TELEPHONE READING COURSE

ON

STEP-BY-STEP
DIAL SYSTEM
CENTRAL OFFICE EQUIPMENT

SECTION 1 *PART I*

GENERAL DESCRIPTION
OF
STEP-BY-STEP
DIAL SYSTEM

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GENERAL DESCRIPTION
OF
STEP-BY-STEP DIAL SYSTEM

SECTION 1—PART 1

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TELEPHONE READING COURSE ON STEP-BY-STEP DIAL SYSTEM

PURPOSE

This reading course describes the Step-by-Step Dial System, as now being used in the Ohio territory of the Bell System, giving more emphasis to its operation than to its engineering features.

The main purpose is to provide text books for use in class rooms, where instruction is given in the operation and maintenance of this equipment in preparation for cutovers; and to help the newer employees in existing step-by-step offices enlarge their understanding of this system.

In addition it is intended to provide means whereby employees, whose work does not require a technical knowledge of this equipment but whose ambition impels them to keep informed on all our company's activities, can get the information they desire on this subject with a moderate expenditure of time and effort.

Any employee may take any part of this course or the whole of it.

This course consists of four sections in which the subdivisions of this subject are taken up in the order in which previous experience has shown that the students get the facts most effectively.

In the first section an overall picture of the system is sketched and some of the words and terms peculiar to this subject are introduced.

The second section is very brief—mainly pointing out the necessity for the precise mechanical adjustments required in all this mechanism to ensure its satisfactory operation and explaining how this information is supplied to employees of any office.

The third section deals with Trunking—that is the wire connections between the various switches including the terminal assemblies—and shows the necessity for the rather intricate arrangements in order that the normal operation of the switches, in response to switch hook and dial operation, may build up talking and signalling paths so as to make economical and efficient use of all the mechanism.

The fourth section describes the operation of all the essential circuits in a typical step-by-step office.

In addition we have a separate course on Step-by-Step Call Indicator Equipment to provide for cases where employees might wish to take either of these two courses but not both.

ENTRANCE REQUIREMENTS

Employees taking this course should have a knowledge of the basic laws governing the action of electricity at least equal to that which may be gained from sections 3 and 4 of our reading course on "Fundamentals"; but this requirement may be waived in cases where it is advisable for the employees to omit study of the detailed operation of the circuits.

FUNDAMENTALS OF THE STEP-BY-STEP DIAL SYSTEM

To get right down to bedrock fundamentals, suppose we take stock of what we have to work with in making telephone connections by machinery.

First, and most important, we have an intelligent human being at or near each of any two telephones to be connected; otherwise the connection fails in its purpose of establishing communication between **those two people.**

But the effort that may be required of them must be small enough to avoid imposing burdens that would tend to make the service unattractive.

Second, we have a pair of wires from each telephone to the central office. (For sake of brevity we may consider one office only.)

Third, we have electromagnets in a sufficient variety of forms to make all the motions necessary for the connection of any one line to any other line in the same local area.

At the telephone itself there is the familiar switch hook providing means for connecting and disconnecting the talking and listening apparatus; hence the addition of a dial, which is merely a circuit interrupting device for controlling the electromagnets at the central office, completes the essentials of the step-by-step dial system.

Without going into tiresome details of the development of this system, it is interesting to speculate on how an ingenious and resourceful person might separate this problem into its elements and gradually work out a solution for each such element.

Actually it has taken the intensive effort of a great many brilliant minds extending over a long period of time to reach the present stage of development; and some of the best improvements are of comparatively recent origin leading one to believe that further improvements will continue indefinitely.

Ten Line System

If there were only a few lines to be interconnected (ten for example) it would not be difficult to equip each line at the central office with a switch consisting of an electromagnet connected by a ratchet and pawl arrangement to a shaft which would rotate through a few degrees each time that the electromagnet is energized. Then, by connecting wipers to an arm on this shaft, and arranging, in the arc of a circle, terminals to which the lines might be connected, one movement of the electromagnet would connect to line 1, two movements to line 2 and so on.

A push button at each telephone would provide means for making the circuit interruptions necessary for oper-

ating its electromagnet the requisite number of times, and thus one element of the problem would be solved.

The other elements, such as how to ring the called station; how to supply talking battery; how to guard against connecting to a busy line; and how to get the shaft and its wipers back to the idle or normal position, need not be considered at this moment; because, right now, we want to concentrate on this step-by-step movement which is the vital principle of the step-by-step dial system.

100 Line System

Obviously a ten line system has little practical value, but this idea may be extended to ten times ten or 100 lines by putting on another electromagnet which will move the shaft vertically to any one of ten levels; and then, by first using this **vertical magnet** to elevate the shaft to any one of the ten levels of terminals, and second, using the first mentioned electromagnet to rotate the shaft until the wipers come in contact with some one set of the ten pairs of terminals on this level we may connect to any one of these 100 lines.

That is the basic principle of the **Connector,** which may be regarded as the foundation of the step-by-step system.

Photo AAA shows a typical switch bank from which it may be seen that the 100 pairs of terminals are arranged on ten levels, each level having ten pairs.

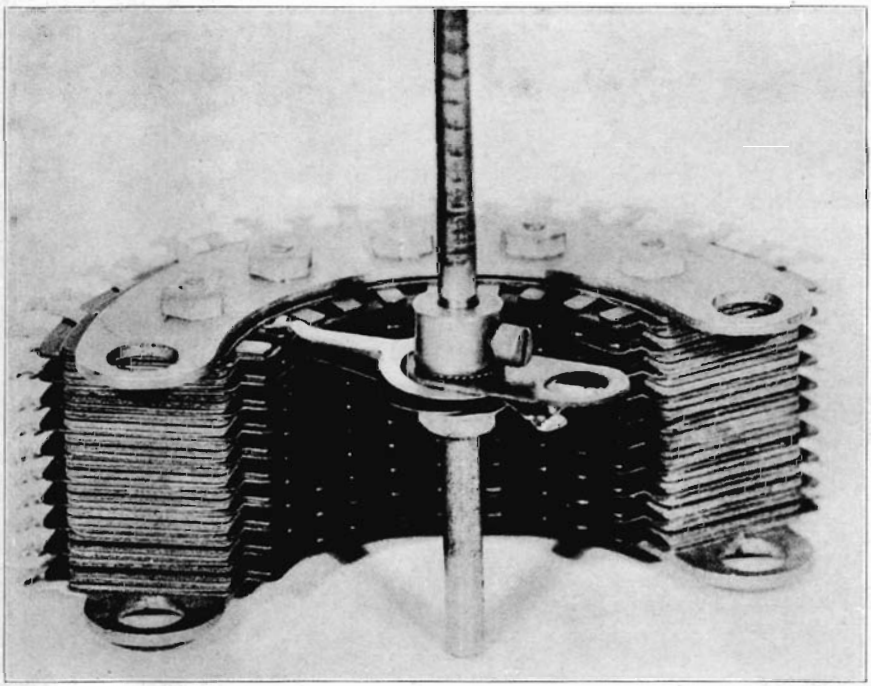
The upper terminals (ring) are visible but the lower or tip terminals are concealed by the insulator which separates the tip from the ring of each pair.

This photo also shows the wipers, previously mentioned, which are attached to the shaft but are insulated from each other and from the shaft.

The ends of the wipers are so formed that they may pass over the ends of the terminals as the shaft is rotated and permit the tip wiper to make contact with the tip terminals and its mate to make contact with the ring terminals.

The Dial

We will examine the structure of the connector presently; but, before doing so, let us speak of the **dial** at the



200 Point Switch Bank and Wipers

Fig. AAA

telephone, because it is evident that even for a two digit number, it would be unreasonable to ask the user to "push a button" eighteen times to get line 99 for example, therefore a more convenient and accurate means of causing circuit interruptions had to be provided.

The **dial** is the means which has been provided to meet this requirement.

It is a mechanism which may be wound up completely or in part by a single motion of the user's hand; and, as it runs down it opens and closes the circuit once or twice or any number of times up to ten depending upon how much it was wound up.

These circuit openings and closings, which are called **dial pulses,** actuate the electromagnets previously mentioned, thereby making connection between the calling line and the called line.

Connector Switching Mechanism

In the **connector,** since there are **two** of these electromagnets, one of which is actuated by the first set of ten or less dial pulses and the other by the second set (remembering that we are still talking about a two digit number) there must be some means for switching the first or **Vertical Magnet** out of circuit as soon as it has raised the shaft to the desired level and for switching into circuit the **Rotary Magnet** so that the wipers may be brought to the terminals of the desired line.

If this were not done we could not operate these **two** electromagnets, one after the other, by circuit interruptions at the calling telephone. The means developed for switching the **Vertical Magnet** out of circuit and the **Rotary Magnet** into circuit which will now be described is one of the most interesting and vital factors in the entire system.

Associated with the **Connector** are two relays A and B, both of which operate when the calling party takes the receiver off the hook.

"Tens" Digit Dialed

When the "tens" digit is being dialed relay A, being quick acting, releases each time that the dial opens the

circuit and re-operates each time that the dial closes the circuit; but relay B is slow to release and therefore stays operated during this time.

The first time that relay A releases it closes a path through a make contact on relay B, and through another relay (C) and the Vertical Magnet, stepping the shaft up to the first level and operating relay C.

Each subsequent release of relay A again operates the Vertical Magnet but relay C, also being slow release, stays operated until all the dial pulses for the first digit have come through and have caused the shaft to be elevated to the level corresponding to this digit.

"Units" Digit Dialed

While the customer is winding up the dial for the units digit, the circuit at the telephone is closed thereby keeping relay A operated and the latter keeps relay B operated and also keeps open the current path through the Vertical Magnet and relay C long enough for relay C to release. The release of relay C establishes a current path through the Rotary Magnet and makes contacts on relay B to the break contacts of relay A, where for the moment this path stands open.

In other words, during this part of a second, while the dial is being wound up in preparation for sending the dial pulses for the units digit, the Rotary Magnet has been prepared to operate in response to those dial pulses; and then the first pulse lets relay A fall back for one-eighth to one-tenth of a second, closing the circuit through the Rotary Magnet and moving the wipers onto the first set of terminals on this level.

If the units digit is 1 there is of course, but one pulse—one opening of the line circuit—and the wipers are moved upon the first set of terminals.

If the units digit is 2 or 3 or 4 or any other digit up to 9 there will be 2 or 3 or 4, etc., circuit openings which will release (and re-operate) relay A a corresponding number of times thereby causing the Rotary Magnet to rotate the shaft a corresponding number of steps and leave the

wipers on the 2nd, or 3rd, or 4th, etc., or 9th set of terminals.

If this units digit is 0, there will be ten (10) dial pulses, making the shaft take 10 steps and leaving the wipers on the 10th set of terminals; which explains why the terminals in the connector bank for any line whose number ends in 0 are located at the extreme right.

Fast and Slow Releasing Relays

While the rotary movement is in progress the Rotary Magnet is kept in circuit by means of another slow release relay (E) which, like relays B and C, does not release when dial pulses are being sent but does release shortly after the last dial pulse for the units digit has come through and cuts the rotary magnet out of circuit.

We have concentrated attention upon these fast and slow releasing relays as they are fundamental to the operation of this system.

