TELEPHONE THEORY AND PRACTICE

AUTOMATIC SWITCHING AND AUXILIARY EQUIPMENT

BY

KEMPSTER B. MILLER, M.E.

Fellow, American Institute of Electrical Engineers; Member, Western Society of Engineers; Author of "American Telephone Practice," 1904, and Joint Author of "Telephony," 1912

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A Note About This Document

This book, Telephone Theory and Practice, Automatic Switching and Auxiliary Equipment, came from the private library of Joybubbles (born Josef Carl Engressia, Jr., 1949-2007), the blind phone phreak of some renown. It was provided to him as a photocopy by an unknown person at AT&T as noted in the following cover letter.

When Joybubbles passed away much of his library went to Phil Lapsley. These documents were eventually given to Sam Etler for safekeeping and digitization purposes.

Feel free to distribute this document widely. However, as a tribute to Joybubbles, please leave this note attached.

-- Sam Etler, 2012-01-12

Dear Mrs. Lofchie

The enclosed Material is sent to you regarding Joseph Engressia.

After talking to Joe about the lack of authoritative books on step switching equipment, we more or less decided that the single most valuble book published was Vol III of Kempster Miller's set and he asked if I couldn't find a way to get a copy sent to you for reading. The enclosed copy was finally made and since it is not the actual original can be kept for reading without having to worrry about a due date at the library. After speaking with Joe at a later date after the material is read, we can arrange for its return.

Joe says to say hello. He has described the almost unbelievable energy you have devoted to helping blind people like himself. I would like to thank you personally for the fine work you are doing, for I know how much it means, particularly for a brilliant boy like Joe.

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In accordance with War Production Board regulations, this book is printed in a war-time economy format with reduced margins. However, the type page is standard for a book of this kind, and ease of reading is maintained.

At the end of the war when paper and binding materials are again plentiful, this book and other similar volumes will be reprinted in larger size with normal margins.

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KEMPSTER B. MILLER

THEORY AND ELEMENTS

MANUAL SWITCHING AND SUBSTATION EQUIPMENT

AUTOMATIC SWITCHING AND AUXILIARY EQUIPMENT

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PREFACE

The title "The Telephone Exchange," originally intended for the second volume of this series, was found to be too comprehensive for a single volume of reasonable size. It was necessary, therefore, either to condense the subject matter logically coming within that title to a degree that seemed undesirable or to present it in two volumes. The latter course was adopted, resulting in the two volumes now presented, the companion volume, "Manual Switching and Substation Equipment," and this one, "Automatic Switching and Auxiliary Equipment." Although closely related as parts of a whole, each is fairly complete in itself in covering the branch of the subject to which it relates. As the titles indicate, the general dividing line between the two is that between manual and automatic or machine-switching systems. Parts of each, however, such as "Auxiliary Equipment" of this volume and "Substation Equipment" of the companion volume, cover matter in large measure common to both types of system.

This, then, is the third volume of "Telephone Theory and Practice." As in the case of the second volume of the series, a foundation of elementary theory and an historic background for it are to be found in the first volume "Theory and Elements." This one treats principally of automatic or machine-switching systems of all four types now in use: step-by-step, panel, rotary and all-relay. It also contains collateral matter in the chapters on Power Plants, Protective Apparatus, Distributing Frames, Private Branch Exchanges, and Toll Switching—subjects which in large measure concern both manual and machine-switching exchange systems and which could best be treated after both types of system had been discussed.

I am glad to acknowledge the generous cooperation of the American Telephone and Telegraph Company, the Automatic Electric Company, the Bell Telephone Laboratories, the International Telephone and Telegraph Corporation, The North Electric Manufacturing Company, and other concerns in furnishing their literature, illustrations, and, in many cases, matter

prepared specially for me in response to my requests for information. To the officers and employees of each of these who made this policy of cooperation possible my thanks are extended.

Among the friends who, as individuals, have assisted in one way or another and to whom my acknowledgment and thanks are due are Mr. L. E. Kittredge of the American Telephone and Telegraph Company for his contribution of the descriptive matter and diagrams relating to the panel system, Mr. Gerald Deakin of the International Telephone and Telegraph Corporation for his contribution of the matter relating to the rotary automatic system, Mr. P. A. Bolander of the Automatic Electric Company for information he prepared for my use concerning the products and practices of his company, Mr. Richard Maetzel of the New York Telephone Company for his suggestions and criticisms regarding the chapter on Power Plants, Mr. H. W. Hitchcock of the Southern California Telephone Company for supplying needed information on more than one occasion, Mr. Ned Crawford of Pomona, California, for assistance on the all-relay chapter, and lastly my former engineering partner, Mr. Leigh S. Keith, for his extensive and competent labors in connection with Chapters III, X, and XI. Other and more specific credits for sources of information on which I have freely drawn and for courtesy in permission to use illustrations are made throughout the book.

Kempster B. Miller.

Pasadena, California,
December, 1932.

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AUTOMATIC SWITCHING AND AUXILIARY EQUIPMENT

CHAPTER I

THE MACHINE-SWITCHING IDEA

Almost as soon as the telephone-exchange idea had taken form and the necessity for switching telephone lines at a central office had become apparent, men began to devise ways and means for doing the switching automatically, under remote control by the subscribers, rather than manually by the central-office operator. Thus, unusually early, did the almost universal trend of development in other lines become manifest in the telephone art—the striving to do by machine the work formerly done by hand.

As early as 1879, a patent was granted to Messrs. Connelly and McTighe, of Washington, D. C., for a machine intended to do the work of the central-office operator.[1] While crude and impractical, it disclosed a device employing some of the principles used in modern systems—among them that of step-by-step switches at the central offices moved by a succession of current impulses sent from the subscriber's station.

Not long after this Almon B. Strowger of Atlanta, Georgia, made a number of inventions, one of which, crude though it was, probably marks the first step in the realization of the ideas advanced by Connelly and McTighe. Strowger devised what we may call the "coordinate switch"—that is, a switch in which the contacts were arranged in coordinated rows in such manner that the selecting arm or "wiper" could move over them in two directions under control of the "stepping impulses" sent by the subscriber. In this way, a given contact could be selected by

[1] U. S. Patent 222458, issued December 9, 1879.

causing the wiper to move in one direction until it was opposite the desired row and then in the other direction along the row to the desired contact. Thus by two relatively short coordinated movements a given contact could be reached with a minimum amount of travel.

In an early embodiment of this idea, the line contacts arranged in straight vertical rows and circular horizontal rows projected from the inner surface of a hollow glass cylinder. The moving member or wiper arm of the switch was carried on a vertical shaft mounted axially within the cylinder, on bearings permitting both longitudinal and rotary movements. This shaft carried two ratchets, one adapted to give it a step-by-step vertical movement and the other a step-by-step rotary movement. The pawl of each ratchet was actuated by its own electromagnet under control of the current impulses sent by the subscriber, who, by sending the proper number of impulses over one of his line wires, could cause the wiper arm of his switch to step *up* to the row containing the contact of the line desired and then by impulses over another wire to step *around* to engage the particular one. The system disclosed in Strowger's patent[1] required no less than five wires between the subscriber's station and the central office. While quite impracticable in its details, the fundamental idea of the "up-and-around" switch was destined to play an important part in subsequent developments. It was Strowger's contribution to the machine-switching art and to the step-by-step automatic system which bears his name.

As far as any practical results were concerned, Strowger's idea went no further than that each switch would, of itself, be able to reach and connect with all the lines in the exchange. This, of course, would have imposed a limitation, not to be tolerated, on the number of subscribers that could be served. Since the cost of automatic switches increases enormously with the increase in number of lines with which they can directly connect, it soon became apparent that some plan of trunking between comparatively small groups of subscribers and the switches serving them would have to be resorted to where the number of lines to be served exceeded the capacity of one switch. Here progress stumbled for a number of years. The problem of a workable automatic-trunking plan was greatly complicated by the fact that provision for many simultaneous connections through

[1] U. S. Patent 447918, issued March 10, 1891.

the switchboard had to be made. It would not do to have a connection between any two subscribers block the path for connecting any other two subscribers, whether they were in the same or other groups. This very clearly called for a number of parallel paths for each possible connection between groups, but a practical way of doing this remained obscure for a considerable time. The difficulty arose from the fact that the subscriber, in his control of the central-office switches, could know nothing of the central-office conditions. He could not be expected to know that there were a number of possible paths to choose from, and, even if he knew this, he would have no means of selecting an idle one and avoiding others that were already engaged. All that the subscriber can be relied upon to do is to manipulate his impulse-sending device (dial) in accordance with the number of the line he desires to call. The dial itself will send separate groups of impulses corresponding respectively to the successive digits of this number and nothing more. Obviously, it is necessary that the central-office apparatus shall of itself be endowed with the ability to perform a purely selective function with which the subscriber has nothing to do. The subscriber can (by his dial) select only the *group* of trunks to which he wishes his line to be extended after which the switch at the central office must act, of its own volition as it were, to *hunt for and connect with an idle trunk of that group.*

This idea of the selection of a group of trunks under the volition of the subscriber and the automatic selection of an idle trunk in that group without the volition of the subscriber has always seemed to me to have marked the dividing line between success and failure in automatic or machine-switching telephony. It is a vital feature of all present machine-switching systems. In retrospect, it was a bold idea, because it seems to demand of the central-office apparatus something akin to intelligence.

The work of Alexander E. Keith and his associates in the Automatic Electric Company of Chicago stands out prominently in the development of machine switching in general and of the step-by-step (Strowger) system in particular. Around the crude switch of Strowger they and their followers built the step-by-step system essentially as it stands to-day and as it has been adopted throughout the world.

But while the step-by-step development was going on, others, quite independently, were working along different lines that later led to what is now known as the power-driven system, of which the "panel system" of the Bell companies in this country and the "rotary system" largely used abroad by the International Telephone and Telegraph Corporation, are prominent examples. The first really practical work in this direction was done by two brothers, Hoyt and George William Lorimer, of Brantford, Ontario, and later of Piqua, Ohio.[1] These two young men, with no previous experience in commercial telephony and without ever having "seen the inside of a telephone central office" designed and in their own small shop with their own hands built a workable automatic switchboard that embodied a number of features now found to be essential to all machine-switching systems. Later, their system, exactly as they designed and built it, was used commercially in a few Canadian towns, among them Peterboro, Ontario, where it was installed in 1905. The work of the Lorimer brothers is all the more remarkable because they were undoubtedly among the first of several inventors to conceive and put into practical form the trunking plan already alluded to, where the desired group of trunks is selected by the subscriber and the individual trunk in the group is automatically selected by the switch.

