
J
13
L
13
COR
G
11+15
P2
H
P1
B
18
F
18
P
1
QR
FLR
D
18
15
B
13
A
B
C
S1R
S2R
RR
A
13.18
R2
J
13
KTL
K
13
A
13.15.18.1
R

Fig. 55.

moving R1 to position 15, the talking position. Conversation can now take place.

If it be assumed that the line tested above is busy, relay FT1R and therefore FT2R will not be energized, so that the moving spindle of the sequence switch R now stops in position 10.

The brush carriage of the final switch is at once revolved towards normal, due to the closure of the circuit for the power magnet P1 over spring contact F (closed in position 10) and back contacts of relays FT2R and FLR.

When the brush carriage reaches normal, it is stopped. This occurs because of a circuit completed by the earthed spring B16 touching the plate B17, which energizes relay FLR. The relay, in attracting its armature, cuts off the power from the magnet P1, and stops the brush carriage. It also completes the circuit for the power magnet R, sending the sequence switch to position 11. The holding magnet H, in parallel with power magnet R, is also energized.

The sequence switch R remains in position 11 until the group switch has released the junction line when it will return to normal, not shown.

The busy tone is given to the waiting subscriber by the interrupter IC1, which is connected to his line over springs H and J in position 9 of the sequence switch R1. It was driven to this position from 8 by relay S2R over its front contact, the latter being energized in a circuit completed by bridging the 600 ohm resistance on the junction line at the final switch (in position 11 of sequence switch R).

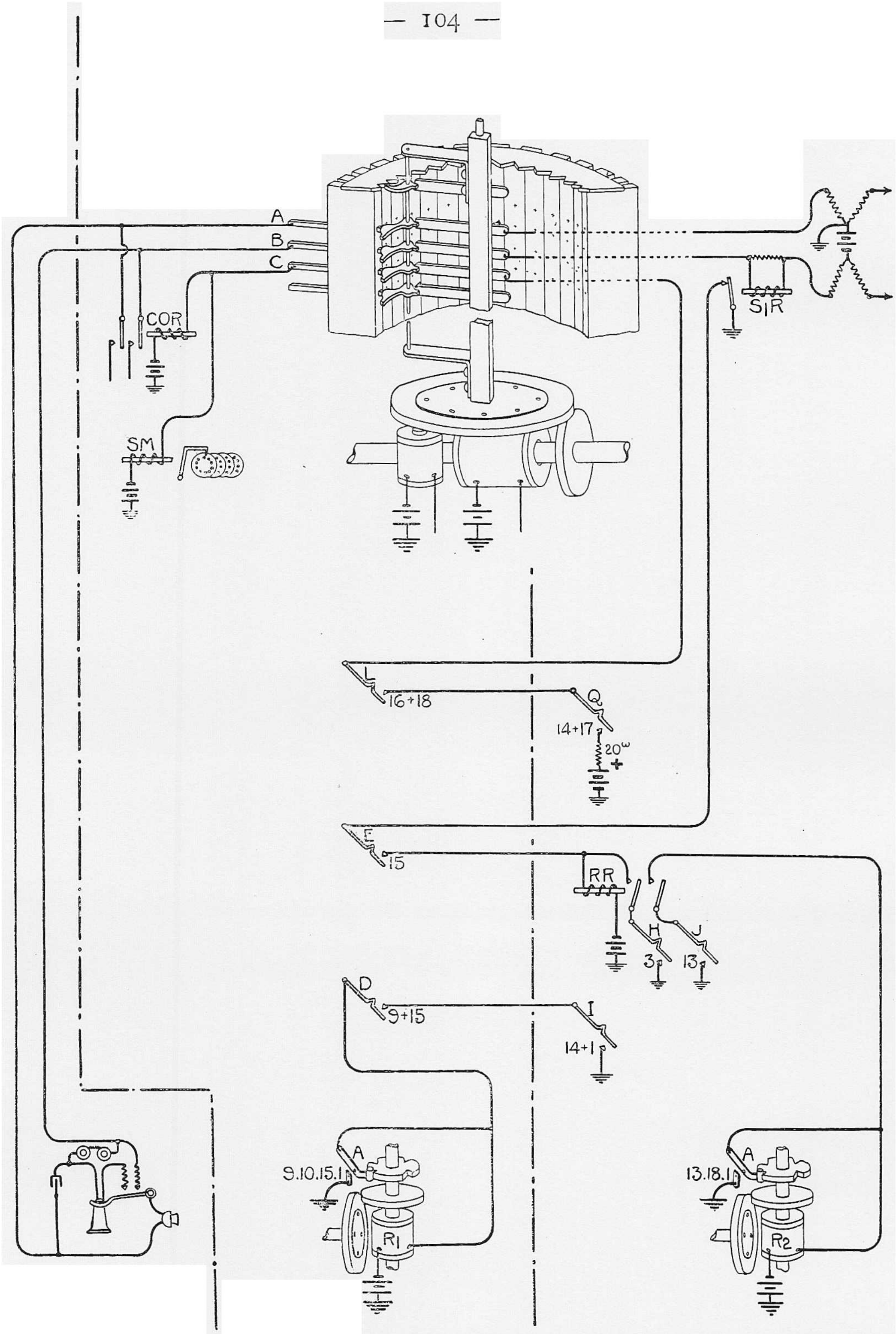
Connection is cleared after conversation (Fig. 55). The calling subscriber in restoring his telephone initiates the clear-out by de-energizing the supervisory relay S1R, which operates relay RR ; the latter moves the sequence switch R2 from position 13 to 18. Thereby the spring K is opened and the relay QR at the final switch is de-energized, initiating the return to normal of the final switch.