Later we will see how **slow operating** relays are employed in a similar manner to perform other essential acts.

This clever use of small differences in time of operation or release of two or more relays which start to operate or start to release at the same instant is characteristic of the step-by-step system, therefore the student should fix this principle in mind at the beginning of his study of this system.

To continue with this simplest 100 line system it is apparent that equipping each of the 100 lines with a Connector like the one above partially outlined will enable any line to be connected with any other lines by using the dial with which each telephone on these lines is also equipped; but the system is not complete, even for this small group of lines.

We have six electromagnets, two of which we have named the Vertical Magnet and the Rotary Magnet; and the other four we have named relays—A, B, C, and E.

These six perform all the acts necessary to bring the wipers into contact with the terminals of the called line

Testing For Busy Line.

but as yet there is no talking connection between it and the calling line; because the tip and ring wipers have to pass over, and make momentary contact with, the tip and ring terminals of other lines; so our wipers must be left "dead" until the terminals of the desired line are reached and even then the calling line must not be connected until it is determined that the called line is idle.

This requirement has been met by adding another terminal (S) to each line, another wiper on the shaft and another relay to the circuit which is called relay G.

These 100 sleeve terminals are arranged in a separate bank mounted just above the bank containing the 100 tip and 100 ring terminals and the circuit is so arranged that when a line is busy this sleeve terminal is grounded.

The tip, ring and sleeve of each of these 100 lines are connected to the tip, ring and sleeve terminals of each of the 100 connector banks in the same order—that is, they are multipled in regular order through all the connector banks.

When the wipers reach the terminals of the called line relay E, being slow release, stays operated for a fraction of a second and makes a connection between relay G and the sleeve terminal of the called line; therefore if the latter is busy, S is grounded and relay G operates, sending a busy tone to the calling customer.

Ringing Desired Line

If the called line is not busy, there will be battery instead of ground on its sleeve terminal, which not only will prevent relay G from operating but will cause the operation of still another relay (K), and the latter will close a connection from the ringing mechanism to the tip and ring wipers which are now in contact with the tip and ring terminals of the called line.

Thus relay G tests the line for busy and does one of two things.

1. If busy it reports that fact to the calling party by putting a tone on the calling line and prevents any connection to the tip and ring of the called line.

2. If not busy it permits ringing current to be sent out to the called station.

Called Party Answers

Now there are but two more items to take care of to complete the connection.

We must cut off the ringing current as soon as the called party answers; and we must supply talking battery to the called telephone. (Talking battery to the calling telephone is already provided for through relay A.)

As usual, another relay is added for each of these requirements.

By taking the ringing current through one winding of relay F and its break contacts and using direct current in the other winding of relay F to hold it operated, ringing is stopped when the called party answers and the calling line is connected to battery and ground through the two windings of relay D.

Releasing Switch

Our Connector is now complete except for some means of getting the shaft and wipers back to normal at the end of the conversation; therefore one more electromagnet, called the Release Magnet, is provided which operates as soon as both parties hang up and releases the dogs that hold the shaft in operated position. Then a spring rotates the shaft counter clockwise until the wipers are clear of the terminals after which its own weight takes it down to normal.

Functions of the Magnets and Relays

To summarize, the **Connector** has:—

1. A Vertical Magnet for elevating the shaft and its wipers to any one of the ten levels. (This vertical magnet also releases the double dog and permits it to engage in the shaft on the first vertical step.)
2. A Rotary Magnet to rotate the shaft until its wipers come in contact with any one of ten sets of terminals on any level.
3. A Release Magnet releases the double dog and allows the shaft to be restored to normal.

4. Relay A which operates and releases rapidly on dial pulses and through which talking battery is sent to the calling station.
5. Relay B which releases slowly and so, although controlled by relay A, does not release while A is being operated rapidly.
6. Relay C, also slow release, which keeps the Vertical Magnet under control of relay A while the dial pulses for the "tens" digit are coming through and switches in the Rotary Magnet while the dial is being wound up for the "units" digit.
7. Relay E, also slow release, which performs a similar function for the Rotary Magnet and waits while,
8. Relay G tests the line for busy.
9. Relay K which is slow to operate and therefore deliberately closes the tip and ring wipers through to
10. Relay F—the ringing relay; and
11. Relay D which furnishes talking battery to the called station; and, at the end of the conversation releases relay K which in turn permits the Release Magnet to function.

In addition relay D operates a message register if the calling party has measured service or causes a coin to be collected if the calling party is at a pay station.

Method of Reducing the Number of Connectors

Thus with one Connector on each line we would have a 100 line system that would operate with entire satisfaction; but it is still too small for city service and it is too expensive; because, normally, only about 10 per cent of the connectors would be in service simultaneously and it would surely be costly to have 90 per cent of any type of plant lying idle during the busy hours.

We could reduce the number of connectors to ten (if that is the largest number of connections to be provided for at any one time) if we had some way of getting any

line joined to one of these connectors whenever a customer desires to make a call over that line.

That need has been supplied by **Line Switches** and **Line Finders** which will be discussed later on in this pamphlet; but first let us see how the system can be enlarged to 1000 lines for example.

1000 Line System

Fix in mind the 100 line system above described but having only 10 Connectors. Which we may call a **Connector Unit.**

A 1000 line system would consist of 10 such units.

Now the problem is how to get any one of these 1000 lines joined to a connector in the **Connector Unit** in which the called line appears.

For instance if the customer wants to call line number 162 he can reach that line by dialing 62 provided he can first get to a Connector in the 1st Connector Unit.

If the called line is 262 or 362 or 462 the calling party could still dial 62 but first he would have to get to a Connector in the 2nd or 3rd or 4th Connector Unit.

To join the calling line with the proper Connector, a line switch (or a line finder) and a Selector are used.

The line switch (or the line finder) works automatically when the calling party takes his receiver off hook and makes connection to the selector, but now the customer must dial 1 or 2 or 3 or some other digit to gain connection to a Connector in the Unit in which the called line is located and then he must dial the 6 and the 2 or whatever the two final digits may be to cause the Connector to complete the connection.

The Selector looks very much like a Connector and has a Vertical Magnet, a Rotary Magnet and a Release Magnet, the same as the Connector but only five relays A, B, C, D and E.

It has the same 100 sets of Terminals T, R and S but they do not go to subscribers lines. Instead, the 10 sets on the 1st level go to the 10 Connectors in the Unit con-

taining lines 100 to 199; the 10 sets on the 2nd level go to the Connectors in the Unit containing lines 200 to 299, and so on; while the 10 sets of terminals on the 10th or top level go to Connectors in the Unit containing lines 00 to 99 which would be written 000 to 099 because each number in this system must have three digits.

Now when our customer takes his receiver off hook he is immediately connected to a selector that we may call a First Selector, which gives him a dial tone, and if he is calling 679 for example, he will dial 6, 7 and 9 in just that order.

As he dials 6, relays A, B and C and the Vertical Magnet in our First Selector function just the same as previously outlined for a Connector and raise the Selector shaft to the 6th level; but now a slightly different action takes place.

Selector Automatic Rotary

The purpose now is to bring the calling line into connection with some one of the 10 Connectors in Unit number 6 (because line 679 is in that Unit); therefore, the Selector is arranged so that, while the customer is winding up the dial for the tens digit, it will test for busy, the terminals on this level and stop on the first idle set. In other words it will "select" an idle trunk to a Connector in Unit 6; hence the name Selector.

Had the first digit been 1 or 2 or 3 or any other digit up to 0 the selection would have been made on the 1st, or 2nd, or 3rd, etc., or 10th level, thereby connecting the calling line to a Connector in the particular Unit in which the called line is located.

Connector seized

Dialing the "tens" digit now raises the shaft of the Connector to (in this case) the 7th level, and dialing the Units digit rotates the shaft until the wipers come into contact with (in this case) the 9th set of terminals, therefore the calling line is now connected to the called line 679.

The wires between any Connector and the corresponding terminals on the Selectors are called trunks.

We may summarize as we did for the Connector and say that

The Selector has:

Functions of the Selector Relays and Magnets

1. A Vertical Magnet for elevating the shaft and its wipers to any one of ten levels.
2. A Rotary Magnet to rotate the shaft until its wipers come in contact with any one of ten sets of terminals on any level.
3. A Release Magnet to restore the shaft to normal.
4. Relay A which operates and releases rapidly on dial pulses.
5. Relay B which releases slowly and so, although controlled by relay A, does not release while A is being operated rapidly.
6. Relay C, also slow release, which keeps the Vertical Magnet under control of relay A while the dial pulses for the first digit are coming through; and switches in the Rotary Magnet while the dial is being wound up for the next digit.

NOTE: So far the functioning of the Selector is exactly the same as for the connector, but now the Selector proceeds on its own initiative to hunt for an idle trunk to some Connector; hence the Selector is called a trunk hunting switch.

7. Relay E—quick acting instead of slow release—which operates as soon as the shaft takes the initial step upward and prepares a circuit for the operation of the Rotary Magnet as soon as relay C releases. Then relay E tests the first trunk for busy, leaving the wipers on this trunk if it is idle, but moving them to the next trunk if the first one is busy.
8. Relay D which operates as soon as an idle trunk is reached, thereby disconnecting relay A from the calling line and closing the latter through to the connector.

1000 Line System

We may still more briefly summarize the 1000 line system by saying that it consists of **Line Switches** or **Line Finders** which automatically connect any calling line to a **First Selector.**

The latter, in response to the dial pulses of the first digit dialed, extends the calling line to a Connector and the latter, in response to the dial pulses of the second and third digits dialed, makes connection to the called line.

The switches mentioned are called the "train."

Method of Enlarging System

From the foregoing it is apparent that the addition of other Selectors to this train would enlarge our system ten times for each Selector added.

That is:

Using First Selectors takes care of 1000 lines.

Using 1st and 2nd Selectors takes care of 10,000 lines.

Using 1st, 2nd and 3rd Selectors takes care of 100,000 lines.

Using 1st, 2nd, 3rd and 4th Selectors takes care of 1,000,000 lines and we might go even further.

In each case the 1st Selector responds to the 1st digit dialed, the 2nd Selector to the 2nd digit, 3rd to the 3rd digit and 4th to the 4th digit dialed.