The Lorimer system is now of historic interest mainly because it was the first one of the so-called "power-driven" systems to achieve any degree of practical success. In power-driven systems of which the "panel-type system" of the Western Electric Company and the "rotary system" of the International Telephone and Telegraph Corporation are highly developed modern examples, the switches derive their motion from separate constantly running motors, each common to a number of switches. The selecting members of the switches are brought to the selected contacts they are to engage by a steady progressive movement, as distinguished from the intermittent or step-by-step movement that is characteristic of switches of the Strowger type.

Still another line of endeavor in the machine-switching field is that which has led to the so-called "all-relay" system. This, as its name implies, employs only relays, and no progressively moving switches, to effect the selecting, connecting, and disconnecting of lines. The all-relay system is one of minimum mechanical movements and consequently of minimum mechanical complexity. In it paths are permanently wired from every line to every other line, these paths being normally broken at the small gaps of relay contacts. By causing the proper relays to operate, the gaps may be closed to complete the connection from any line to any other.

[1] British Patent 8648 of 1901.
U. S. Patent 1,187,634, issued June 20, 1916, filed April 24, 1900.

Theoretically the all-relay system is applicable to exchanges of any size, but practically it seems, as far as it has yet been developed, to be limited to those serving a comparatively few lines. The reason for this is the enormous multiplicity of relays that would be involved in large exchanges. For small exchanges, however, it appears definitely attractive. It is manufactured in this country by the North Electric Manufacturing Company and advocated by it for small exchanges and for branch-office equipment of larger exchanges.

From the foregoing it is seen that there are broadly three types of automatic or machine-switching systems:

1. The step-by-step system, wherein each switch has its own driving magnets adapted to move the selecting contact members or wipers into engagement with the selected contacts by rapid successions of short steps, usually in two coordinated directions. In this system the driving power is derived from impulses of current through the driving magnets.

2. The power-driven system, wherein the switches through individual clutches derive their power for moving their selecting members from a continuously operating motor common to many of them. In this system, the selecting impulses serve to control the application of the common source of power to the individual switches.

3. The all-relay system, wherein relays instead of progressively moving switches are relied on to connect and disconnect the lines. In this system, the selecting impulses serve merely to determine which combinations of relays shall be operated to close the desired one of the already existing paths.

Because the mechanism given the subscriber for exercising this control has now universally taken the form of a dial, these subscriber-controlled systems are now often called "dial" systems, principally to distinguish them from manual systems. Up to this point we have considered only those machine-switching systems that were controlled by the subscribers. After the practicability of machine switching had been generally established, Edward E. Clement, of Washington, D. C., an engineer, patent attorney, and prolific inventor, came forward with a system which has since been manufactured by the North Company and its predecessor. In this, the control of the central-office switches was exercised by a few simple keyboards at the central office instead of by the many dials at the subscribers' stations. The control was thus taken from the subscribers and placed in the hands of a few skilled operators who manipulated the keyboards in response to calls given orally by the subscribers. This, then, was an "operator-controlled" instead of a "subscriber-controlled" automatic or machine-switching system. Clement coined the name "automanual" to apply to it, to indicate that it partook of both the automatic and manual systems: automatic in that the connections were set up and taken down wholly by machine; and manual in that the subscribers' station apparatus was the same as that of the common-battery manual system and that the subscriber merely asked for his connection as in the manual system. Some have called this a "semi-automatic" system but this is clearly a misnomer, for it is as fully automatic as the dial system. Both are full machine-switching systems, the difference being that one is dial or subscriber controlled and the other keyboard or operator controlled. The keyboards may be considered in the nature of "master dials" for use by operators rather than subscribers.

Operator control of central-office switches has played an important part in the gradual conversion of manual to machine switching in large multi-office systems. During the period while some of the offices are operating on a machine-switching and others on a manual basis, special equipment must be provided for establishing connections between lines in the two kinds of offices. In these "mixed systems" a call from a manual station to a dial station is received, of course, by a "manual A" operator and by her trunked to a "cordless B" operator at the machine-switching office. From here on the operation closely resembles that of the automanual system. The "cordless B" operator is provided with a keyboard for controlling the switching apparatus in the terminating office. She receives the call orally and sets it up on her keyboard, and the switching machines complete the connection in response to this "set-up."

The first automatic systems to meet any degree of commercial success required local batteries at the subscribers' stations for transmitter current. Common-battery working was a proven

success in manual operation but was difficult to apply to machine switching because of the method of switch control then in vogue. In the Strowger system of that time,[1] for instance, one wire of the metallic-line circuit was required with a ground return for stepping the switches vertically in response to the selecting impulses from the subscriber's dial, the other line wire with a ground return was required for the "change-over" which brought about the trunk-hunting movement of the switches so selected, while both wires together with a ground return were required for the final release of the switches. It was difficult to reconcile these requirements with the use of the metallic circuit for supplying direct current to the substation transmitters. It was not until a radically different method of switch control was found that the way was paved for common-battery machine-switching operation. The key to the solution of this problem of doing so many different things over a single metallic circuit without the use of ground returns was found in the use of fast and slow relays, all operating by current from the common battery flowing in the metallic circuit. A rapid series of dial break impulses, corresponding in number to the digit being selected, effected, through a fast relay, the selection of a group of trunks; a succeeding pause between break impulses, through a slow relay, effected the "change-over" to permit the automatic selection of a trunk in the chosen group; and a final long break in the circuit effected the release of the switches. This introduction of the time element so prominently to differentiate between successive functions to be performed over the same circuit removed the last serious technical obstacle in the way of a satisfactory machine-switching system, whether of the step-by-step, power-driven, or all-relay types and whether controlled by subscribers or operators.

There were, however, other questions than mere technical operativeness that had to be determined before machine switching was ready for general, country-wide adoption. Its operativeness being granted, there were still such questions as whether the public would like it or not and whether, all things considered, it could compete economically with the manual system.

A paper[2] given by the writer in 1904 before the International Electrical Congress, at St. Louis, Missouri, shows how some of

[1] MILLER, KEMPSTER B., "American Telephone Practice," McGraw-Hill Book Company, Inc., New York, 4th ed., 1905.

[2] "The Automatic v. The Manual Telephone Exchange," Sec. G, Electrical Communication, International Electrical Congress of St. Louis, 1904.

these questions appeared to him at that time. The questions of doubt at that time have since been resolved mainly in favor of machine switching. The question, that later arose, as to whether the switching machinery should be dial-controlled by the subscriber or keyboard-controlled by a comparatively few central-office operators acting under oral instructions from the subscriber, has been generally resolved in favor of the dial control by the subscriber although there are outstanding examples of keyboard, operator-controlled systems now in operation.[1] Both are unquestionably good methods as has been amply demonstrated, but those who have been inclined to favor operators' keyboard control, because of the greater simplicity permitted in the substation apparatus and the minimum of work required of the subscriber, now find themselves in a decided minority.

Looking back over the fifty odd years of telephone-exchange development, it seems quite in the natural course that the manual method of switching should have been the first to be generally favored, developed, and put into commercial use. The needs of the telephone business had first to be determined. The lack of knowledge concerning these needs and the lack of methods, equipment, and trained personnel, during the time that knowledge was being acquired, of necessity kept the early practices in the simplest and most obvious channels. But meanwhile, as has so often been the case in the early development of other arts, a succession of pioneer inventors with little encouragement—nay, in spite of every discouragement—had clung tenaciously to the idea of devising a machine that, under the control of the subscribers, would connect lines and disconnect them and perform the collateral operations that in manual switchboards had been required of human operators. To the practical telephone man of the time this idea seemed preposterous, as indeed it was, in view of the then existing conditions in the telephone business. But, as the art advanced, as knowledge and technique grew and conditions changed, far-sighted men began to see in it really practicable possibilities. It began to appear that, in some measure at least, hand switching would have to give way to machine switching in telephony, just as in the older arts, for instance, hand weaving had given way to the machine loom;

[1] One of these is the automanual system of about eight thousand lines at Lima, Ohio.

handwriting to the typewriting machine, and hand typesetting to the linotype and monotype machines.

It is, of course, as impossible to state just when machine-switching telephony passed out of the realm of failure and into that of success, as it is to state when darkness ends and daylight begins. By 1904 and 1905, as attested, for instance, by the operation of the Strowger exchanges at Grand Rapids, Michigan (1904), and Columbus, Ohio (1905), it had clearly demonstrated that it would work under the comparatively simple conditions of single-office exchanges in medium-sized cities. The evidence was fairly good that the public liked it then, but there were doubts as to how much of this popularity was attributable to its novelty or to certain favorable conditions of widespread local ownership that existed in those cities. There was also an almost complete lack of fundamental data on which to base judgment of its ability to compete economically with the older type of service. Naturally only time, use, and experience could answer some of the questions necessary to a determination of comparative economy. The life of the equipment and its rate of depreciation were quite unknown, its maintenance and operating costs were matters of speculation, and, as was learned afterwards, the first costs based on a fixed price of $35 a line, including complete substation telephones, were altogether misleading.

From the knowledge gained from a few such early successes to that which would warrant the more general adoption of machine switching, and particularly its adoption for the vastly complex conditions of large metropolitan areas, was a long step. Encouraged, however, by these experiences and others which soon followed, rapid progress was made and by about 1918 it was considered fit for use in very large centers like New York and Chicago—a long step indeed. Since that time the process of conversion from manual to machine-switching telephony, already well under way, has been going on with increased rapidity throughout the world.

It took more than the mere technical development of the system itself to bring about the adoption of automatic telephony in this really large way. Two other principal factors contributed: first, the enormous growth in the use of telephone service with its more exacting demands, and, second, the changes in economic conditions brought about by the World War. In some respects, particularly in very large cities, the manual system was almost breaking down under the increasing demands on it. Many features that had been developed in the automatic system were, as has been shown, engrafted bodily on existing manual systems and a general policy of replacing larger manual equipments, as they were outgrown or outworn, with those of the machine-switching variety was adopted by most of the companies and governments operating telephone systems throughout the world.

The World War changed economic aspects in the telephone business as in most other lines. For one thing, by greatly increasing the demand for female labor in other industries, it taught the telephone operator something of her own economic value. In this and in many other respects the economic problems involved in the adoption of machine switching were changed by the war so as to present an entirely new aspect. In some cases, it enabled machine switching to "prove in" purely on a basis of economy, where before the war it could not have done so.

The process of conversion, still going on, must, of necessity, be a gradual one for three principal reasons: in order to keep within the bounds of reasonable capacity for the manufacture of the required equipment; in order to conserve investment in manual equipment that is still adequate for the demands upon it; and in order to give proper service continuously during the period of change.