The method of returning the switches to normal will be described in connection with the final switch, it being similar for the group switches.

Before returning the brush carriage to normal, the apparatus tests to determine whether the subscriber has restored his receiver, so that — if he be slow in doing so — he will not connect uselessly a register to his line. This is done by having relay QR, in releasing its armature, complete the circuit of power magnet R which moves the sequence switch to position 15, in which the relay FLR is connected to the line. Until the subscriber restores his receiver, the relay FLR will remain energized.

When the subscriber has restored his receiver, the brush carriage is revolved to normal, because magnet P1 is now energized over the back contact of relay FLR and the spring F closed in position 18, switch R having been moved from position 15 to 18 when relay FLR dropped back.

The brush carriage stops, when it reaches the normal position. The power magnet is opened in this case by relay FLR, which is energized when the spring



A
B
C
COR
SM
S1R
L
16+18
Q
14+17
20ω
+
F
15
RR
H
J
3
13
D
9+15
I
14+1
A
9.10.15.1
R1
A
13.18.1
R2

Fig. 56.

B16 touches the plate B17 at normal. At the same time the circuit for the holding magnet H is closed.

The sequence switch R is also energized over the contact of relay FLR and moves its spindle to the first or normal position.

The trip spindle of the brush chooser was returned to normal, when sequence switch R has reached position 7. In this position, the circuit of the power magnet P2 is closed over the power contact spring engaging the power cam. The trip spindle revolves until normal is reached, which is marked by a deeper notch in the power cam, so deep that the contact of the power spring is now opened. The power magnet is de-energized and the trip spindle stopped.

The final switch is now in readiness to serve another register which is trying to establish a connection to one of this group of subscribers' lines.

Connection is registered after conversation (Fig. 56). In case the subscriber was successfully connected to a line, his message register must be advanced a step to record the connection.