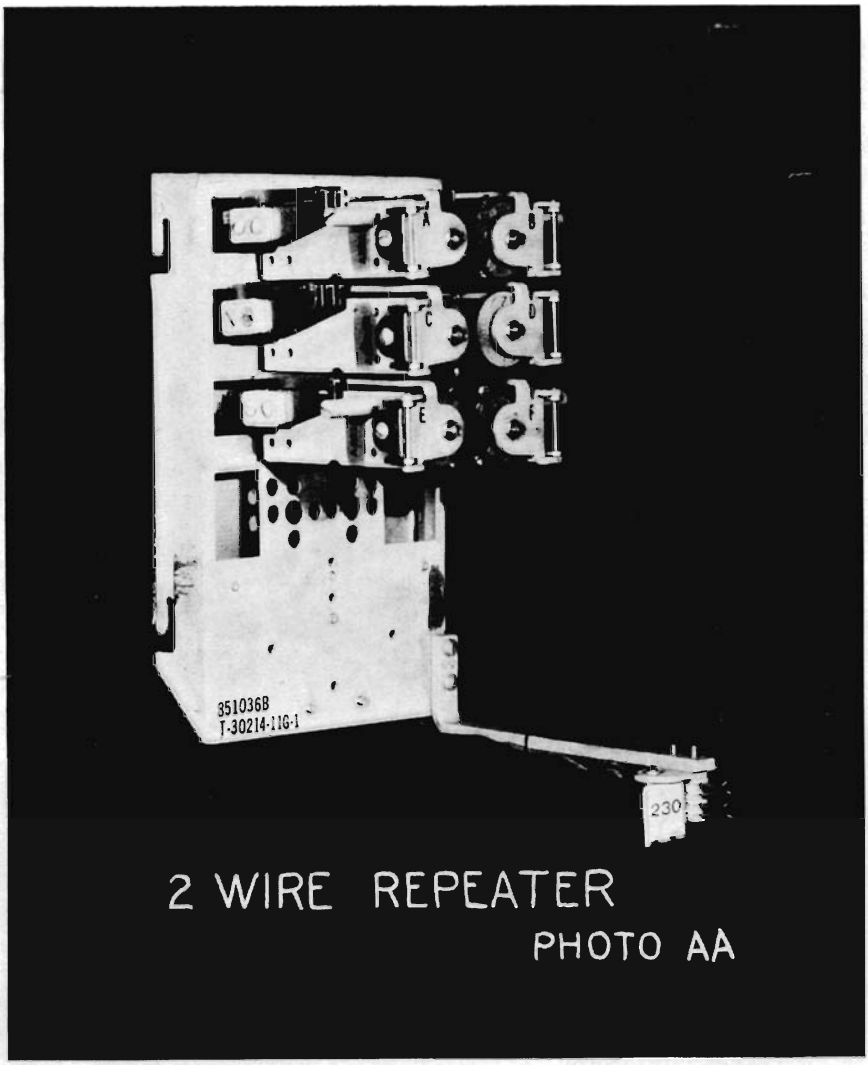
Irrespective of the size of the system the last two digits dialed are those which actuate the connector.

Limitation of Number of Stations in any Office

These "lines" would be direct lines.

If party lines are involved each party would require a separate set of terminals in the Connector banks, therefore two-party lines would require two sets of terminals and four-party lines, four sets making a corresponding reduction in the number of lines that a given system could serve.

There are other limitations which we need not consider now that reduce these capacities to about 80 per cent of the figures above given.



2 WIRE REPEATER

PHOTO AA

Repeaters

If the system has two or more offices located in separate buildings which may be a considerable distance apart, it would not be economical to use the same kind of trunks between offices as are used between switches in the same office, because the latter are three wire trunks; therefore a **Repeater** has been developed for use on inter-office trunks.

It is also called a **Repeater Switch** although it does not have the switching mechanism of Selectors and Connectors.

One side is wired to a set of terminals on the last Selector in the train outgoing to the distant step-by-step office and the other side is wired to the cable pair of the inter-office trunk with which it is associated.

It has six relays A, B, C, D, E and F of which the A and B relays function substantially the same as in a Selector or Connector and cause the other relays to open and close the circuit toward the distant office in exact step with the circuit interruptions made by the dial at the calling station.

In other words it "repeats" the dial pulses for certain digits on the inter-office trunk and provides a local holding circuit, thereby doing away with the need for a third wire on these trunks.

The dialing path is divided into two sections, the first being from the Repeater to the calling station and the second section being from the Repeater to the Selectors and Connectors in the distant office making the operation of the latter more positive.

Multi-Office Areas

We have roughly outlined all the essential parts of a full step-by-step system for any number of lines; but we know that large step-by-step systems usually replace manual systems composed of several separate central offices and in such cases it is not always practicable to make the replacement all at one time.

Then, too, it is frequently necessary to install one or more new offices to take care of growth before replacing any of the older offices, hence in any exchange area it

may become necessary to have step-by-step and manual offices in service and inter-connected.

Manual Office Dialing Equipment

In such cases equipment must be installed in the manual offices to handle calls originating at manual stations and completed at step-by-step stations; and to handle calls originating at step-by-step stations and completed at manual stations.

The first mentioned calls require dials at the A operators positions so that the A operators by dialing may complete the calls given them verbally by the manual subscribers.

Call Indicator

The other calls mentioned, that is those originating at step-by-step stations, require, at the incoming end of the inter-office trunks to the manual offices, a device known as a Call Indicator; which, actuated by the dial at the calling station, displays the called number by lighted lamps so that the B operator may put the trunk in the called number's jack without verbal communication with the calling party.

The Call Indicator is described in a separate reading course of that name.

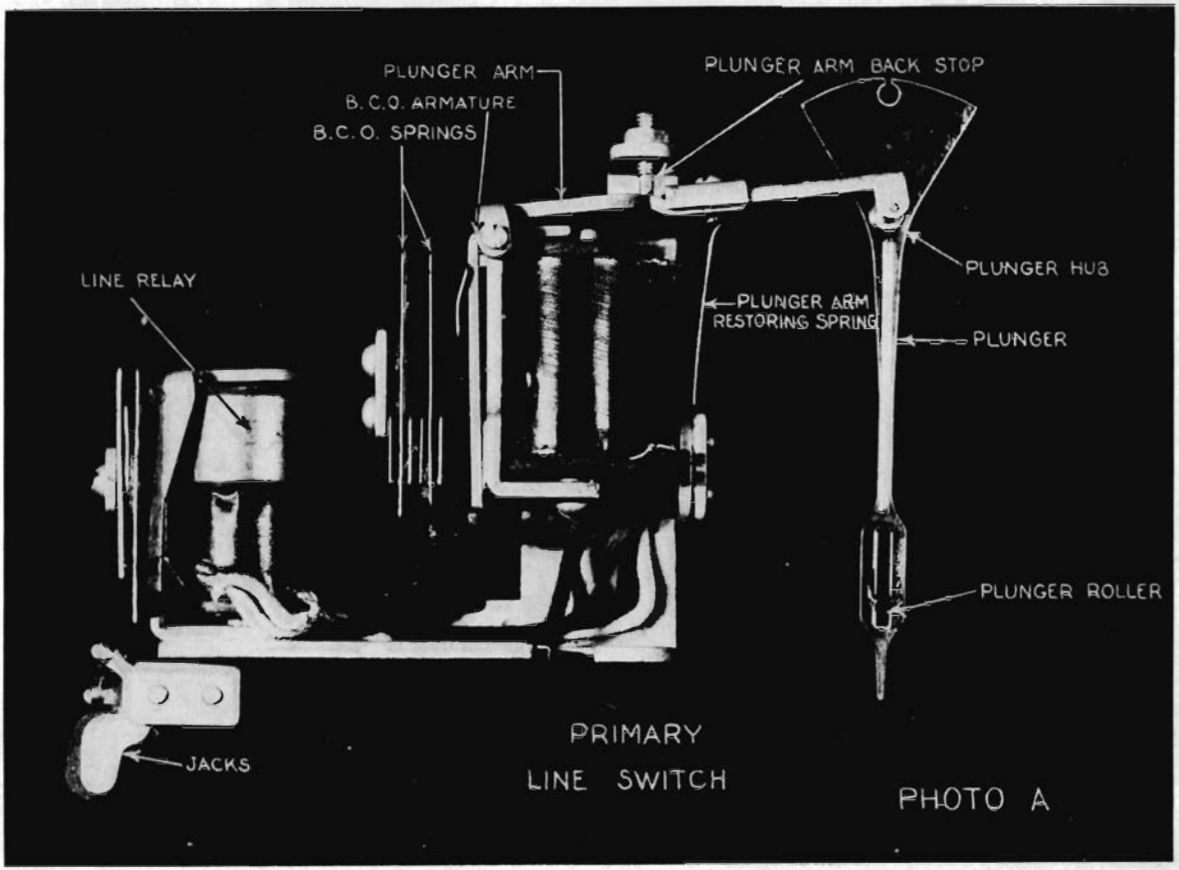
In this outline we have omitted all but the bare essentials of operation to enable each student to get the general scheme unhampered by details that it seems preferable to leave for discussion in the other sections of this course.

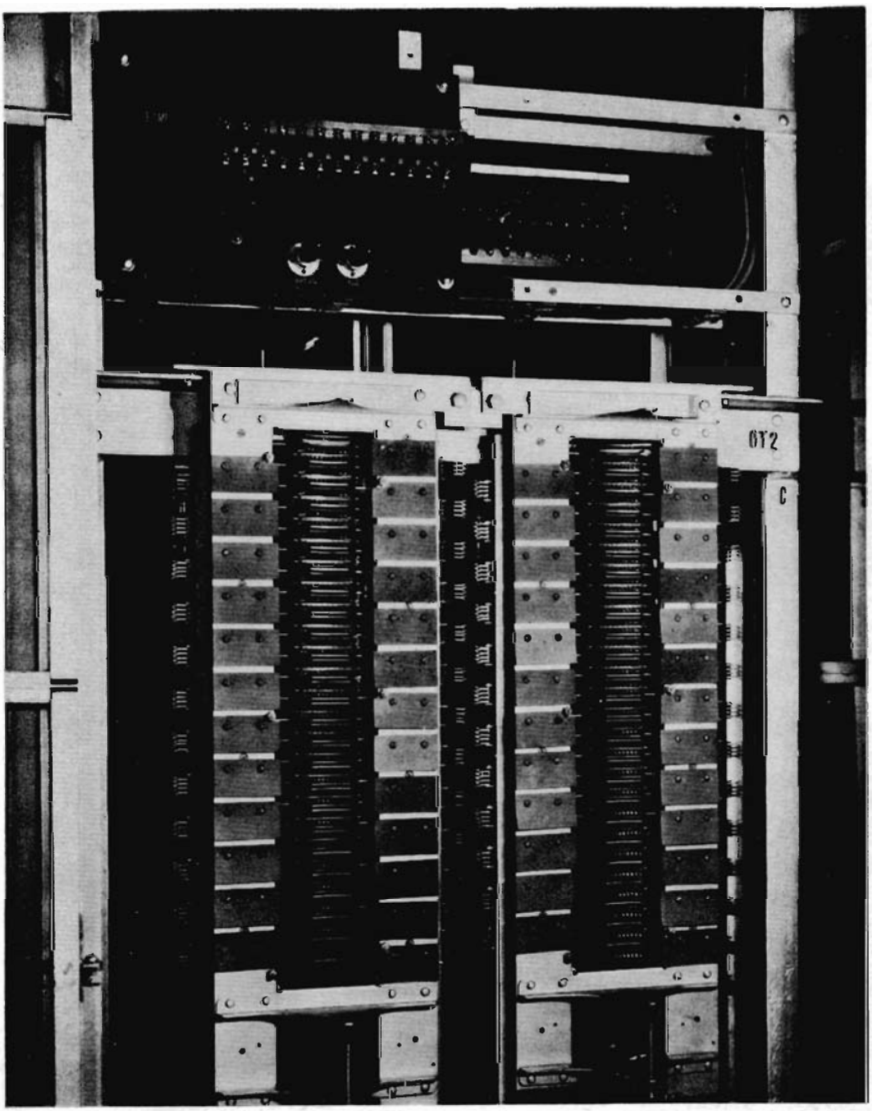
In this section, however, we may now go back to the line switch and to the line finder giving a better outline of their purpose and operation, and also giving some additional information as to their structure and the structure of the switching mechanism of the selectors and connectors. Some further discussion of the dial is also included.