In this chapter the attempt has been made merely to touch upon a few of the high spots in the growth of the machine-switching idea, as a preliminary to the more detailed consideration to follow. In such an intricate subject matter, unless there is some perspective, one is likely to "lose sight of the forest because of the trees."

CHAPTER II

CONTROL DEVICES AND NUMBERING PLANS

In any machine-switching system the control of the central-office switching apparatus, as far as the subscriber is concerned, must be done on a decimal basis, since the decimal system of numbering is the one universally used in everyday affairs.[1] Accordingly, in telephone directories, the numbers by which subscribers are to be called are listed on the decimal basis. This is true, in machine-switching systems, whether the directory listing consists wholly of numerals, as "4978," or of an office name and numerals, as "Lennox 4978." In the latter case, some of the letters of the office name would be given numerical digit significance on a decimal basis, in a manner that will appear later.

It will be helpful in studying automatic-switching systems to keep in mind the significance of the successive digits in a number that is used to designate the place of a particular unit thing in a large group. Thus, among 10,000 unit things, the particular one referred to by such a number as "4978" is found in the *fourth* group of thousands, the *ninth* group of hundreds in that thousand, the *seventh* group of ten in that hundred, and the *eighth* one in that ten. Each successive digit narrows the selection down by picking one out of ten.

The Substation Dial.—It was shown in the last chapter that the subscriber in a subscriber-controlled automatic system exerts his control on the central-office switches by several successive series of rapidly recurring breaks in the line circuit, the number of breaks in each series corresponding to the successive digits in the

[1] In some systems, for reasons that will be pointed out, the central-office switches themselves operate on other than a decimal basis, so that the numbers used by the calling subscriber are not the ones which actually control the switches. Where this is done, devices are employed at the central office which, in effect, translate the directory numbers into numbers more suitable for switch operation. This will be discussed in later chapters but it does not alter the fact that, so far as the subscribers are concerned, all systems operate on a decimal basis.

called subscriber's number Each substation must, therefore, be provided with a device by the manipulation of which the subscriber may rapidly and accurately transmit to the central office several successive series of break impulses, each series corresponding in its number of breaks to the numerical value of the digit it represents. Each series must, therefore, have from one to ten breaks. It was also shown that, between each series of break impulses corresponding to the successive digits, there must be a pause to allow time for the "trunk-hunting" and "change-over" operations of the central-office equipment—that is, for selecting an idle trunk and passing the control to the next switch or function to be involved in the chain of operations.

The substation control device, therefore, must enable the subscriber easily and accurately to translate the directory designation of the subscriber he desires to call into several series of from one to ten rapidly recurring breaks in the line circuit; and it must allow a pause after each series during which the line circuit remains closed. More than this, the device must be so arranged as to prevent its circuit-breaking functions from disturbing the talking apparatus of his own station. Obviously also, like substation apparatus in general, it should be as simple, rugged, and "fool-proof" as possible and as inexpensive as is consistent with its exacting requirements.

The familiar automatic telephone dial, developed originally in connection with the Strowger system and later adopted in principle by all important systems, has proved to be better adapted to the purposes of a subscriber's "calling device" or "impulse sender" than any of the numerous other forms involving push buttons or levers that have been designed for the same general purpose. Its outward appearance, as now used by the Bell System, is shown in Fig. 1, which also indicates the method of its use.

The finger wheel or dial proper has near its periphery ten finger holes through each of which, when the dial is in its normal position, may be seen respectively one of the Arabic numerals, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0, in the order mentioned. These figures, and the letters which sometimes accompany them, are on a stationary white enamelled number plate lying a short distance below the dial. By placing the finger in one of the holes, the dial may be turned in clockwise direction against the action of a coiled spring, until the finger engages the stationary finger stop

shown near the normal position of the "zero" hole. When released, the dial rotates in the opposite direction to its normal position under the action of the spring.

Briefly, the functioning of the dial is this: When the subscriber lifts his receiver to make a call, the metallic circuit of his line is closed through the normally closed pair of "impulsing contacts" of his dial. These contacts hold the line circuit closed during the forward movement of the dial, but during its return movement they alternately open and close the circuit, the number of breaks depending on the distance traveled by the dial in this

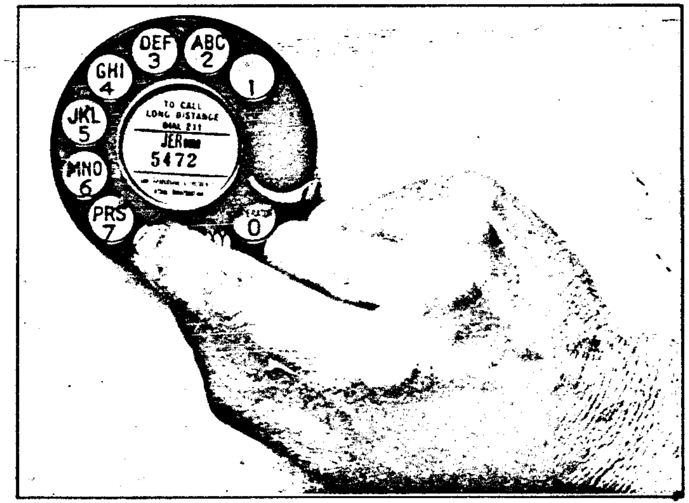


FIG. 1.—Substation dial and method of use. (*Courtesy of The American Telephone and Telegraph Company.*)

movement. Obviously, the distance of dial travel will depend on what finger hole was used in moving it from its normal position to the stop, and, as the mechanism is so geared as to cause one break for an angular movement corresponding to the distance between two adjacent dial holes, it follows that the number of break-impulses sent by the dial will be equal to the number represented by the figure seen through that hole. Thus the number of breaks will always correspond to the numeral in the hole "pulled," the "0" or zero hole always counting as ten, as will be explained. A small centrifugal governor geared to the dial shaft only during its return movement controls its speed of movement in that direction, so that the speed will be uniform and such as to cause the breaks to occur at the rate of ten per second.

Another set of springs associated with the dial mechanism are the "off-normal" or "shunt" springs. At the first movement of the dial, an attachment to its shaft causes these springs to shunt the telephone transmitter and either shunt or open the receiver, depending on the type of talking circuit used. These circuits affecting the talking set are restored to their normal operative conditions by the off-normal springs just as the dial reaches its normal position at the end of its return movement. The purpose of thus removing the talking apparatus from the circuit during the dialing operation is in order to remove the variable resistance of the transmitter and the reactance of the

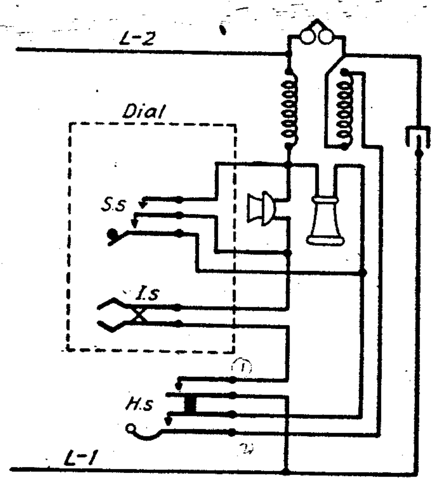


FIG. 2.—Automatic Electric Company's dial substation circuit.

receiver from the dialing circuit and to prevent the dial impulses from affecting the receiver.

Two specific types of dial will be described, these being the ones most used in the United States and elsewhere. Either of these is suitable for use with any of the dial automatic systems later to be described.

The dial of Automatic Electric Company as developed by that company for the Strowger system being taken first, Fig. 2 shows how it is connected in the substation circuit. The parts of the dial involved in the circuit connection are indicated within the dotted rectangle of this figure, the contact springs being shown in the position they assume when the dial is at rest. In this condition, the standard booster type of common-battery substation

circuit will be recognized. When the dial is moved out of its normal position, the shunt springs *SS* short-circuit the transmitter and receiver respectively and on the return movement of the dial the impulse springs *IS* open, to break the circuit of the line, a number of times corresponding to the number of the hole pulled.

Figure 3 is a rear view and a cross-sectional diagram of this dial. In the rear view, the pair of impulse springs is seen at the left, the three shunt springs at the right and the worm-drive for the centrifugal governor lying diagonally under the impulse springs. The three shunt springs are normally out of engagement with each other but, as soon as the dial is moved slightly

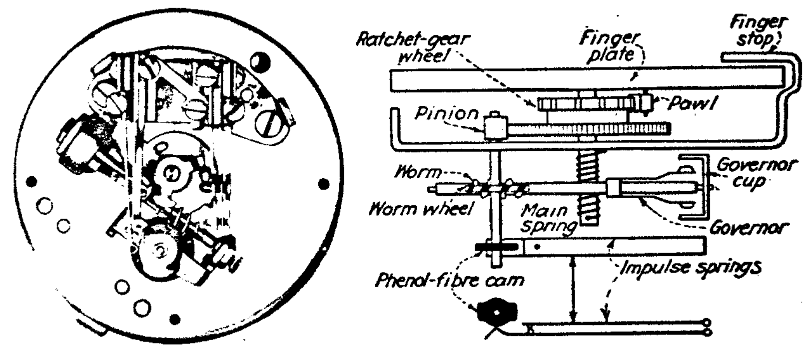


FIG. 3.—Rear view and cross-section diagram of Automatic Electric Company dial.

from its normal position, a projection on its shaft allows them to close their contacts and to remain so until again opened by the final movement of the dial in its return. The impulse springs are actuated by a cam driven by an auxiliary shaft geared to the main shaft of the dial plate.

The mechanical action may be better understood from the cross-sectional diagram. From this it will be seen that, on account of the pawl-and-ratchet connection between the finger-plate shaft and the main gear wheel, the cam wheel and the worm-driven governor shaft will be rotated only on the backward rotation of the dial. During this backward rotation, however, the cam shaft actuates the impulse springs, meanwhile driving the governor shaft which, by its "fly-ball" action, serves to limit the speed of return and therefore the speed of the impulsing.

The external appearance of the Western Electric dial used by the Bell System in both its panel-type and its step-by-step type automatic systems was shown in Fig. 1. A rear view showing contact springs and governor is given in Fig. 4. The upper pair of springs shown are the impulse springs, the contact between them being normally closed but opened periodically during the return movement of the finger wheel. The four springs below are the off-normal springs. These act in somewhat different manner from those of the Strowger dial, the upper pair, normally open, serving to short-circuit the transmitter and the lower pair, normally closed, serving to open the receiver circuit when the dial is moved out of its normal position. The long thin spring of the impulse pair is driven by a cam-actuated pivoted finger

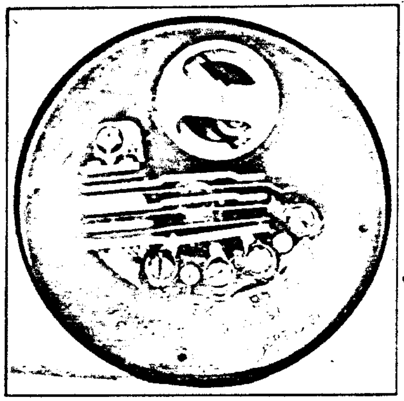


FIG. 4.—Rear view of Western Electric dial.