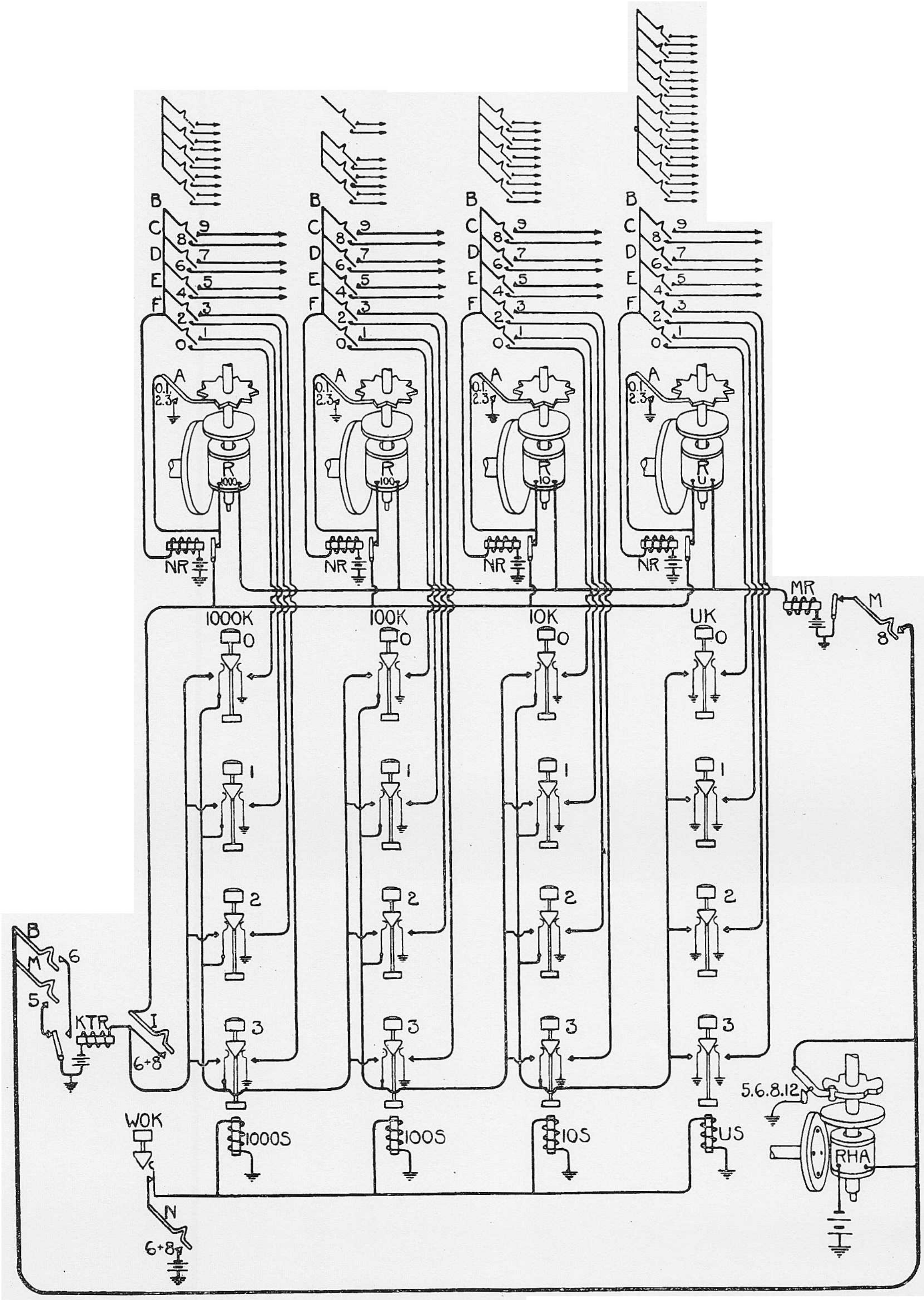
Each line is provided with a service meter or message register SM of the type usually provided in manual exchanges. It consists of a counting train stepped forward with each operation of an associated electro-magnet.

The message registration only occurs after the calling subscriber clears out. Restoring the receiver de-energizes the relay S1R, closing the circuit for the break-down relay RR, which over its front contact moves sequence switch R2 out of position 13.

The message register is operated by the special service meter battery, when sequence switch R2, in going from position 13 to 18, passes through positions 14, 15, 16 and 17, while the second sequence switch R1, also associated with the connection circuit, in going from position 15 to 1, passes through 16, 17 and 18. The motion of these two switches will be simultaneous, as switch R2, in moving from position 13, closes the spring 1 in position 14, thus energizing the sequence switch R1 over spring D and moving it out of position 15.