LINE SWITCH

Economic Purpose

The cost of line switches and their associated master switches, for a given number of lines, is materially less than the cost of equipping each of those lines with a selector; therefore the primary purpose of line switch equipment is economy.


PLUNGER ARM
B.C.O. ARMATURE
B.C.O. SPRINGS
PLUNGER ARM BACK STOP
LINE RELAY
PLUNGER HUB
PLUNGER ARM RESTORING SPRING
PLUNGER
PLUNGER ROLLER
JACKS
PRIMARY
LINE SWITCH
PHOTO A



LINE SWITCH MULTIPLE BANKS
AND SIGNAL PANEL

PHOTO B

In addition, and of greater importance, service is improved because the mechanism of line switches is simpler than that of selectors and therefore less liable to out of service troubles.

Mechanical Purpose

The mechanical purpose of a line switch is to connect its line to a selector immediately upon the removal of the receiver on outgoing calls.

This may be done directly or through secondary line switches as described in Section 4. At present we will consider only the first mentioned or primary line switch.

Parts of a Line Switch

As shown on Photo A the essential parts of a line switch are: a line relay (A); a combination relay and pull down magnet (B); a line plunger and arm actuated by B; and a bank of terminals.

The relay part of B consists of a high resistance winding, a light armature and four contacts known as the BCO or "battery cut off" springs which normally connect relay A and ground to the R and T of the line. This high resistance winding is connected to exchange battery and to the S of the line in such manner that a ground on S (such as that caused by an incoming call) will operate the light armature and thereby open the BCO springs. This light pull will not pull down the plunger arm but it will hold it down if first pulled down by other means.

The pull down magnet part of B consists of the plunger arm, which is the heavy armature of B to the tip of which the line switch plunger is pivoted, and a low resistance winding, one side of which is connected to battery at the master switch, while the other side goes through the BCO springs to a make contact on relay A. When this winding is energized it drives the line switch plunger into the bank and also operates the BCO springs.

Line Switch Banks

The bank consists of ten sets of contacts having eight in each set. Three contacts in each set are connected to the T, R and S of this line and one to ground; one contact is left dead while the other three are connected to one of ten three-wire trunks leading to ten first selectors. (Four-

wire trunks are used between primary and secondary line switches.)

Line Switch Plunger

The line switch plunger does not form a part of any electrical circuit. It is merely a mechanical device so arranged that, when plunging, the two hard rubber rollers near its tip press against one of the ten sets of contacts and so connect the T, R and S of its line to the three-wire trunk to a first selector.

The terminals are so arranged and the line switch plunger is so pivoted that the plunger may thus engage with any set of these contacts. In other words this line may use any one of ten trunks each terminating in a first selector; but of course, these trunks are shared with other lines (possibly 50, if ten trunks can handle the originating calls from 50 lines during the busy hour). Hence some provision must be made to ensure an idle trunk for any line at any time that an outgoing call is to be made.

Master Switch Divisions

The master switch takes care of this.

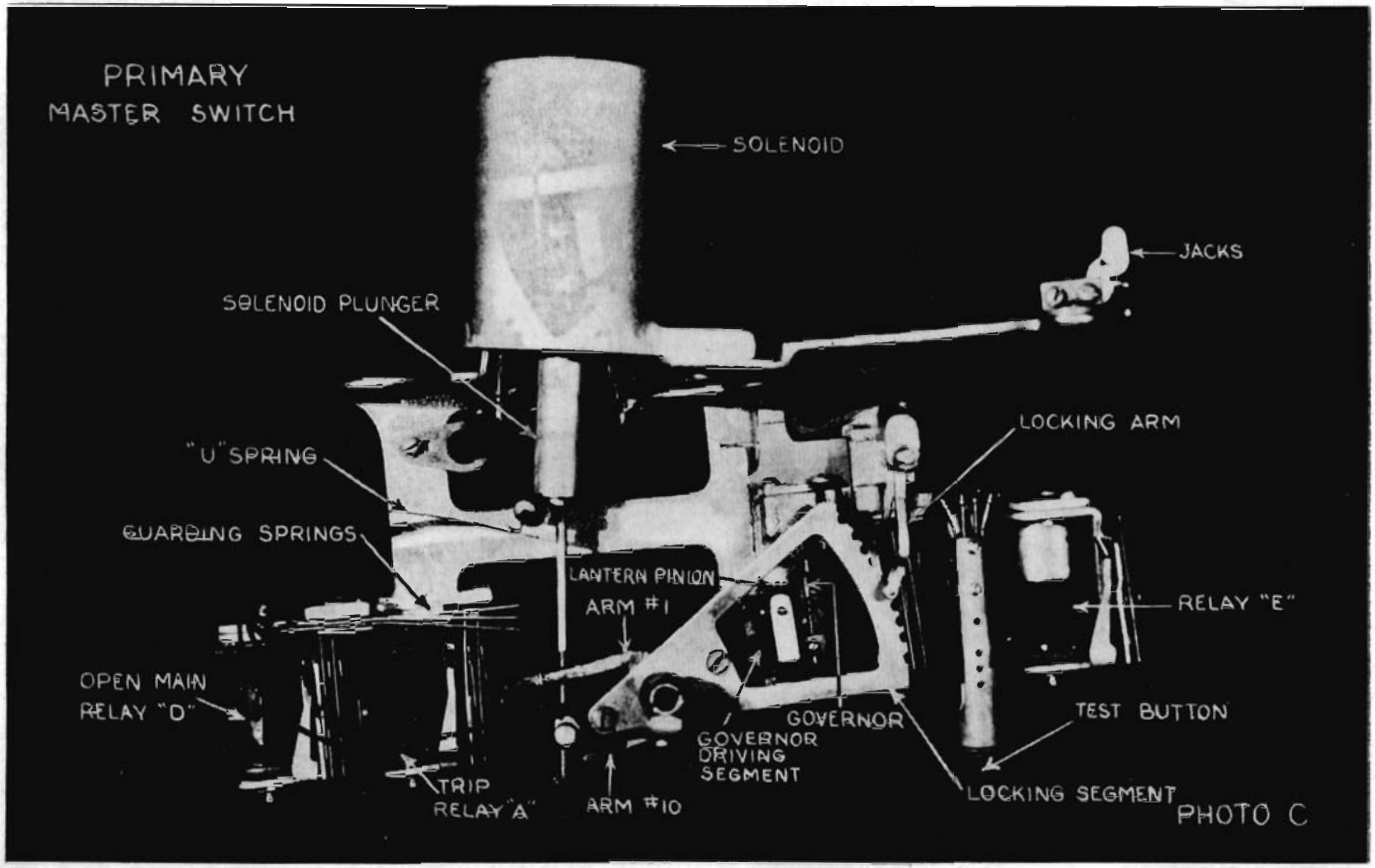
Line switches are mounted on frames called line switchboards, having a capacity for 100 switches each. There are four divisions—A, B, C and D—of 25 each arranged so that one master switch may be provided for each division; or one master switch could serve two or three divisions, or (in extreme cases) all four divisions.

Taking the usual case of one master switch for divisions A and B for example, the 25 banks of each division are mounted in a vertical pile with 13 line switches on the right and 12 on the left so that the line plungers are in vertical alignment. Division B is directly below division A and arranged the same way except that here 12 switches are on the right and 13 on the left.

The ten trunks to ten first selectors are multipled through the entire 50 line switch banks.

Plunger Guide Shaft

For each of the two divisions a vertical bar or guide shaft associated with the master switch is pivoted in such manner that normally the slot in the fantail of each idle


PRIMARY
MASTER SWITCH
SOLENOID
JACKS
SOLENOID PLUNGER
"U" SPRING
GUARDING SPRINGS
LOCKING ARM
LANTERN PINION
ARM #1
RELAY "E"
OPEN MAIN
RELAY "D"
GOVERNOR
GOVERNOR
DRIVING
SEGMENT
TEST BUTTON
TRIP
RELAY "A"
ARM #10
LOCKING SEGMENT
PHOTO C

plunger engages with a ridge on the shaft and when the shaft rotates on its pivots it rotates the plungers on their pivots.

The rotation of the shaft is limited to about 40 degrees.

When a line switch plunges, the fantail is moved away from the plunger guide shaft hence any rotation of the latter does not affect busy line switches.

As the line switch releases, the fantail comes back into contact with the shaft but the ridge will not engage with the slot until the shaft has moved through some part of its oscillation. This is known as picking up idle plungers.

The movements of the master switch are controlled by the busy (or idle) condition of the trunks from its group of lines to the first selectors.

Master Switch Assembly

The master switch consists essentially of: a hub and locking segment to which the plunger guide shaft is attached and to which a solenoid and a U spring are also attached.

The U spring furnishes the power to rotate the hub and locking segment counter clockwise, and the solenoid when energized rotates it clockwise against the pressure of the U spring.

This rotation of the hub rotates the bar and consequently the line switch plungers so that the latter may point toward any one of the ten sets of terminals in the banks.

Two wipers are attached to the hub and sweep over two sets of master switch bank contacts (10 in each set) which are numbered to correspond to the trunks in the line switch banks.

They are called the "upper" and "lower" contacts.

There are also two fingers on the hub, one of which operates certain electrical contacts as the hub reaches the position corresponding to trunk 1 and the other operates a latch associated with the armature of relay A as the hub reaches the position corresponding to trunk 10.

A governor is attached to the hub to limit the speed of travel.

Function of Master Switch Relays

Associated with this mechanism and controlling its movements are five relays as follows:

C. Start relay, having two windings wired to the wipers for the "upper" and "lower" master switch bank contacts. In this case the two sets of contacts are strapped together and are wired to the S leads of the trunks.

When a trunk becomes busy, its S lead becomes grounded, hence relay C is energized and **starts** the operation of the master switch.

B. Locking Magnet, whose armature engages with the locking segment. When energized it permits the hub to rotate.

A. Trip relay. In conjunction with the springs operated by the fingers on the hub this relay controls the Solenoid in such manner that when trunk 1 is seized the hub is rotated to and stops at trunk 10.

D. Open Main, which takes battery off the line switches while the master switch is moving.

E. This relay is used in conjunction with secondary line switch equipment. It is not required in the present case.

Supervisory Equipment

Associated with these relays but not included in the master switch there is an S relay which in turn is associated with a timing circuit and gives an alarm in case the completion of certain operations of the master switch is delayed, indicating trouble.

There is other equipment also associated with the master switch relays to record the number of calls handled by this switch and the number of times all the trunks from its line switches are busy.

Action of Primary Line and Master Switch

With this outline in mind, one may follow the action of a primary line switch and its master switch when the receiver is taken off hook on an outgoing call.

For simplicity we may assume that this is the first call made therefore all the 50 line plungers will be standing in front of trunk 10.