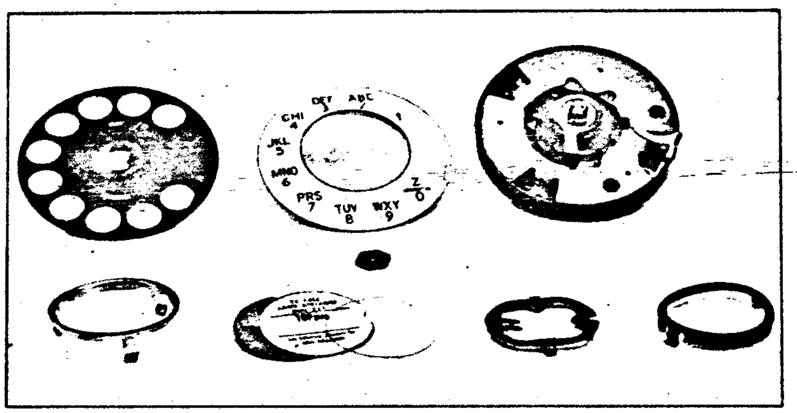


FIG. 5.—Western Electric dial—partly disassembled.

shown adjacent to its free end, while the thin springs of the off-normal set are moved by an arm rigidly attached to the dial-wheel shaft. The governor of this dial like that of the Stowger has two centrifugally operated weights exerting friction against the inner cylindrical surface of the governor housing but differs

in that it is driven on the backward rotation of the dial by gear and pinion instead of by worm gearing.

Figure 5 shows a front view of this dial partially disassembled. The three-tined ring at the left is for clamping the enameled number plate to the stationary framework. The two-tined ring at the right is a part of the card holder and serves to clamp the instruction card and its transparent covering to the face of the finger wheel.

Finger-hole Designations.—In numbering the finger holes of the dial, we cannot give the cipher 0 its ordinary significance of "zero" or "naught," because *no* breaks in the circuit would accomplish nothing at all. To omit the zero mark would leave only nine of the Arabic figures, and, as ten are needed, the cipher 0 is used for the tenth finger hole and made to follow nine in the series. On dials, therefore, the cipher is given the value of 10 and the 0 hole is placed next beyond the 9 hole so that when it is pulled, ten breaks will be produced in the line circuit.

Giving the zero mark a value of ten leads to a variation from the ordinary sequence of numbers which may be most easily illustrated by considering, for the moment, the action of the ordinary Strowger connector switch, in which the switch action directly follows the dial action.

This switch, as will be shown in the next chapter, serves 100 lines, its "bank" contacts being arranged in 10 horizontal rows of 10, as indicated in Fig. 6. The wiper arm of this switch may be brought into engagement with any one of these 100 contacts by two successive series of dial impulses, the first series stepping it *up* to the desired "tens" row and the second series stepping it *around* to the desired unit in that row. It is the dial that tells the switch what to do, and, in selecting line 95, for instance, it directs the switch first to take nine steps upward and then five steps around. Always two movements of the dial are required to select any number within the 100, the first pull corresponding to the tens digit and the second to the units. Obviously,

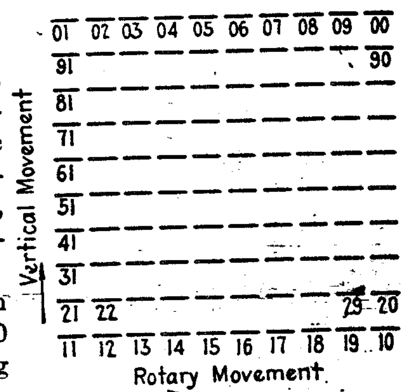


FIG. 6.—Numbering plan of Strowger switch.

therefore, the numbers of the contacts in each horizontal row or level must all begin with the same tens digit corresponding to the number of the level; and they must end with the units digits progressively from 1 through 9 to 0 in the direction of the rotary selecting movement. This results in the group of 100 contacts reached by the switch being numbered from 11 to 00, as shown in Fig. 6, instead of from 0 to 99 or from 1 to 100, as the numbers would ordinarily run. In the same way, for the "hundreds" and the "thousands" groups in a 10,000-line system, for instance, the groups would be numbered from 1 through 9 to 0 in each case. The lowest number in 10,000 would be 1111 and the highest 0000, the series thus including the entire 10,000 numbers.

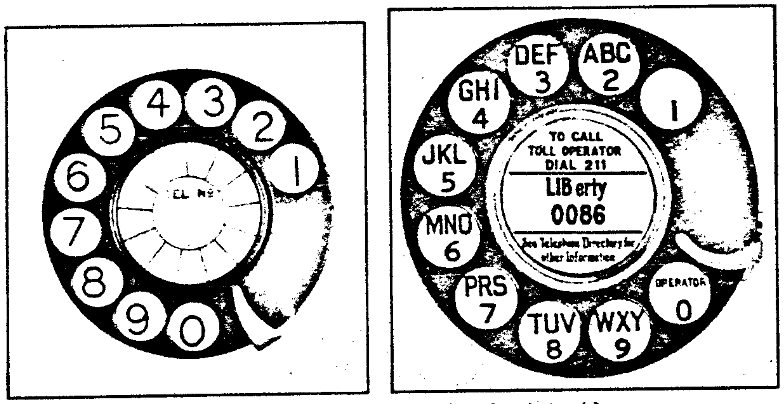


FIG. 7.—Dial faces—lettered and unlettered.

When a system does not require numbers of more than four or five digits, the finger holes of the dial need have only numeral marking, as in the Strowger dial face shown at the left of Fig. 7. Such marking usually suffices in a single-office exchange or in a multi-office exchange not requiring more than four or five digits. Even when the number of subscribers is so large as to require a number of central offices, it is possible, of course, to disregard office names and to designate all subscribers' lines by number only, as might be done by assigning a different "ten-thousands" group of numbers to each of the offices. This, in effect, is what is done in practice but, since it is easier for most people to remember a short number with an office name than a long number without the name, it has been found conducive to accurate service to retain office names as part of the directory

designations and to use the first one, two, or three letters of the office name as well as the switching numbers in dialing. This involves placing letters along with the digit numerals in the finger holes of the dial and giving the first few letters of each office name a corresponding numerical significance.

The right-hand cut of Fig. 7 shows a Bell System dial so marked. Each of the eight finger holes from 2 to 9, inclusive, contains three different letters. All the letters of the alphabet except *Q* and *Z* are thus included and they are arranged in alphabetical order. In this way, the letters *A*, *B*, and *C* are each given the same significance, as far as the dial is concerned, as the numeral 2, the letters *D*, *E*, and *F* as the numeral 3, and so on. The same effect is produced, therefore, whether the subscriber pulls the letter *A*, *B*, or *C* or the numeral 2. Likewise, if he pulls in the order mentioned *L-I-B*, it produces the same dial effect as the numerals 5-4-2. Taking this latter example, *L-I-B* as being the equivalent of 5-4-2, the directory listing of a subscriber in an office named "Liberty" might be LIBerty 0086 or it might be 542-0086, both requiring the same manipulation of the dial and both, therefore, producing the same effect on the central-office switches. In this case, the combined name and numeral would be the better one to adopt for directory purposes because the office name would automatically suggest to the subscriber the proper letters to pull to select the Liberty office.

Numbering Plans.—The form of numbering plan to be used in a particular case depends upon the special requirements and peculiarities of the dialing area, such as the telephone development, rate of growth, amount of traffic to suburban points, and the method of handling such traffic. The use of several types of numbering plans differing from each other even among areas of the same approximate telephonic size has resulted from such individual requirements.

The numbering plans described below are the most common types now in use. The number of offices for which these plans are designed is always based on some ultimate engineering period, estimated far enough into the future to avoid too frequent modifications of the numbering plan, which are always to be avoided if possible.

Areas Requiring from Two to Eight Office Codes.—In multi-office areas where eight office codes or less are required, a single-digit prefix is used to designate the called office. In the directory this digit is usually separated from the rest of the number by a hyphen, as for instance, 7-1234. The limitation of eight offices exists because the number 0 *as a preliminary digit* is reserved for reaching the operator, and the digit 1 cannot be distinguished from an accidental preliminary depression of the switchhook. Since neither of these can be used to designate central offices, the eight digits from two to nine, inclusive, remain for this purpose.

Areas Requiring from Nine to Sixty-four Office Codes.—It is generally felt that it is difficult for a subscriber to keep in mind more than five digits while he is dialing them. Therefore, when two or more office-code digits are required, the subscriber's dial is equipped with a number plate having both letters and numerals (Fig. 7, right). The reason for omitting the letters *Q* and *Z* is that it is not desired to crowd more than three letters in one finger

Caron Alcide r 4037 Claude......YO rk 1826-M
Caron Alex r 6732 Denormanvl.CA lumet 2597-J
Caron Alfred r 1814 St Jerome.FR ontenac 6919
Caron André r 5956 Jogues......FI tzroy 8238
Caron Mme Antoine r 1983 Kent.AM herst 1468
Caron Armand r 2013 Dandurand.CA lumet 8115-M
Caron Armand r 920 Decarie bl.WA lnut 6279-W
Caron Armand r 4242 Parthenais..AM herst 1402
Caron Art r 2287 Frontenac....CH errier 7094
Caron Art r 566 Vimont..........CL airval 3968
Caron Arthem r 416 Chmp de Mars.HA rbour 4696

Fig. 8.

Barnes Wm J 145 E 45.......LE xingtn 2-5227
Barnes Wm R 710 W End av...RI versde 9-3821
Barnes Wm S books 229 W 29.LA ckwana 4-1768
Barnes H N Co brkrs 33 Nassau. HI tchck 4-0600
Barnet Tag Co 126 W 13......CH elsea 3-3064
Barnett A 784 Franklin av.....PR ospct 9-2672
Barnett A L antiques 129 E 57 ..PL aza 3-1464
Barnewall H G 285 Longwood av.IN tervale 9-6393
Barney C E lwyr 15 Broad......HA novr 2-1080
Barney's Dairy 1063Flshng av.WI lliamsbrg 5-0082

Fig. 9.