The registration cannot occur when the line is busy or the called subscriber has not answered, for then the sequence switch will remain in position 9 (or 10 when subscriber has not answered) (Fig. 54). When under these conditions the sequence switch R2 is moved out of position 13 by the calling subscriber hanging up his receiver, it closes the spring 1 as before and starts sequence switch R1 from position 9 through all the positions to normal. But as both switches travel at the same speed, sequence switch R1 will pass through 11, 12, 13 and 14, when spring L is not yet closed while R2 is passing through 14, 15, 16 and 17 when spring Q is closed.

In this case the service meter will not be operated as the circuit from the meter battery will not be completed over the springs Q and L, the first closing and opening before the second closes.


B
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9
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0.1.
2.3.
R
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10
U
NR
MR
M
8
1000K
100K
10K
UK
KTR
I
6+8
5
6
WOK
N
6+8
1000S
100S
10S
US
5.6.8.12
RHA

Fig. 57.

SEMI-AUTOMATIC SYSTEM CIRCUITS.

In the semi-automatic System the characteristic circuit operations are like those described for the full automatic System with one or two exceptions.

There are provided two line finders instead of one. The method of connecting the first line finder to the calling line is similar to that discussed in Fig. 47. When the calling line is found, the sequence switch of the first line finder closes a contact, which starts a series of second line finders, searching the calling junction leading to the first line finder. The method of stopping a second line finder on the terminals of the calling junction is again like that shown in Fig. 47.

A calling lamp associated with the connection circuit and located before the operator, is lighted over a sequence switch spring, closed as the sequence switch of the second line finder takes its next step after stopping the brush carriage. This lamp burns steadily until the idle operator's telephone circuit and register is picked up. The above sequence switch then moves into its next position, which connects the operator's telephone set to the connection circuit, produces a short buzz in the receiver to notify the operator and sets the calling lamp to flicker by connecting it to a commutator.

The method of finding an idle register is that described in connection with Fig. 48. Each connection circuit has access to six registers, which are distributed among three operators. If the operator is busy, both her registers report busy, so that the sequence switch R3 in rotating will test successively register A and B of the operator before whom the call appears, then the registers A and B of the operator to the left and finally the registers A and B of the operator to the right. This makes possible the automatic helping out feature and gives a subscriber an opportunity to reach automatically one of three operators.

The method of operating the number keys and the method of the register control present some new features and will be described in detail.

By means of a listening key the operator can supervise when required. The key, when thrown, makes her position busy.

To clear out she depresses a releasing key, which completes the releasing circuit over the back contact of the supervisory relay S1R de-energized when the subscriber hangs up his receiver. The arrangement is therefore such that an accidental depression of the key will not clear if the relay has not closed its back contact. If a release is nevertheless desired under such conditions, the operator can perform a forced release, by depressing a master key when operating the release key.

Message registration takes place automatically, when the apparatus is cleared out as in the full automatic system. To prevent message registration, the operator throws a master key, while depressing the release key. This opens the circuit of the meter battery while the sequence switches R1 and R2 are passing through their metering positions (Fig. 56).

Operator depresses keys to record the number (Fig. 57). The operator, having received the number of the line wanted from the subscriber, records it by depressing the corresponding number keys of the key set before her.

For calling numbers up to 9999, there are placed before the operator four rows of keys, each row serving for a decimal place and each row having ten keys for the ten digits. In the figure, only four are shown per row numbered 0, 1, 2, 3.

Each digit key, once depressed, is held down by clutch magnets 1000S 100S, 10S and US, which are energized over the spring N in position 6 to 8 of the sequence switch RHA ; this sequence switch, associated with the register, moves to this position, once the register has been picked up by the connection circuit. The magnets receive enough current to hold down a key depressed but not enough to pull down those not depressed.