Then line relay A operates, causing a strong pull in its relay B which drives the line plunger into the terminals in the line bank belonging to trunk 10, and cuts off the current through relay A.

The operation of relay B closes the bank contacts thereby extending the calling line through to a first selector which causes its A and B relays to operate and place a ground on the S lead of the trunk. Relay A of the line switch is made slow release so that this ground from the selector may be returned and hold relay B operated before its operating path is opened again by the release of relay A. This ground also operates relay C of the master switch which in turn operates relay B of the master switch thereby pulling its armature away from the locking segment. Then the U spring rotates the hub and consequently all the remaining 49 line plungers until the latter come in front of trunk 9, which we have assumed is idle; since the S lead of this trunk is not grounded, relay C releases, releasing relay B and stopping the hub at this point.

Relay B, when operated, causes relay D to operate and take battery off the "open main" lead so that no line switch can plunge while the hub is rotating.

The above action is repeated for each trunk seized until trunk 1 is reached when one of the fingers on the hub closes a set of contacts which prepares a circuit to bring relay A into action whenever trunk 1 becomes busy. Then relay A operates, and locks mechanically, closing a circuit through the Solenoid which rotates the plungers to trunk 10, picking up on the way any plungers that may have been released.

Then a finger on the hub releases the armature of relay A, thereby opening the circuit through the Solenoid and the switch stops here unless trunk 10 is busy.

If it is busy its lead S will be grounded thereby operating relay C and the action previously described will be repeated.

All Trunks Busy

If all trunks are busy the switch will oscillate continuously until an idle trunk is found; and should this condition remain for longer than a certain time the timing circuit will sound an alarm to summon an attendant.

Mechanical Operation of Selector

All this takes place so quickly that by the time the user gets the receiver to his ear, connection has been made to the selector and dial tone is given.

We may now briefly sketch the operation of the first selector as the first digit is dialed.

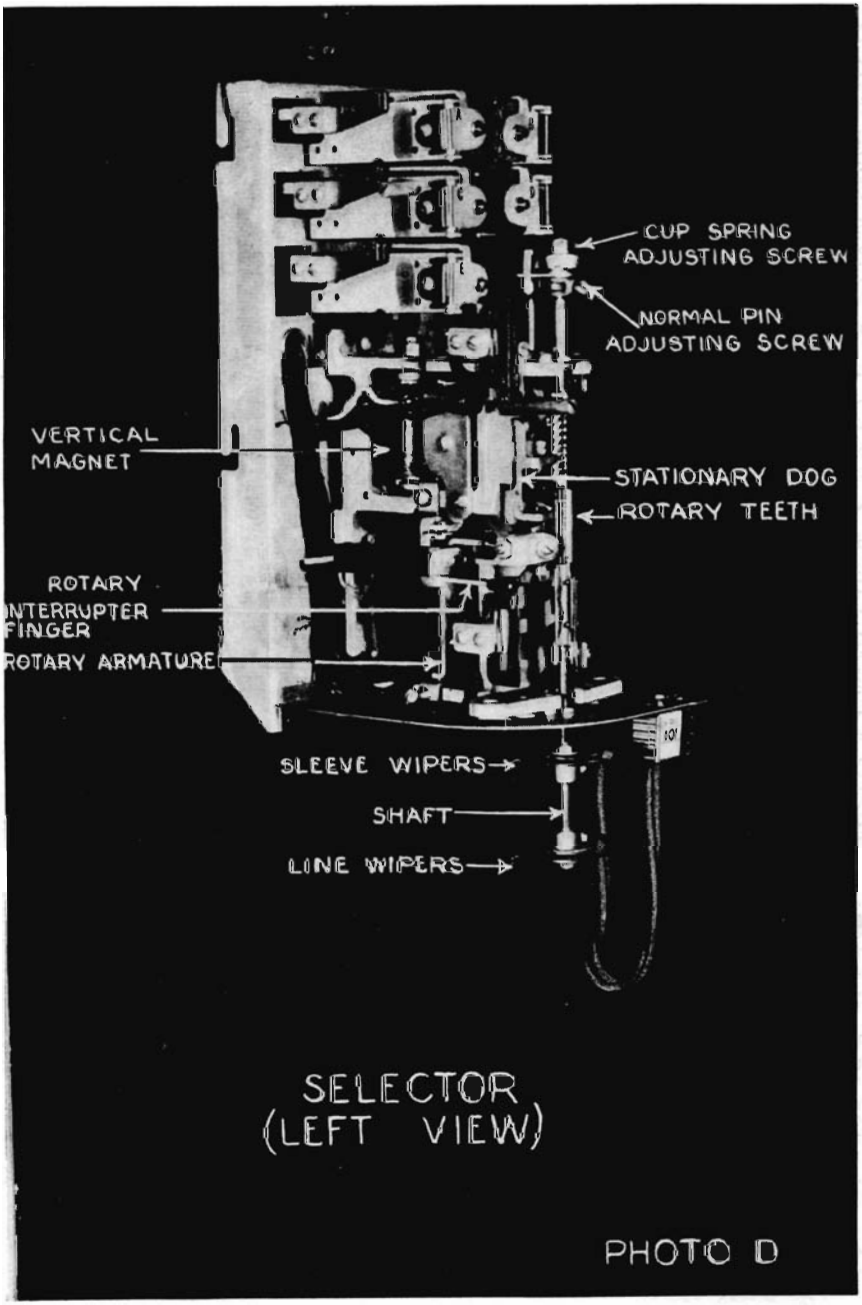
SELECTOR

Photos D and E are two views of a typical trunk hunting selector, on which are lettered the names of its principal parts.

We need not pay much attention at this time to the circuit operation, as our interest now centers on the mechanical operation of the selector. We may remember, however, that relays A and B in the selector are operated thereby preparing for the operation of the vertical magnet each time that relay A falls back on the short interruptions caused by the dial pulses.

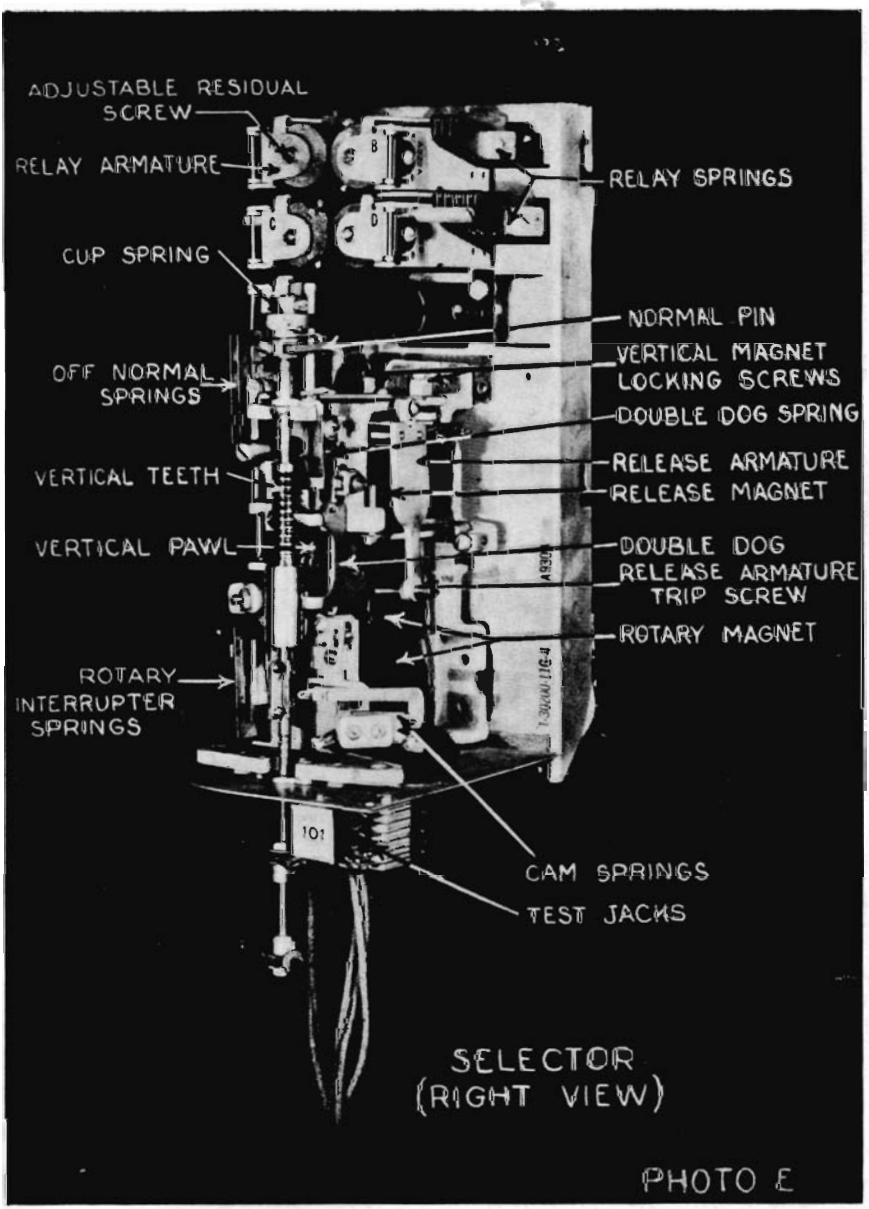
Operation of Selector Vertical Magnet

When the vertical magnet is energized on the first dial interruption the front end of the vertical armature is pulled upward, first moving the vertical pawl into engagement with one of the vertical teeth on the hub and then raising the shaft one step. At the same time the first part of the upward movement of the vertical armature actuates the double dog release link permitting the double dog spring to move the double dog into engagement with the vertical teeth and with the rotary teeth on the hub so that, as the vertical armature falls back to normal, the double dog holds the shaft in operated position.



SELECTOR
(LEFT VIEW)

PHOTO D


ADJUSTABLE RESIDUAL SCREW
RELAY ARMATURE
CUP SPRING
OFF NORMAL SPRINGS
VERTICAL TEETH
VERTICAL PAWL
ROTARY INTERRUPTER SPRINGS
RELAY SPRINGS
NORMAL PIN
VERTICAL MAGNET LOCKING SCREWS
DOUBLE DOG SPRING
RELEASE ARMATURE
RELEASE MAGNET
DOUBLE DOG RELEASE ARMATURE TRIP SCREW
ROTARY MAGNET
CAM SPRINGS
TEST JACKS
101
SELECTOR (RIGHT VIEW)
PHOTO E

At this time the cup spring exerts counter clockwise pressure holding the normal-pin against the normal-pin-stop thereby keeping the shaft normal as to its rotation. In this position the upper projection of the stationary dog rests in a slot cut lengthwise of the shaft through the vertical teeth, preventing the shaft from turning except at the correct height at each level.

For each subsequent dial pulse for the first digit the shaft is raised one additional level. (If the digit is 6 the shaft is raised to the 6th level.)

During the pause while the calling party is winding up the dial for the second digit, a circuit change takes place which prevents further action by the vertical magnet and immediately puts the rotary magnet into action.