Fig. 8.—Directory listing for areas requiring from 9 to 64 offices.
Fig. 9.—Directory listing for areas requiring more than 64 offices.

hole and they are the least frequently used of all the letters of the alphabet.

Office names are assigned to the different office units and the subscribers are instructed to dial the first two letters of the name, followed by the line number. Of course, as outlined above, the office names are so chosen that the first two letters of any office will always represent the proper numerical code for that office and, therefore, a code different from that of any other office. For the reasons given above, only the holes from two to nine can be used for office-code purposes.

In the telephone directory for such a system, the letters of the office code to be dialed by the subscribers are printed in bold-face type, as shown in Fig. 8.

The number of two-digit codes which can be built up from these letters is sixty-four. Although twenty-four letters are available, they do not, of course, represent twenty-four independent digits because the three letters in each finger hole have identical numerical significance.

This use of the letters which constitute the beginning of the office name provides a system much easier for the subscriber to use than numbers, or even arbitrary letters, would be. It also accords very well with the use of central-office names as in manual practice. The dial system, with such a numbering plan, can be introduced in a manual area with minor directory changes and, occasionally, the change of an office name which would conflict in dialed code with the name of another office.

Areas of More than Sixty-four Office Codes.—If more than sixty-four codes are required, three code digits must be dialed. In some cases, the practice has been to require the dialing of the first three letters of the office name followed by the numerical digits. Theoretically, the number of possible codes with this plan is 512, more than any dialing area has so far required. Practically, however, the number of usable three-letter codes is much smaller. One difficulty which limits the number is the selection or invention of office names which will utilize these codes and still be easy to spell, pronounce, and understand. As an instance of this, the five hole contains the three letters *J*, *K*, and *L*. The difficulty of finding a name having as its first three letters any combination of these is apparent and the code 555 is therefore useless. The result of this difficulty is to materially reduce the number of useful codes. This has led recently to the adoption, in the largest areas, of a plan in which the first two letters of the office name are dialed followed by a third numerical code digit. In the directory this digit is separated from the rest of the number by a hyphen. Directory listings utilizing such a numbering plan are shown in Fig. 9. In addition to facilitating the selection of office names this plan also permits 0 and 1 to be used as a third code digit, increasing the possible office codes to 640.

In some areas, where the number of codes required is only slightly greater than a two-digit code plan will serve, a practice of using some two- and some three-digit codes has been adopted. In this case, the first two letters of the office name are dialed as in two-digit areas, and the third code digit, when it is used, is printed and dialed as an auxiliary number preceding the line number. In the directory this digit is separated from the line number by a hyphen.

CHAPTER III

THE STROWGER STEP-BY-STEP SYSTEM[1]

Of the three general types of automatic or machine-switching systems, "step-by-step," "power-driven," and "all-relay," the former, also called the "Strowger system," will be treated in this chapter. It is extensively used by the Bell System and by independent companies in the United States and by both governments and telephone companies in many foreign countries.

Strowger Step-by-step Principle of Switching.—The Strowger principle of switching is the outgrowth of the fundamental idea of Almon B. Strowger conceived as early as 1889. The first exchanges embodying the step-by-step principle were installed at Michigan City and La Porte, Indiana, in the year 1895. Later notable early installations on a larger scale were those at Fall River, Massachusetts, in 1903, and Grand Rapids, Michigan, in 1904. The system has been developed as a whole by the engineers of the Automatic Electric Company and its predecessors, under the able leadership of Alexander E. Keith, T. G. Martin, and others, but, however, the fundamental principle of Strowger is still employed in the present-day system.

This method of switching employs as its basic equipment a switch with coordinated "up" and "around" movements. To the brush rod or "wiper shaft" is first given a vertical and then a rotary motion, both motions occurring in short rapidly recurring steps. Means are provided for holding the shaft in the intermediate and final positions, and for finally releasing and restoring it to its normal or "ready-for-use" position. While other functions must be performed by the switch, only those dealing with the above-mentioned features will be described at this time, the others being explained at appropriate times as the treatment of the system develops.

Vertical Movement.—The vertical, rotary, and release features will first be considered separately, then as combined in one structure. Figure 10 shows, in diagrammatic perspective,

[1] The photographs and in many cases the circuit diagram sketches that were used in preparing the illustrations of this chapter were furnished by courtesy of the Automatic Electric Company of Chicago.

the mechanical elements involved in the vertical movement of the wiper shaft, and an elementary operating circuit for causing the movement. The wiper shaft *WS* is mounted in fixed bearings at top and bottom (not shown), these permitting vertical and rotary motions of the shaft. The vertical magnet *VM*, mounted on the framework of the switch, has an armature pivoted at its rear end, to which is attached an arm, or finger, with a pawl at its front end. Adjacent to this pawl, but normally free from it, and forming a part of the wiper shaft, is a vertical ratchet cylinder, or hub, having circular grooves cut in it.

The key *A* in this and the immediately following figures is to be taken merely as a circuit-closing device responsive to

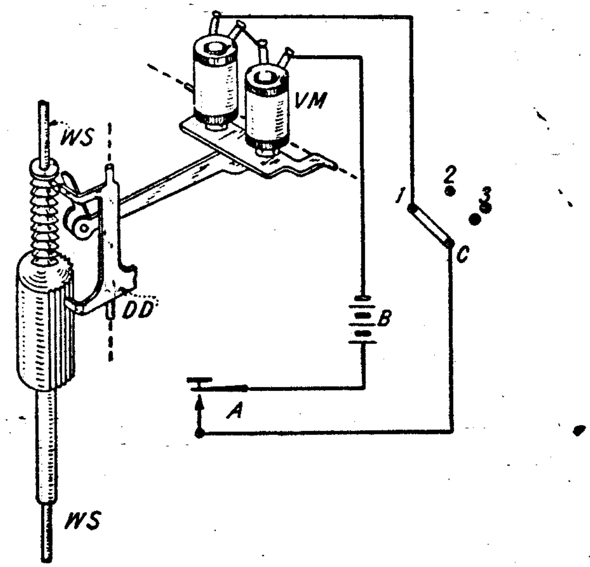


FIG. 10.—Vertical movement of Strowger switch.

the movements of the subscriber's dial. When it is pressed, with switch *C* in its first position, as shown, the magnet *VM* will attract its armature, causing the pawl to engage a tooth of the vertical hub and lift the shaft one step. A detent finger on the upper end of the "double dog" *DD* prevents the wiper shaft from dropping back when the magnet is de-energized. This double dog is normally held out of engagement with the ratchet hubs but, however, is released on the first movement of the vertical pawl, so as to engage the teeth of the vertical hub. It will, therefore, be evident that, each time the key *A* is pressed, the shaft *WS* will be moved upward one step and will be held in the raised position by means of the dog *DD*. The number of vertical steps will, of course, depend on the number of times the key *A* is pressed.

Rotary Movement.—Figure 11 shows the same shaft and double dog but a rotary magnet *RM* with associated armature, finger, and pawl is shown instead of the vertical magnet. The rotary magnet has been brought under control of the key *A* by moving the switch *C* into its second position. Mounted on the shaft immediately below the vertical hub is the rotary ratchet cylinder, or hub, with vertical grooves or teeth cut in its surface. In order that the rotary hub may always be

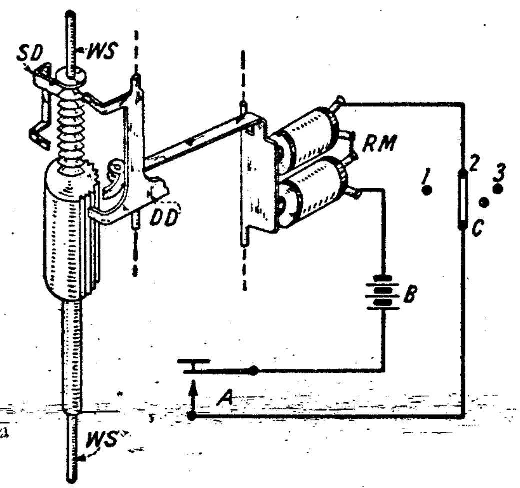


FIG. 11.—Rotary movement of Strowger switch.

in a position to be engaged by its pawl, its length is made at least equal to the length of the vertical travel. The operation is the same as already described for the vertical movement except that the shaft is turned instead of lifted, the lower end of the double dog holding the shaft in the proper rotary position each time the magnet *RM* is demagnetized.

In order to relieve the weight of the shaft from the double dog and to prevent an accidental vertical movement, a stationary dog *SD* is fixed to the frame work of the switch in such position as to lie in a vertical groove in the upper or vertical ratchet hub (Fig. 16). This had no part in the vertical operation, since before the shaft is rotated it permitted free vertical move-

ment, but when the first rotary movement took place it engaged one of the grooves of the vertical hub, thus preventing further vertical movement. The shaft is rotated to any desired position, depending upon the number of times the key *A* is pressed.

Release Action.—Figure 12 illustrates how the switch is released and restored to its normal position. It shows the same shaft, vertical and rotary hubs, double dog, and stationary dog as before, but the vertical and rotary magnets are omitted and a release magnet *RM* is shown instead. This release

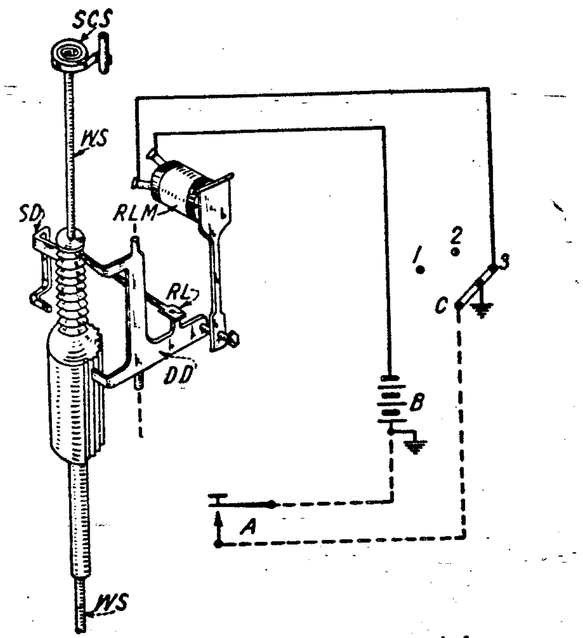


FIG. 12.—Release action of Strowger switch.

magnet is energized when its switch *C* is brought to its third position. The armature of the release magnet is pivoted at its upper end and has a projecting finger at the end of which is an adjustable stud which, when the magnet is operated, will press against an extension finger of the double dog *DD*. Immediately above the extension finger of the double dog is a release link *RL*, which can engage a pin extending upward from the extension finger. Also, at the top of the wiper shaft is shown a clock spring called the "shaft cup spring" *SCS*, one end of which is fastened to the shaft and the other bears against a fixed vertical rod. This spring and gravity furnish the forces to return the shaft to its normal position, when the double dog is removed from engagement with the vertical and rotary hubs.