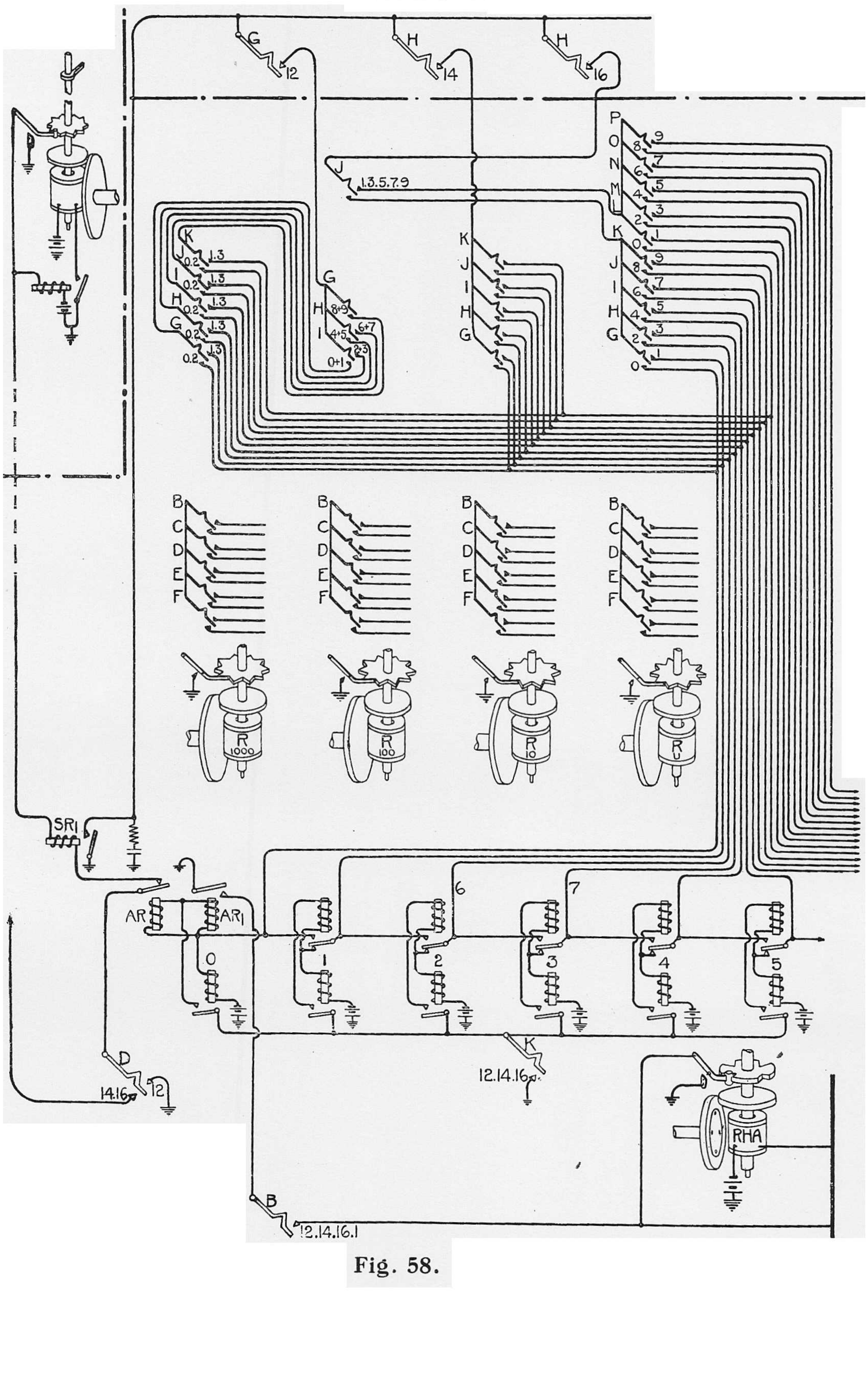
If the operator desires to correct an erroneous depression of keys, she pushes the wipe-out key WOK which de-energizes the magnets 1000S, 100S, 10S and US to release the buttons depressed.