Operation of Selector Rotary Magnet

Its armature moves toward its pole pieces first throwing the rotary pawl into engagement with the first rotary tooth and then rotating the shaft one step clockwise. As the armature approaches the end of its travel it releases a relay which opens the circuit through the rotary magnet and the armature returns to normal; but the shaft is prevented from rotating backward by the action of the lower arm on the double dog.

The wipers are now in contact with the terminals of the first trunk on this level; and, if it is idle, they stay there—circuit changes immediately taking place to prepare the switch ahead for receipt of the dial pulses for the second digit.

If this trunk is busy its S lead is grounded and that reoperates the relay above mentioned, again energizing the rotary magnet, thereby stepping the wipers to the next trunk. This action is repeated until an idle trunk is found; or, if all are busy, the shaft continues to move to the 11th rotary step at which time the cam springs are operated by a projection on the hub.

11th Rotary Step

The cam springs put busy tone on the calling line and release the relay above mentioned, thereby opening the circuit through the rotary magnet.

Operation of Selector Release Magnet

If the calling party hangs up before dialing the second digit (on account of hearing the busy tone, abandoning the call, or for any other reason) relays A and B release thereby closing a circuit through the release magnet, contacts on the off normal springs, and back contacts of relays A, B and D to ground.

Then the release armature is pulled sharply toward the release magnet and the release armature pin strikes the rear extension of the double dog disengaging its lower part from the rotary tooth, and its upper part from the vertical tooth associated with the level to which the shaft has been raised.

The shaft is now free to rotate counter clockwise under the pressure of the cup spring but is kept from falling by the stationary dog upon which the vertical tooth of this level is resting.

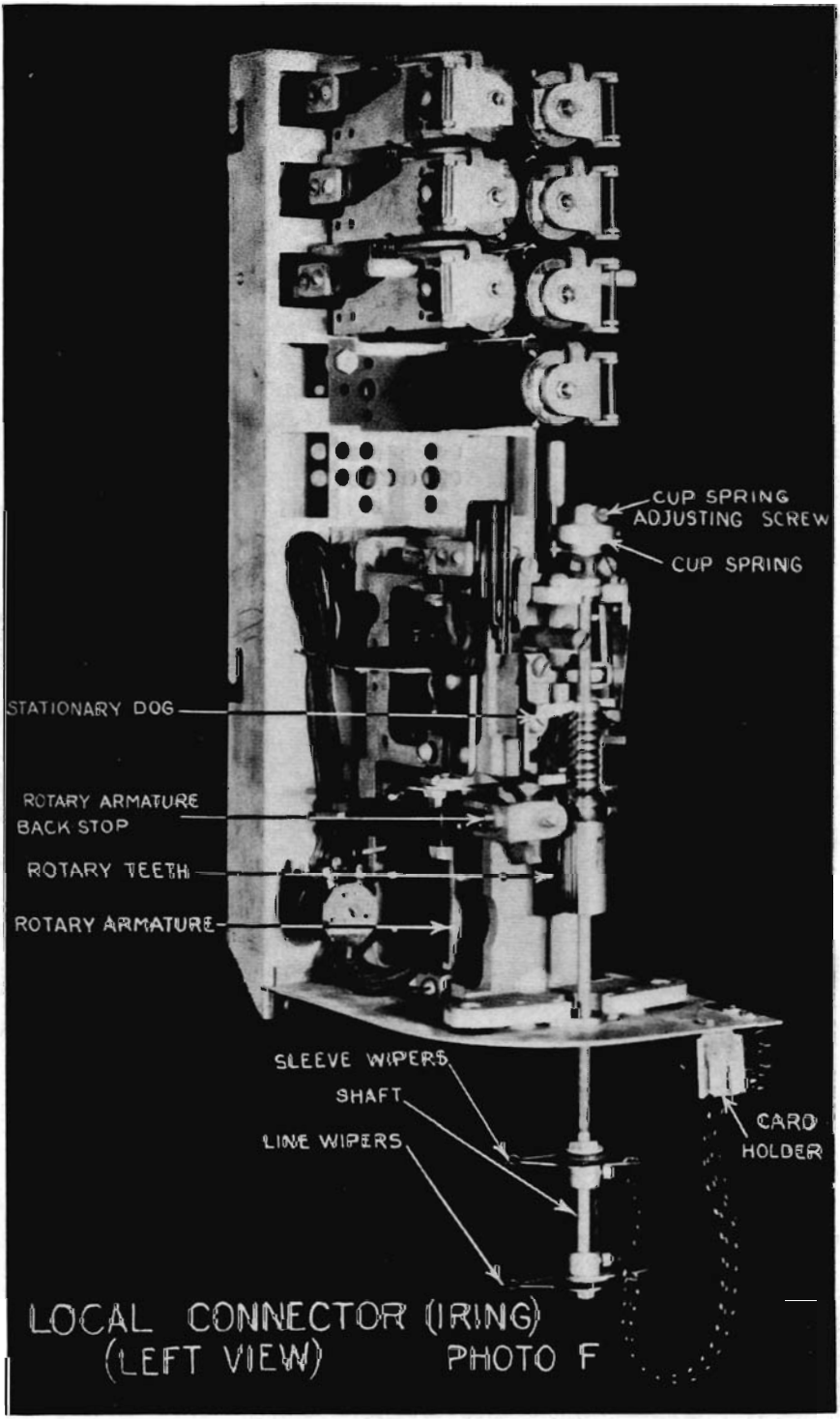
When the shaft reaches the limit of its counter clockwise rotation, it is stopped by a projection on the shaft striking the normal pin. Then the wipers are out of the bank and a little to the left of the first set of terminals and the stationary dog is in the vertical slot; hence the shaft falls by its own weight to the normal position. Upon reaching this position the off normal springs are opened thereby opening the circuit through the release magnet and also opening the circuit of relay E which controls the rotary magnet.

The selector is now normal—ready for another call.

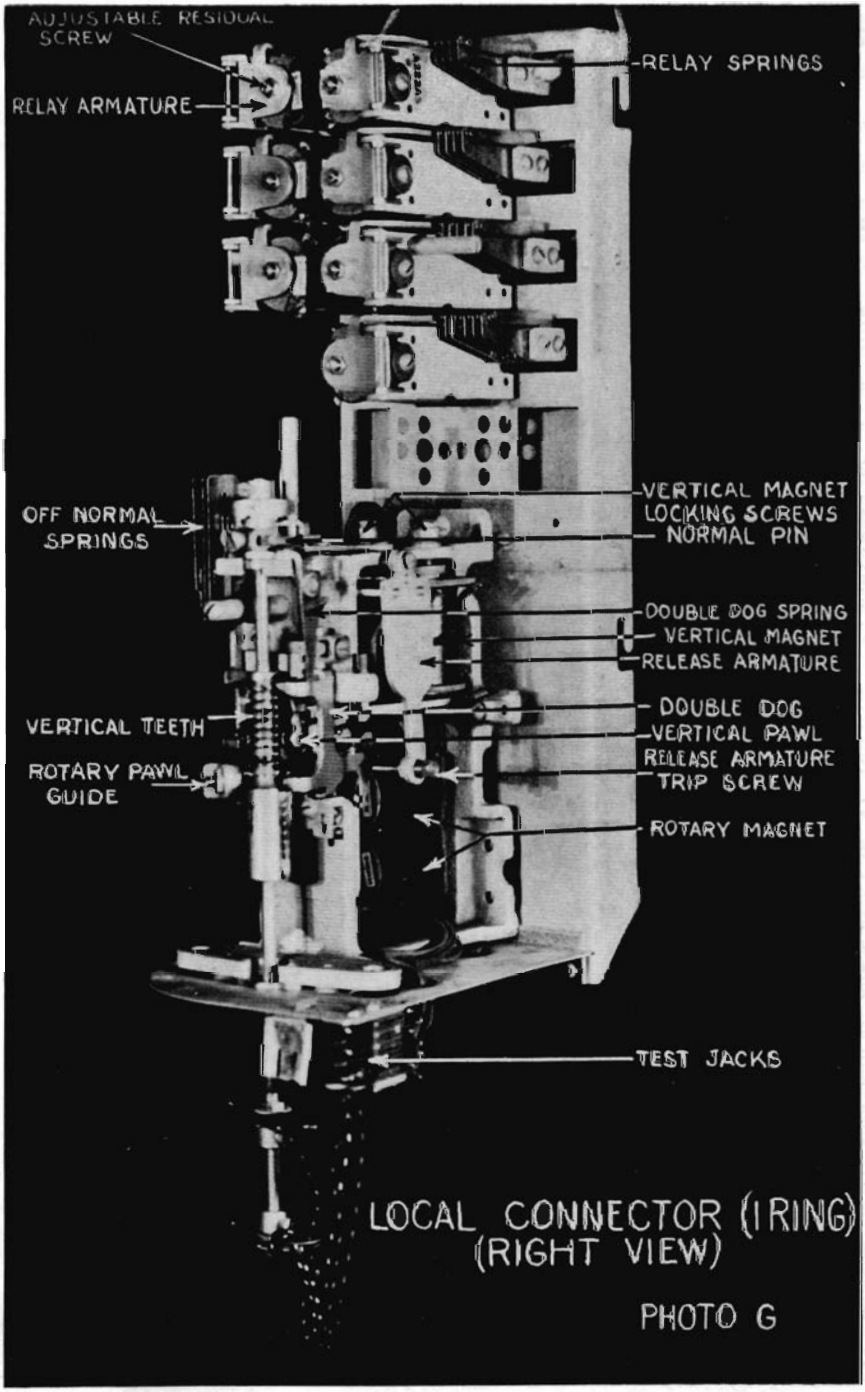
Operation of 2nd Selector

If an idle trunk had been found (which is the usual case) the dial pulses for the second digit would have been directed into the second selector and it would have operated the same as the first selector except that no dial tone would have been sent out.

If the number dialed has 5 digits there would be 1st, 2nd and 3rd selectors and a connector in the train; and for this description we may assume that such is the case. Then further assuming that the first three digits have been dialed, completing the train to the connector, we may outline the operation of the latter.



LOCAL CONNECTOR (IRING)
(LEFT VIEW) PHOTO F


ADJUSTABLE RESIDUAL SCREW
RELAY ARMATURE
RELAY SPRINGS
OFF NORMAL SPRINGS
VERTICAL MAGNET LOCKING SCREWS
NORMAL PIN
DOUBLE DOG SPRING
VERTICAL MAGNET
RELEASE ARMATURE
VERTICAL TEETH
DOUBLE DOG
VERTICAL PAWL
RELEASE ARMATURE
ROTARY PAWL GUIDE
TRIP SCREW
ROTARY MAGNET
TEST JACKS
LOCAL CONNECTOR (1 RING)
(RIGHT VIEW)
PHOTO G

CONNECTOR

Photos F and G show a typical connector.

Vertical Stepping of Connector

At this time relays A and B in the connector are operated and as soon as the dial pulses for the fourth digit start to come through, the vertical magnet starts to operate and steps the shaft up to the level corresponding to this digit in exactly the same way that the vertical stepping of the selectors was done; but now the shaft stops and does not cut in at this level until the dial pulses for the last digit come through.