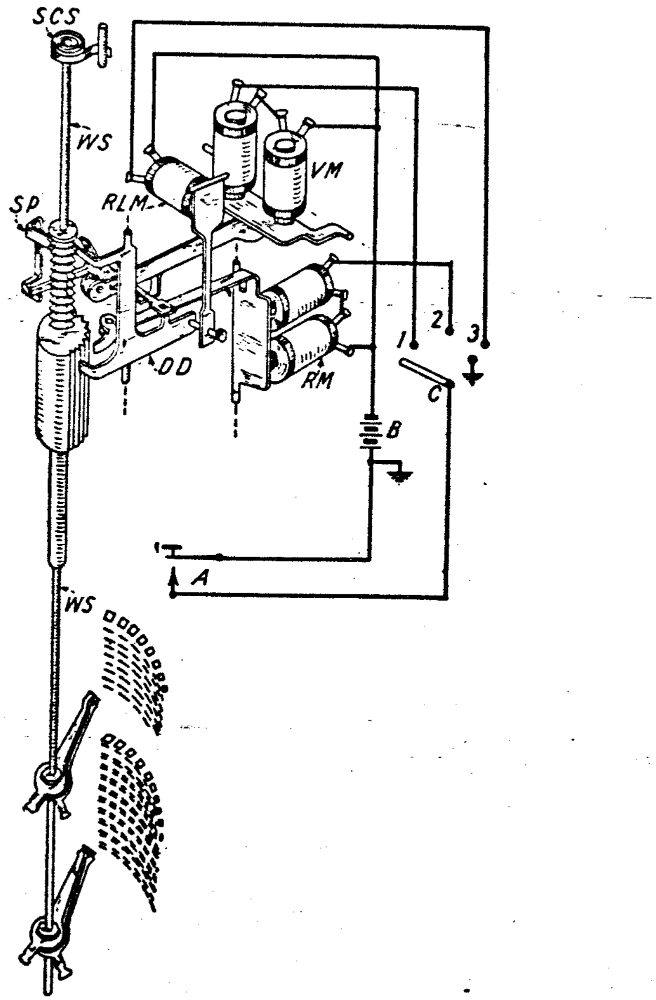


FIG. 13.—Vertical, rotary and release principles.

Since the release is performed independently of the dial, the manually operated key used in providing the stepping impulses may now be dispensed with. When the connection through the step-by-step switch is no longer desired, the switch *C* is moved to its third position, establishing a ground connection

which provides an operating circuit for the release magnet. As the release magnet attracts its armature, the adjustable stud presses against the extension finger of the dog *DD* and removes the dog from engagement with the vertical and rotary hubs. The shaft *WS* is then returned to its rotary starting position by means of the spring *SCS*, and during this return movement it is prevented from dropping through the agency of the stationary dog *SD*. When completely restored horizontally, the stationary dog is no longer effective, since it at that time rests in the vertical slot of the vertical hub, and the shaft is allowed to drop to the normal position by gravity. The release link *RL* is provided to hold the double dog in its disengaged position after the release magnet has been de-energized. The switch is now completely restored.

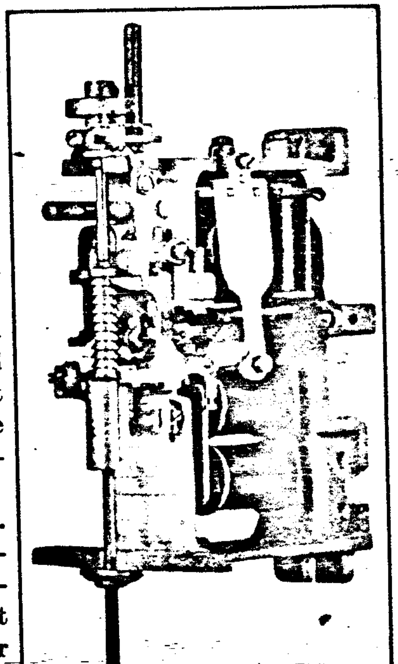


FIG. 14.—Strowger switch mechanism.

Complete Switch Mechanism. Figure 13 shows how the operations just described are all coordinated in one structure. It also shows the means used for keeping the pawl of the vertical magnet normally out of engagement with the vertical hub, and also the means for releasing the double dog from its disengaged position on the first step of the vertical magnet. In the lower portion of the drawing are also indicated the wiper brushes and bank contacts with which they are brought into engagement by the vertical and rotary movements of the shaft.

The foregoing drawings have been made in purely diagrammatic form to permit an easy understanding of the principles. Figure 14 is a view of an actual switch unit with the wipers and banks removed.

Control Circuit of Strowger Switch.—In the foregoing descriptions, the simplest forms of electric circuits were assumed in order to make clear the mechanical details. In actual practice the key *A* of Figs. 10 to 13, inclusive, is a relay controlled by the subscriber's dial, and the switch *C* consists of two relays and

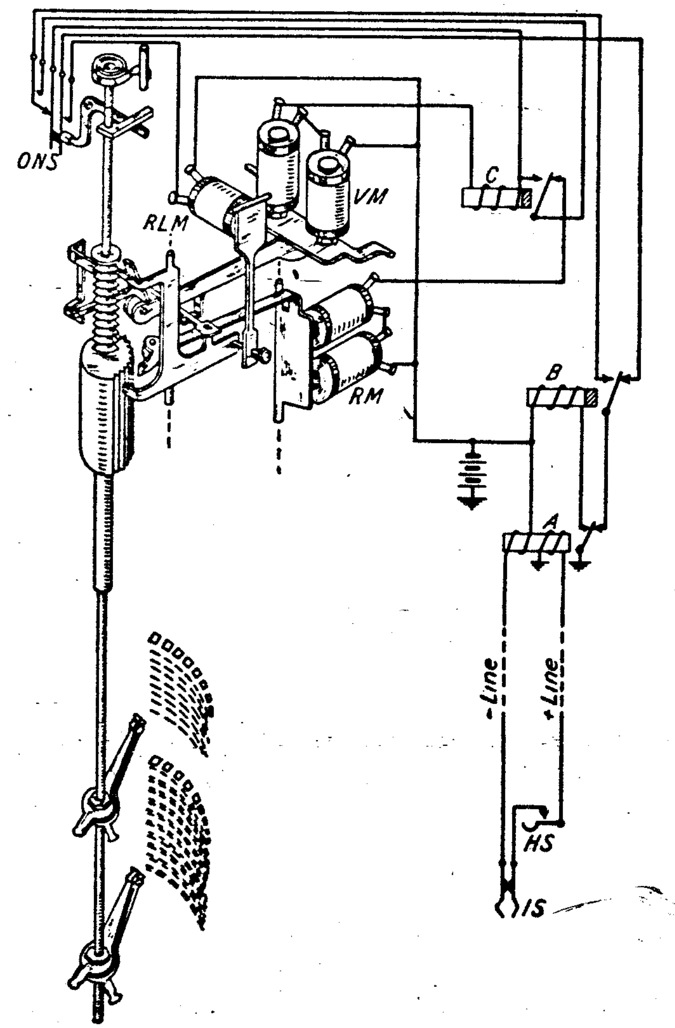


Fig. 15.—Control circuit of Strowger switch.

a switch. Figure 15 shows the electrical circuits and complete switch mechanism. The switch structure is the same as in Fig. 13, but with the addition of what is called the "off-normal switch" seen near the top of the wiper shaft, immediately

below the shaft cup spring. As the shaft takes its first vertical step upward, a finger fixed on it permits the end of a bell crank lever to rise and shift the position of the off-normal switch springs. As the shaft takes its final step downward in returning to its normal position, the reverse action takes place.

At the lower right of the drawing are shown the portions of the subscriber's instrument involved in the control of the switch circuits. Immediately above and connected to the subscriber's line circuit are the relays required, in connection with the off-normal switch, to perform the circuit changes previously described for key *A* and switch *C* of the preceding figures. On Fig. 15, *A* is a double-wound "line relay," *B* is called the "release relay," and *C* the "series relay." Both *B* and *C* are designed for slow release.

In the normal position, as shown, all of the electrical circuits are open at some point, and therefore all relays and magnets are in their de-energized positions. At the subscriber's instrument, with the telephone receiver on the hook switch, the circuit is open at the hook switch *HS*. When the receiver is removed, the hook switch closes a circuit over the line and through the impulse springs *IS* of the dial. This energizes line relay *A*, both windings of which produce magnetic flux in the same direction. Relay *A*, through its grounded armature spring, causes the operation of relay *B*. The pulling up of *A* also removes ground from the armature spring of relay *B* and thus holds open the circuits of all the other relays and magnets associated with the switch.

The dial contacts *IS* are normally closed but when the dial is operated they open and close in quick succession a number of times, corresponding to the numerical value of the digit dialed. It will, therefore, be seen that the armature of relay *A* will be released and pulled up each time the circuit is opened and closed by the dial. Since relay *B* is of the slow-release type, it will not release its armature during the pulsing period, that is, during the series of break-impulses transmitted.

When relays *A* and *B* are first operated before a series of dialing impulses begins, a circuit is prepared for the operation of the vertical magnet *VM*, and thereafter this magnet will operate each time the armature of relay *A* falls back as the circuit is broken at *IS*. This circuit may be traced as follows: starting with the grounded armature spring of relay *A* through its break contact, through armature spring and make contact of relay *B*, springs of the switch *ONS*, thence to the winding of relay *C*, magnet *VM* and to battery. As magnet *VM* operates, it will lift the shaft of the switch a number of steps corresponding to the digit dialed. On the first break-impulse, or the first operation of magnet *VM*, the original circuit through which *VM* and *C* were operated, is broken by the action of the off-normal switch *ONS*, but an alternate path is established for the second and succeeding vertical impulses by the pulling up of relay *C*. Owing to its slow-release action, this relay will remain energized as long as the dialing impulses continue and thereby maintain a circuit for the successive operations of the magnet *VM*. While relay *C* is slow to release, the delay is not sufficient to prevent its release during the pause before the next series of impulses corresponding to the next digit.