The four spindles R1000, R100, R10 and RU of the register, there being as before a spindle for each decimal place, must be revolved to take the positions corresponding with the number keys depressed and thus to record the number wanted. When all four keys are depressed, a circuit is completed over the left-hand contacts to earth which energizes relay KTR moving sequence switch RHA to position 8. In this position all of the power magnets R1000, R100, R10 and RU are energized and rotate their respective spindles, these magnets being in parallel with each other and in series with the relay MR, and finding circuit to earth over the key contacts.

Each spindle revolves, closing successively the ten contacts of the five contact springs B, C, D, E and F. When one of these finds an earth over the closed right-hand contact of a number key, it completes the circuit for the relay NR which immediately opens the circuit of the associated power winding and stops the spindle. If thus key 4 had been depressed the spindle would stop in position 4, there being positions 0 to 9 on the spindle to agree with the keys 0 to 9.

The depressed keys will be released indicating to the operator that the key-set is free and ready to be used for recording a second number, as soon as all four spindles have stopped, when the circuit of all power magnets will be opened and relay MR without current. Relay MR in closing its back contact, sends the sequence switch RHA to position 12. The keys are now released by the de-energizing of the magnets 1000S, 100S, 10S and US, when the contact N is opened.

The key-set is now ready to be used for recording another number on the second register whose ten conductors per spindle leading to the key contacts are connected in multiple with those of the first register. The contacts of the relay KTR are connected to the corresponding springs M and B of the second register, so that when keys are released, relay KTR is also released and, closing its back contact, sends the sequence switch of the second register from its guard position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J
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K
J
I
H
G
0.2
1.3
H
8+9
I
4+5
6+7
2+3
0+1
B
C
D
E
F
R
1000
R
100
R
10
R
U
SR1
AR
AR1
0
1
2
3
4
5
6
7
K
12.14.16
D
14.16
12
RHA
B
12.14.16.1

Fig. 58.

5 into position 6 where it awaits the depressing of the digit keys for the next number.

If both registers are in use, the operator cannot record a new number, as the keys will not be held down. The operation of the selecting machines is so rapid that an operator cannot keep more than two registers busy.

The digits of the number wanted are now recorded on the register spindles, which are ready to control the establishing of the desired connection.

Operator's register controls the building up of the connection towards the wanted line (Fig. 58). The same register spindles that took positions corresponding to the telephone number wanted, will control the connection to the line wanted. They are shown again but this time with a second set of contact springs, the first set B to F playing no part in the sending. These springs are numbered like sequence switch springs, to indicate in which position of the register spindle they are closed.

The number of steps to be taken selectively by the distant trip spindle or brush carriage are in the semi-automatic System measured off in a different manner than that already discussed. In the full automatic System, the register spindle is revolved for this measurement through the number of steps of displacement from normal. In the semi-automatic System, the spindle is not moved, but instead the number of steps of displacement are counted off by a series of counting relays. There is such a relay for each step of displacement, and each relay is connected with a different contact on the register spindle, these contacts being closed successively as the spindle passes through its positions. The set of counting relays which are used repeatedly for each series to be controlled, consists of 20 pairs of relays, only six pairs being shown in the drawing.

The three spindles (R100, R10 and RU) controlling the impulses in the c, b and a place, when the capacity is 2000 lines, must be connected successively by sequence switch RHA in positions 12, 14 and 16 to the fundamental circuit.

The 100's spindle R100 is first connected with the front contact of relay SR1 by closing spring G. If it be assumed that the operator has depressed 100's key N° 2, the 100's spindle went to position 2. In this position the circuit extends from spring G over top contact of spring I of the 100's spindle, bottom contact of spring H of the 1000's spindle (closed bottom when thousands are even), conductor 6 to the third pair of relays marked 2.

Selection may begin as soon as the trip spindle of the group switch is connected to the fundamental circuit and the latter closed at spring D, which occurs when the sequence switch is moved into position 12 (Fig.58). Relay SR1 in operating energizes the lower relay of the pair marked 2 which locks up over its front contact. The mate or upper relay in the locking circuit cannot operate as yet, its winding being held in short-circuit by the circuit to earth over the front contact of relay SR1.