Operation of Rotary Magnet of Connector

While the dial was being wound up for the last digit a circuit change took place (specifically by the release of relay C) which cut the vertical magnet out of circuit and cut the rotary magnet into circuit but in this case under control of relay A, so that as the dial pulses come through, each interruption operates the rotary magnet once, thus stepping the shaft around until the wipers come to rest on the terminals on this level corresponding to this last digit.

Called Line Busy

The wipers are now resting upon the terminals of the called line and, if it is busy, relay G in the connector will operate before slow release relay E has had time to fall back, in which case a busy tone is sent back to the calling line and the calling party hangs up. Then the release magnet is energized by a circuit set up through the V. O. N. springs and the back contacts of relays A and B, which kicks the double dog out and restores the connector to normal just as described for the selector.

In fact, the entire mechanical operation of the connector is almost exactly the same as the selector.

Called Line Idle

If the called line is not busy relay G does not operate, and a different sequence of circuit conditions are set up resulting in ringing the called party's bell and supplying talking battery to both parties when the called station answers; but they need not be enumerated now as they are covered in Section 4.

Conversation Ended

Likewise at the end of the conversation when the parties hang up, circuit conditions are set up which cause the connector and each selector to bring their release mechanisms into action and restore them to normal. The mechanical operations are as previously described. The circuit conditions are covered in Section 4.

LINE FINDERS

Use of Line Finders

Line finders have been developed to supersede line switches and their master switches.

The present intention is to retain the line switches which are now in service but to use line finders on new installations including additions to offices now having line switches.

Photos H and I show two views of a **line finder** and Photo J shows a view of two line finder banks.

Line Finder Assembly

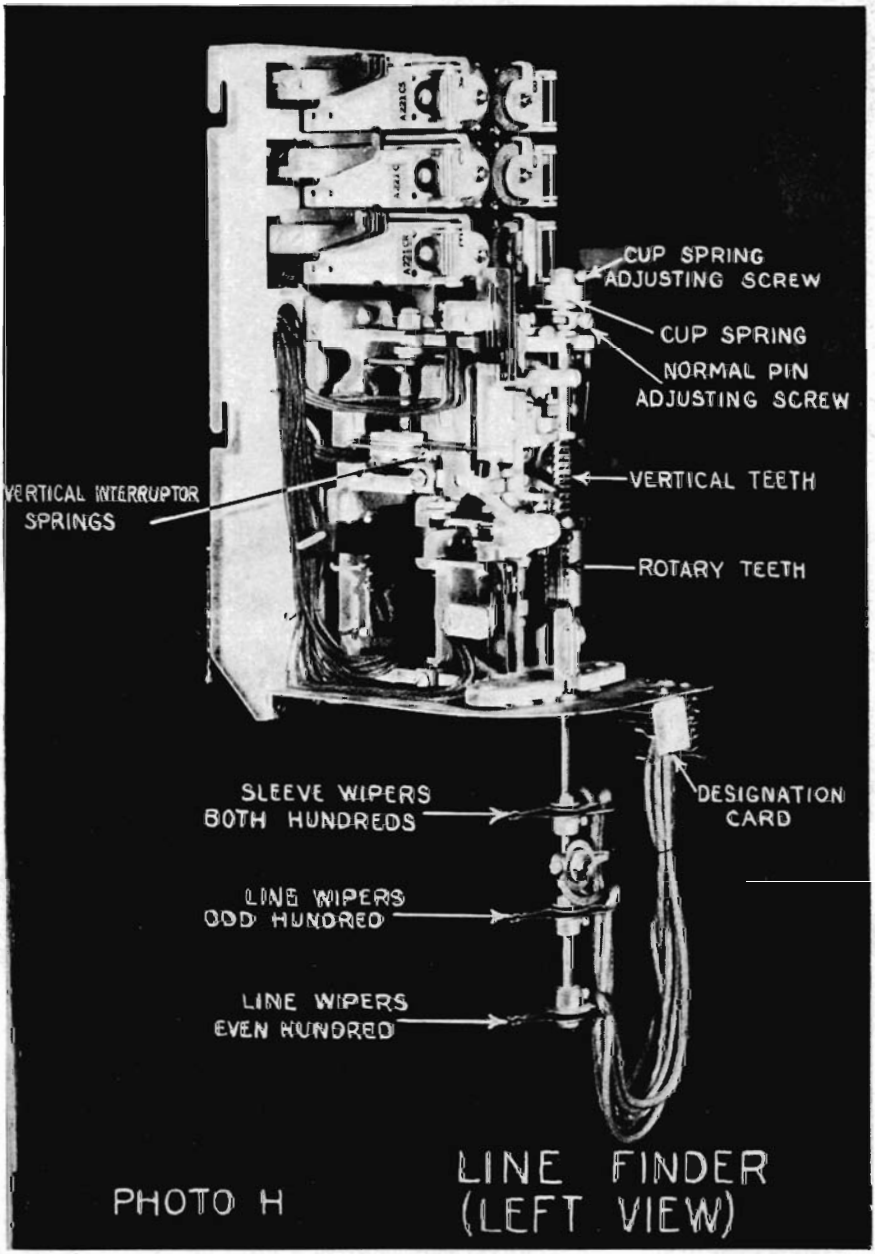
As shown, each **line finder** has a vertical magnet, a rotary magnet, and a release magnet which are substantially the same as those in a selector or a connector and which function in much the same manner.

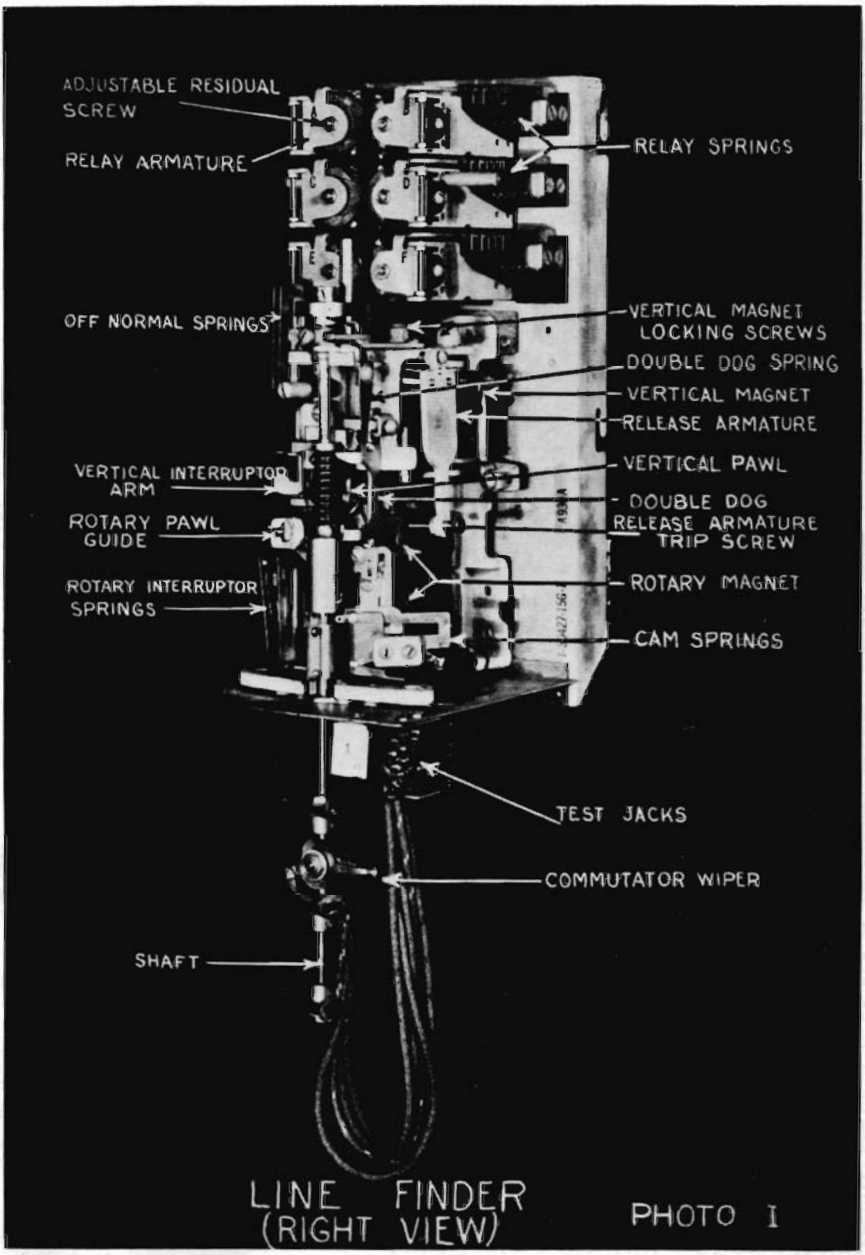
It also has six relays, A, B, C, D, E and F which are similar in appearance to the relays in selectors and connectors but have decidedly different functions.

Line Finder Banks, Wipers and Commutator

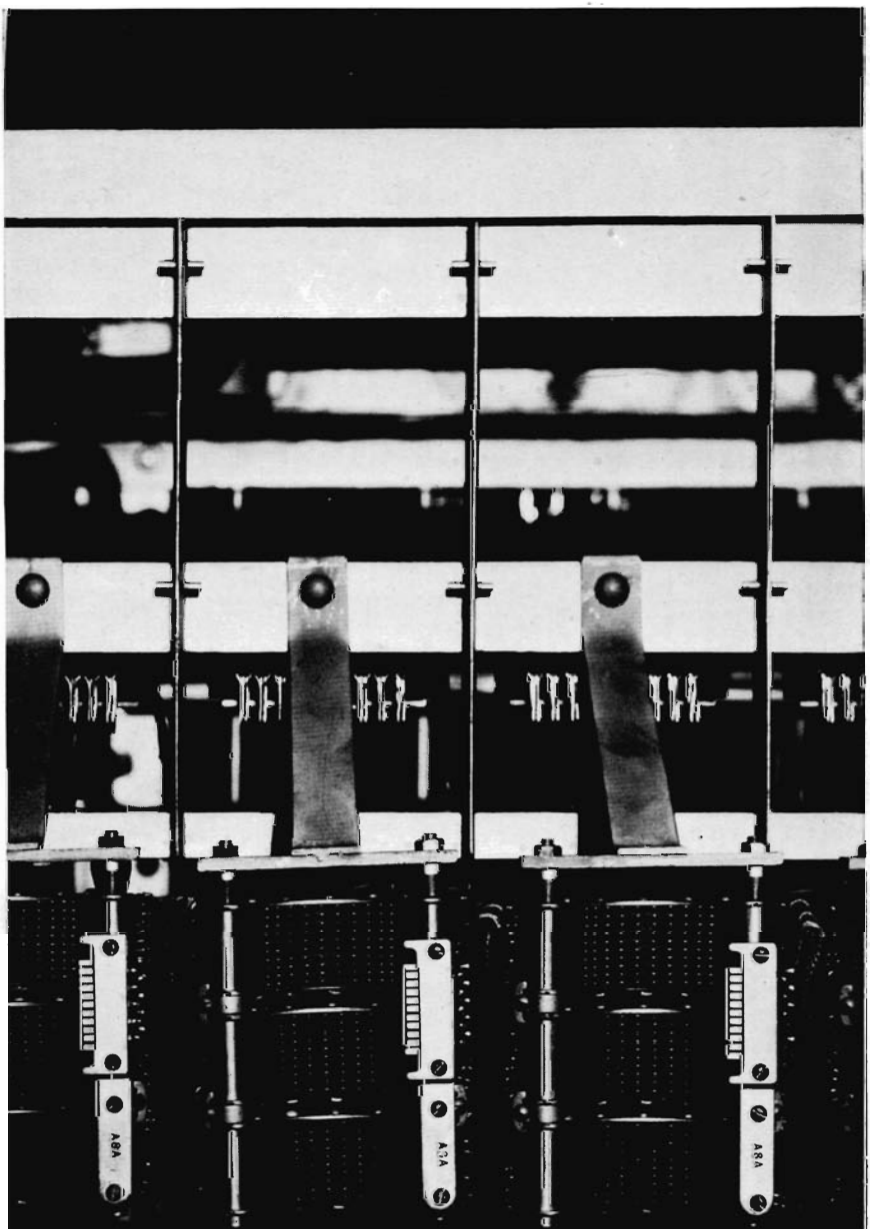
Each **line finder** has three standard banks—the lower one being the tip and ring terminals for what is known as the "lower hundred" of 200 line circuits served by a group of line finders; the middle bank being the tip and ring terminals for the "upper hundred" and the top bank being the sleeve terminals for both hundreds.