During this interval, and after relay *C* has restored, a circuit is prepared for the subsequent operation of the rotary magnet. It will be recalled that the circuit by which relay *C* was operated has been opened at the switch *ONS*, so that this relay cannot be again energized. A circuit for the operation of the rotary magnet *RM* is therefore established through its back contact. The second digit is now dialed and magnet *RM* will follow the break-impulses of the subscriber's dial. The wipers, through the vertical and rotary operations of the switch, have now been placed on the desired contacts in the switch bank. The switch is maintained in this position until the connection is no longer required.

When the telephone receiver is replaced on the hook switch, contact *HS* will be broken and thereby open the line circuit and release relays *A* and *B*. When the shaft was raised from its normal position and switch *ONS* operated, a circuit was prepared for the release magnet *RM*, but this circuit meanwhile has been held open at the break contact of relay *B*. On the release of both relays *A* and *B*, this circuit will be closed to ground, thereby operating the release magnet *RM* and permitting the switch shaft to return to its normal position. Just before it has completed its final vertical movement downward, the switch *ONS* will again be operated and the circuit of magnet *RM* opened. The switch mechanism has now been completely restored to an idle or ready-for-use position.

In the foregoing description of the principles of the Strowger switch, it will be observed that provision was made for connections to points appearing in an individual bank only, and, as each bank has a capacity of 100 lines, these principles might be assumed to apply to a telephone system having a capacity of not more than 100 lines. However, later in this chapter it will be shown how this switch may be used in consecutive steps in larger step-by-step systems. In certain applications of the Strowger principle, as for example in selector switches, the rotary magnet is provided with an interrupter means which breaks its circuit when operated, and causes the switch to rotate automatically under the control of a test circuit, instead of being positively driven by break-impulses from the dial.

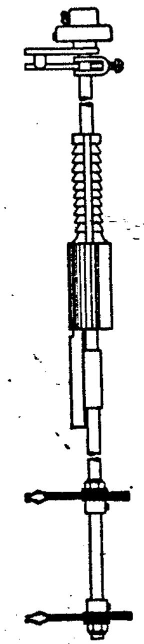


Fig. 16.—Shaft and wiper assembly.

Shaft and Wiper Assembly.—The complete shaft and wiper assembly is shown in Fig. 16. The shaft cup spring will be seen at the top; below is the vertical hub, with the vertical slot for the stationary dog; next, the rotary hub; and, at the bottom, the wipers for making connection with the bank contacts. Two sets of wipers are shown, the functions of which will be more specifically described later.

Contact Banks.—Figure 17 shows, at the left, a complete bank, with the separate horizontal rows of contacts clamped between two heavy metal plates. These plates have holes near each end for the purpose of clamping on vertical rods, which project downward from the framework of the switch. At the right is shown one of the "levels" of bank contacts. The radial pieces are the metallic contacts, and the dark and cloth-like portions the insulating materials. The ends of the contact pieces which project from the inside of the cylindrical surface are the portions over which the wipers slide in their rotary movements, and the outer projecting ends are for the attachment of wires. The contact pieces of each pair are inserted on opposite sides of the dark insulating material, their soldering lugs being staggered to provide ample clearance for the connection of wires.

In order to permit simultaneous connections to a given group of lines or trunks, it is, of course, necessary that a number of switches shall have access to the same group. This is provided for by "multipling" or connecting together the corresponding contacts in the banks of a group of switches. The method of doing this is shown in Fig. 18.

The foregoing switches, employing Strowger's original up-and-around principle, may be classified as "numerical" switches

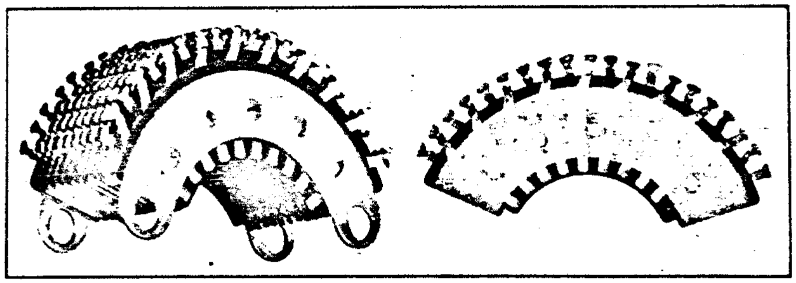


FIG. 17.—Complete bank and single level of contacts.

since they are capable of performing a numerical selection. They are, either directly or indirectly, responsive to the impulses transmitted by the subscriber's dial in making numerical selections. Another class of switches, to be described next, may be called "non-numerical" because they "pay no attention" to numbers but perform their selections wholly on some other

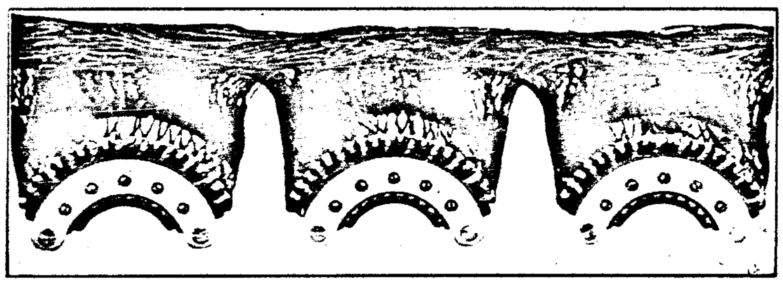


FIG. 18.—Multiple wiring of contact banks.

basis—usually according to whether the terminals to be connected with are idle or busy. Line switches of various types fall within this classification.

Plunger Line-switch Principle.—In all earlier Strowger installations, each subscriber's line had its own individual switch of the general type just described. This involved a wasteful use of rather expensive apparatus since the average

subscriber uses the telephone for making calls only a short time each day, his switch remaining idle the rest of the time. To eliminate this uneconomical use of switches, a principle has been evolved which permits the use of a much less expensive non-numerical "line switch" for each line and requires only enough numerical switches to carry the busy-hour traffic.

The plunger type of line switch, often called the "Keith" line switch from its inventor, was the one at first developed for concentrating the traffic arising on a larger number of lines into a smaller group of numerical switches and is still largely used in the Strowger system. The diagram of Fig. 19 will aid in understanding its principle. In this, each of the larger group of telephone lines is assumed to terminate in relatively simple and inexpensive apparatus, and each of the smaller group of trunks in Strowger type switches or selectors. Now if it is assumed that, at any intersection, these horizontal and vertical lines may be connected together electrically, then any one of the telephone lines may be connected to any trunk, thereby making each one of the numerical switches available to a number of lines. If the large dots are assumed to represent such electrical connections, it will be seen that telephone line 1 has been connected to trunk 3, line 2 to trunk 1, and line 4 to trunk 2. The number of numerical switches needed would then be only that required for the simultaneous connections desired by the subscribers of the group. In actual practice, it has been found that in many cases only ten numerical switches are required to meet the needs of 100 subscribers' lines.

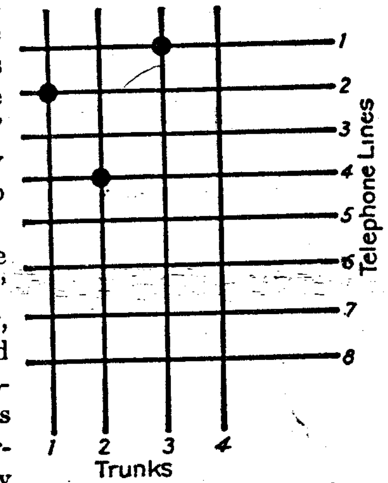


FIG. 19.—Fundamental plan of plunger line switch.

In somewhat more detail the principle of the plunger line switch is shown in Fig. 20. In this, the telephone lines and trunks are arranged in the same manner as in Fig. 19, but in addition a means of connecting them is illustrated. Each telephone line has spring contacts adjacent to corresponding contacts on each of the trunks. With each telephone line is associated a line-switch operating mechanism as shown at the right of the drawing. Each line switch has a pull-down coil *PDC*, a plunger arm, and a plunger, the pull-down coil being controlled by a relay in the telephone line. When a connection is desired, the plunger arm is attracted by the pull-down coil, thereby moving the plunger towards the left. Now assume that the line-switch plungers may be moved successively adjacent to each of the trunk lines, so that, when operated, the plunger will cause the contacts of the line to engage the trunk contacts in the position which the line-switch plunger has taken. By this means, a telephone line may be extended to a trunk and its connected numerical switch. When a line switch has been plunged for a connection, it remains in that position while in use, and all the others are moved adjacent to the next available trunk. This method of trunk selection before an actual demand for use is called "pre-selecting" and is frequently used where minimum delays in extending connections are required.

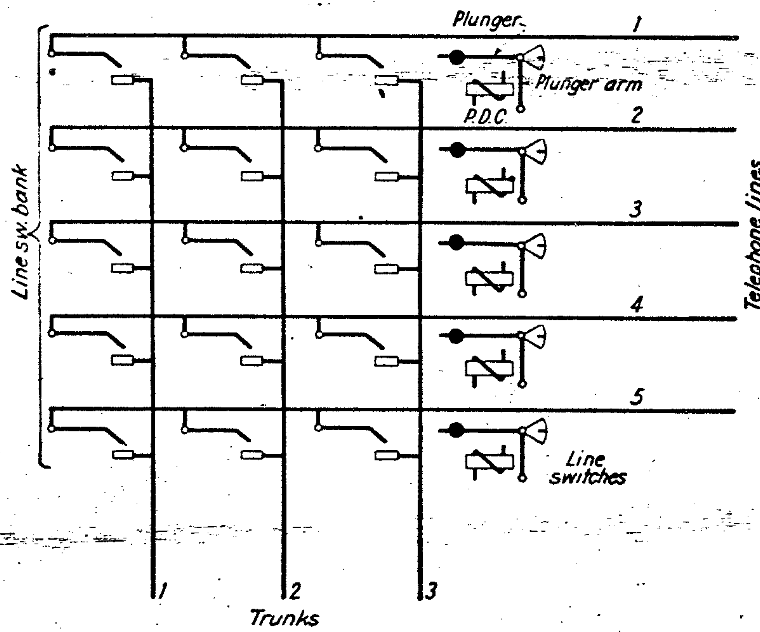


Fig. 20.—Schematic diagram of a group of plunger line switches.