Before the trip spindle completes any step, it earths the fundamental circuit and releases SR1. The release of relay SR1 opens the front contact and removes the short-circuit from the upper relay of the pair marked 2, which is now energized and connects the lower relay of the pair marked 1 to the conductor 6.

As the trip spindle has completed the first step, the relay SR1 is re-energized and closes the circuit now for the lower relay of the pair marked 1 while holding its mate relay in short-circuit.

For each step completed by the trip spindle, a pair of relays is thus locked up until at last a release of relay SR1 energizes the cut-off relay AR, which opens the fundamental circuit and stops the trip spindle.

The trip spindle has thus been stopped in the third position having sent back three impulses, and locked up three pairs of relays corresponding with the third position of the 100's register spindle and the third key depressed (marked «2» for 200).

Translation as already explained requires that an impulse be deducted from the series in the c place when the hundreds depressed on the keys are odd, and an impulse be added when the thousands are odd.

The deduction of one impulse is simply performed by keeping each of the springs on the spindle closed for two positions, as, for example, the spring I is closed for position 2 and 3, so that the odd hundred (300) will cause the same conductor (6) to be connected as the even hundred (200); and, as before, only three impulses are taken out.

The addition of an extra impulse, when the thousands are odd, is as simply performed by the springs G, H, I, J and K on the 1000's spindle, which close bottom contacts, when the thousands are even, and top contacts, when they are odd. If in the above case an odd thousand had been called, the spring I would be connected over spring H of the 1000's spindle (closed top) to conductor 7, instead of conductor 6, thus including one more pair of counting relays, involving one more impulse being taken out before cut-off relay AR is operated.

Sequence switch RHA is energized by relay AR1, which is in parallel with the cut-off relay AR, and moves to position 14. In this position the 10's register spindle is connected over spring H to the front contact of relay SR1. The counting relays that are locked up, will all be released by the opening and closing of the spring K. The fundamental circuit will be again closed at spring D.

The 10's spindle is now ready to determine the number of impulses in the b place to control the brush chooser of the final switch. This is done, as before, by having each operation of relay SR1 lock up a pair of counting relays, beginning with the pair whose circuit is closed by a contact of one of the springs G to K on the 10's spindle to the front contact of the relay SR1. In locking up the last pair of counting relays marked O, relay AR is energized, opening the fundamental circuit and stopping the trip spindle.

Sequence switch RHA will also be energized and go to position 16, connecting the springs of the units spindle to the front contact of relay SR1, opening and closing the spring K which releases all relays locked up, and again closing the fundamental circuit at spring D.

The units spindle, now connected, determines the number of the impulses in the a place to control the motion of the brush carriage of the final switch. This is done exactly as in taking out the impulses in the b place.

Translation, which, as already explained, is necessary when the hundreds are odd, requires that ten additional impulses be taken out in the a place. This is readily performed by providing five extra springs L, M, N, O and P on the units spindle, which are connected with counting relay pairs numbered 10 to 19 (not shown), and a spring J on the 100's spindle, which closes the top contact when the hundreds are odd and the bottom contact when the hundreds are even. When calling an odd hundred, the upper set of contact springs L to P are in use, connecting to one of the counting relays N° 10 to 19. In this case the relay SR1 measuring off the steps will begin from one of the second ten and then continue to lock up relays N° 9 to 0, thus sending the brush carriage ten additional steps, before energizing cut-off relay AR.

The sequence switch RHA is again energized and now moves to normal. In doing so, it causes the sequence switch R2, associated with the connection circuit, to advance a step and disconnect the register.

The control of the distant group and final switches under the influence of impulses taken out over the fundamental circuit is exactly like that described in the full automatic System. Again, the testing and ringing of the line of the wanted subscriber is also performed as already described. Similarly, the busy tone is connected when the subscriber's line reports busy. For these reasons, these circuits will not be described again in connection with the semi-automatic System.