The line finder shaft has six wipers that engage with these bank terminals; and since it has the same travel as a selector or connector it follows that the wipers rest on the terminals of two lines simultaneously. But electrical connection is made with only one of these two lines because the one making the call has battery on its sleeve which if it is in the "lower hundred" operates **one** relay in the line finder completing the connection between the


CUP SPRING ADJUSTING SCREW
CUP SPRING
NORMAL PIN ADJUSTING SCREW
VERTICAL INTERRUPTOR SPRINGS
VERTICAL TEETH
ROTARY TEETH
SLEEVE WIPERS BOTH HUNDREDS
DESIGNATION CARD
LINE WIPERS ODD HUNDRED
LINE WIPERS EVEN HUNDRED
PHOTO H
LINE FINDER (LEFT VIEW)

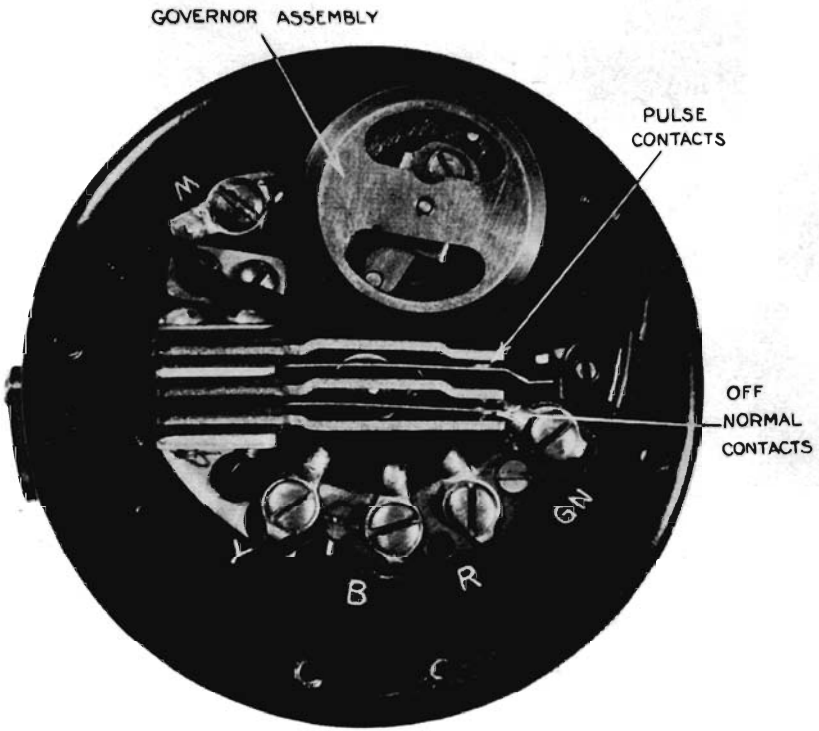


LINE FINDER (RIGHT VIEW) PHOTO I



LINE FINDER MULTIPLE BANKS

PHOTO J



DIAL
REAR VIEW

PHOTO L

DIAL
FRONT VIEW

PHOTO K

"lower" set of wipers and a first selector; while, if the calling line is in the "upper hundred", its sleeve battery will operate this same relay in the line finder and another relay also, completing the connection between the "upper" set of wipers and this same first selector.

Each **line finder** also has ten vertical commutator bars, and a wiper on the shaft which makes contact with them as the shaft moves upward but is thrown out of contact as soon as the shaft cuts in at any level.

Equipment of Line Finder Groups

A **line finder group** consists of 200 line circuits (line and cut off relays) to which the lines are wired but not necessarily in consecutive order; some 22 relays common to the group; and not more than 30 line finders depending upon the calling rate of the lines.

The wiring and circuit operation is explained in Section 4 but a brief outline is given here as a necessary adjunct to a description of the mechanical operation of the line finder.

Line Finder Operation

When the receiver on any one of these 200 lines is taken off hook its line relay operates and does two things. First it puts a ground on a certain lead that starts the operation of some one line finder; and second, it puts battery on the sleeve of the calling line to stop this line finder when its wipers reach that line.

This ground just mentioned indirectly grounds the commutator bar corresponding to the level in which the calling line appears in this line finder's multiple bank; and at the same time, also indirectly, completes a circuit through the vertical magnet. The latter continues to function until the shaft is raised to this level, at which time the ground on this commutator bar operates some of the line finder relays, causing circuit changes that stop the vertical magnet and start the rotary magnet. The latter then functions until the wipers reach the line having battery on its sleeve at which time certain relays operate and open the circuit through the rotary magnet

stopping the switch at this point and at the same time these relays close the trunk through to its first selector.

When the train is released the release magnet is brought into action and returns the line finder to normal.

The vertical, rotary and release motions are in their mechanical features substantially the same as those of the selector or connector.

THE DIAL

The Dial

In a quite literal sense we now return to the place of beginning.

As previously shown, the dial controls one after another all the switches in the train except the line switches and line finders, therefore reliability of its performance is essential to good service.

Two views of the dial used in some parts of our territory are shown in Photos K and L.

In other parts the dial used has exactly the same mechanical construction but the letters are omitted because the telephone numbers used have digits only—no letters.

Dial Operation

The dial has a finger plate with ten holes spaced about 30 degrees apart which may be rotated in a clockwise direction through arcs of 60 degrees, 90 degrees, etc., up to 330 degrees. This winds up a spring which returns the finger plate to its normal position when the dial is released.

As the dial runs back, a cam arrangement actuates a pair of springs called the pulse contacts which open and close the telephone circuit (with the receiver off the hook) from 1 to 10 times depending upon the arc through which the finger plate was rotated.

There are three other springs called **off normal contacts** which operate as soon as the finger plate is rotated off its normal position and short circuit the transmitter to take its resistance out of the circuit while dialing, and also

open the local circuit that includes the receiver to prevent annoying clicks being heard by the user.

The numbering and lettering is for the convenience of the user in dialing.

Use of Office Names

By retaining the office name and instructing the customers to dial the first two letters, dial system offices may be put into service in multi-office exchange areas previously served by manual offices without wholesale changes in existing telephone numbers, and without having to give additional instructions as to use of the telephones remaining manual.

The position of the letters on the name plate shows that dialing any letter is just the same as dialing the digit which is seen through the same hole in the finger plate, therefore some number changes may be necessary in case the first two letters of two offices in the same exchange area are identical when translated into their equivalent digits.

System of Numbering

It may be interesting to know the system of numbering used in the several cities in our territory now served wholly or in part by the step-by-step dial system.

For example, in **Alliance** and **Massillon** every telephone number has just four digits which are listed in the directory thus: 6234, 4781 etc.

This simple system of numbering is possible in these cities because each is served by one step-by-step office in which every station on direct lines or party lines has its own set of terminals on the connector banks.

A direct line has one set of these terminals and one pair of wires from the office to the station or P. B. X. in which this line terminates.

A four-party line has four sets of these terminals, suitably cross-connected at the Line Intermediate Distributing Frame and one pair of wires out of the office common to the four stations.

At **Canton** the telephone numbers are slightly different, some having four digits and some five, as: 6234, 2-0973, 3-2792, etc. Here the switch train for the four digit numbers includes 1st and 2nd selectors; while the train for the five digit numbers includes 1st, 2nd and 3rd selectors.

At **Youngstown** the numbers in the dial offices have five digits as 9-4388, 6-2797, etc. while those in Struthers (a manual office) have five digits for direct lines and six digits for stations on party lines as 5-0355-4.

In this case the first digit (5) indicates the level on the 1st selectors at each step-by-step office on which outgoing trunks to Struthers appear; and the last digit (4) indicates that this is the 4th party on Struthers line 0355.

At **Columbus** and at **Toledo** the numbers in the step-by-step offices have six digits of which the first two are letters as MAin 6452 etc.; while those in the manual offices have six digits for direct lines and seven for party line stations as RAndolph 8645, RAndolph 1391-W, JEfferson 2749-J etc.

At Columbus and Toledo a plan is used which, in effect, cancels the second digit of the office code as the A in MAin and RAndolph, the E in JEfferson, etc., but provides for the use of these digits later on when the number of offices becomes large enough to make this necessary. In fact at Columbus now, the second digit for the KEnmore and LAwndale Offices is effective while for the other offices the second digit is absorbed.

This is accomplished by digit absorbing selectors in the dial offices and by a digit absorbing feature in the call indicator trunks at the manual offices.

The digit absorbing selector is more fully described in Section 4, Part 2 of this Reading Course.

QUESTIONS

1. Assume that you have ten two-wire telephone lines meeting at a central point, each equipped with one common battery telephone set and that you want to put in switching mechanism which may be operated by the stations. What five things would you have to provide for that mechanism to do?

2. Name the type of electrical apparatus that makes such a system possible.

3. What is the basic principle of the connector as used in step-by-step systems?

4. What two kinds of relays are used in switching the vertical magnet out of circuit, and the rotary magnet into circuit on a selector or connector?

5. Explain in a general way how ringing current is applied to the line and how it is tripped out.

6. What is the principal mechanical action of the dial?

7. How is the fact that there is a longer interval between two sets of pulses than each individual pulse made use of?

8. Why has it been necessary to add a third terminal S to each set of line terminals?

9. How many relays and magnets are required to perform the usual functions of a connector? Name them.

10. Why were Line Switches and Line Finders developed?

11. What is the main difference between the operation of a Selector and a Connector?

12. When are Repeaters used?

13. Under what conditions is a Call Indicator required?

14. (a) How many subscribers' lines are connected to each primary line switch?

    (b) How many subscribers' lines does a line finder have access to?

15. What is the principal duty of a Master Switch?

16. If a dialed number has 6 digits, how many selectors are required to complete the train of switches?

17. If a dialed number has 6 digits, one of which is absorbed, how many selectors are required to complete the train of switches?

18. What is the maximum number of lines which a connector can have access to?