In actual practice, instead of moving the line switches from trunk to trunk, the line and trunk contacts are arranged in arcs and the plungers only are rotated before the contacts. This arrangement is shown in Fig. 21, in which the same relation between telephone lines and trunks as previously described will be recognized. In this drawing it will be noted that the plungers, when not in use, are under the control of a rotatable plunger guide shaft *S*, the bearing of which (*B* & *B'*) are in line with the centers about which the plungers rotate. It will be noted that line 3 has been connected to trunk 3 through line switch 3, and the plunger moved out of control of the guide shaft. The plungers of line switches 1, 2, and 4 have been set before the contacts of trunk 4 in a position to permit the connection of line 1, 2, or 4 to that trunk. While only 4 telephone lines are shown in this drawing, in practice from 25 to

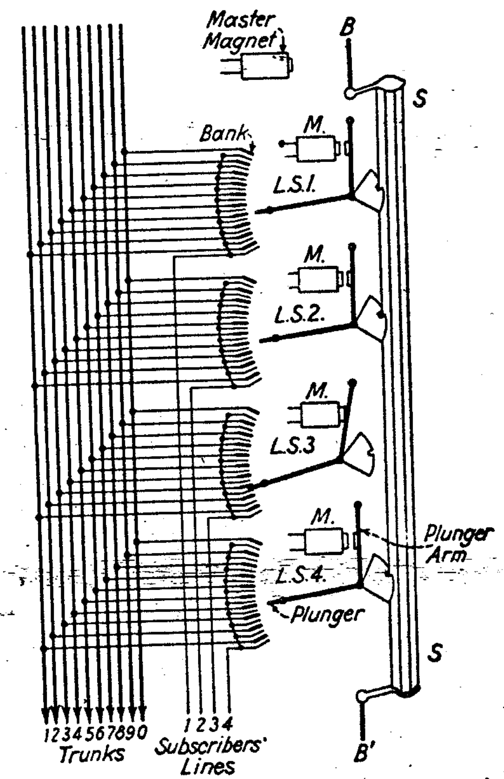


Fig. 21.—Principle of operation of plunger line switch.

100 such lines may be arranged to have access to a group of ten trunks.

Fan-tail Type.—Figure 22 shows a "fan-tail" type plunger line switch with its associated bank. At the right is the slow-acting line relay and near the center is the double-wound line-switch magnet. At the left will be seen the plunger, plunger arm, and associated contact bank. At the left of the magnet is the plunger-restoring spring and at the right the cut-off springs, which are operated either by the bridge cut-off armature shown just below the magnet coil or by the plunger armature shown resting against the back stop. When only the bridge cut-off winding of the magnet is energized, the cut-off springs are operated and not the plunger, but, when the pull-down

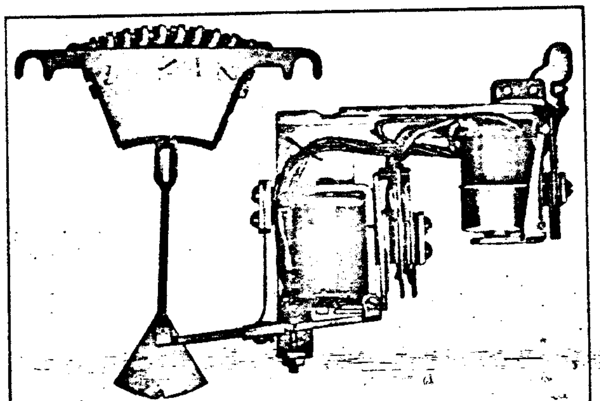


FIG. 22.—Fan-tail type of plunger line switch with contact bank.

winding of the magnet is energized, both the plunger and cut-off springs are operated. However, when the magnet has once been energized by the pull-down coil, both the plunger and cut-off springs will be held in an operated position by the bridge cut-off winding only. The purpose of this will be made clear in connection with the circuit operation. The notched rear end of the plunger, for holding the plunger in engagement with the guide shaft, as described in connection with Fig. 21, will be seen at the lower left of the photograph. The arrangement of the bank contacts will be understood from the description of the circuit diagrams.

The circuit diagram of the line switch and of the other apparatus directly associated with it is shown in Fig. 23. A sub-

scriber's telephone circuit is at the left, and, since line switches are non-numerical, the station dial has been omitted. In the center of the drawing is the circuit of the line switch proper with a portion of the master-switch circuit just below. At the right of the drawing is a portion of the circuit of a numerical switch, in which *A* and *B* relays are the ones previously described in connection with the Strowger switch (Fig. 15). At the top

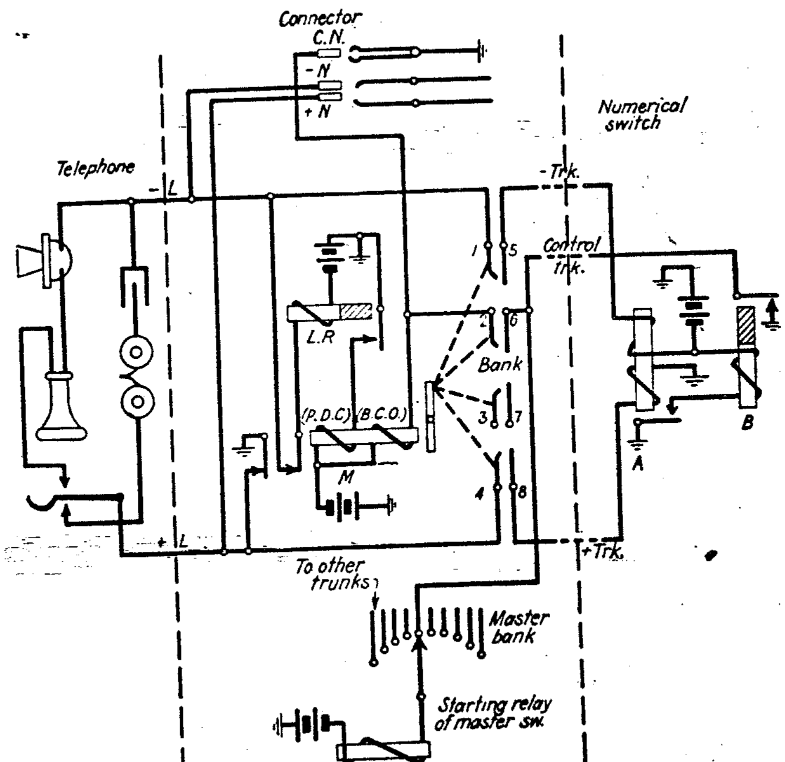


FIG. 23.—Circuit of fan-tail type of plunger line switch.

center are shown the wipers and bank contacts only of a "connector," this term being applied to the numerical switch which makes connection with the subscriber's line when it is called. These connector contacts correspond to a multiple jack of the subscriber's line, in manual practice, and provision is made through them to guard the line against intrusion when in use. In the center portion of the drawing presenting the line switch proper, the apparatus parts will be recognized as those already described in Fig. 22, except that the plunger and plunger arm are here represented by four dotted lines in order to simplify the circuit diagram. It is to be understood that, when the plunger is operated, the bank contacts 1-5, 2-6, etc., will be closed.

Lifting the substation receiver closes the line circuit energizing the line relay *LR*. The operation of this relay closes a contact to ground, which completes a circuit through the pull-down coil *PDC* of magnet *M*, thus causing the plunger to move and close the bank contacts. The operation of magnet *M* will also open the circuit of relay *LR*, but, since this relay is of the slow-release type, its armature will hold the circuit of winding *PDC* closed for a slightly longer period. The line circuit is now extended through the line-switch bank to a numerical switch in which the relay *A* will operate immediately and cause the operation of relay *B*. Relay *B* places ground on the control trunk and through the line-switch bank contacts, energizing the *BCO* winding, which maintains the plunger in its operated position. It also places ground on the control-normal *CN* contact of the connector bank. Relay *LR* of the line switch is now no longer needed to hold magnet *M* in an operated position, so that no effect is produced when its delayed release occurs. By means of the ground on *CN* the subscriber's line is protected from intrusion through the connectors, being made "busy" to all incoming calls. The ground placed on the control trunk by relay *B* is also extended to a contact of the master-switch bank, which operates the starting relay of the master switch and causes this switch to move the plungers of all other idle line switches, associated with the group, to the next free trunk as will be described later.

The line has now been extended through to a numerical switch and the impulses from the dial may be sent, as previously described in connection with the principles of the Strowger switch. The line calling has been protected against interference by others desiring to connect with it, and the master switch has made another trunk available for the use of the other subscribers in the group. It will also be noted that all line-switch apparatus has been disconnected from the line wires.

When the connection is no longer desired and the calling subscriber hangs up, relay *B* will release and thereby cause the restoration of the line switch to a normal ready-for-use condition.

On an incoming call to the subscriber's line, the line switch must be prevented from operating, since normally it would attempt to appropriate a trunk to a numerical switch when the called subscriber answers. This is accomplished through the control-normal *CN* contact and wiper of the connector. When a connector has been selected for use, ground is placed on its control normal *CN*, which remains until the circuit is disconnected, thus guarding the connection from interference by others. This ground is extended through the *BCO* winding of magnet *M* to battery, causing the bridge cut-off armature to operate and open the cut-off springs at the left of magnet *M* and thereby disconnect the line-switch relay *LR* from the subscriber's line. The *BCO* winding has only sufficient power to operate the cut-off armature and therefore the line-switch plunger will not be operated to connect a numerical switch. Figure 22 shows one type of design which provides for the operation as described. The bridge cut-off armature is light and has a short air gap, whereas the plunger armature is heavier, has a longer air gap, and must be operated against the force of the restoring spring. The operation of the bridge cut-off armature, in addition to disconnecting relay *LR*, also removes the ground connection from the positive line; thus the subscriber's line is cleared of bridges and attachments at the line switch.

Master Switch.—In the foregoing description the master switch has been referred to as the means by which the idle line-switch plungers are maintained opposite an idle trunk. Figure 24 shows the mechanical construction of one type of master switch, and Fig. 25 its operating circuits. With reference to Fig. 21, it will be recalled that the plunger guide shaft *S* controls the position of the plungers and that the position of the guide shaft is controlled through the means of the master switch. Therefore, it is obvious that the principal function of the master switch is to provide and control the oscillatory movement of the guide shaft. The power for this movement is furnished by means of a U-shape spring, which, when allowed to act, will rotate the guide shaft in a counter-clockwise direction. When the end of its travel is reached, a solenoid magnet will restore the guide shaft to the starting position. The movement, in a counter-clockwise direction, is controlled by the condition (idle or busy) of the trunks in the corresponding positions. In practice, the trunks are numbered in a clockwise manner, but, since the numbering scheme is purely arbitrary, it will be disregarded in the following description.

In Fig. 25, the portion above the dash line will be recognized as the circuit of the line switch described in connection with Fig. 23 except that the battery lead to the *PDC* windings, marked "open main," is now carried through the double contacts of the open-main relay of the master switch. The portion of the drawing below the dash line is the circuit of the master switch. The master-switch bank at the right has ten contacts corresponding with the vertical positions of the ten trunks in

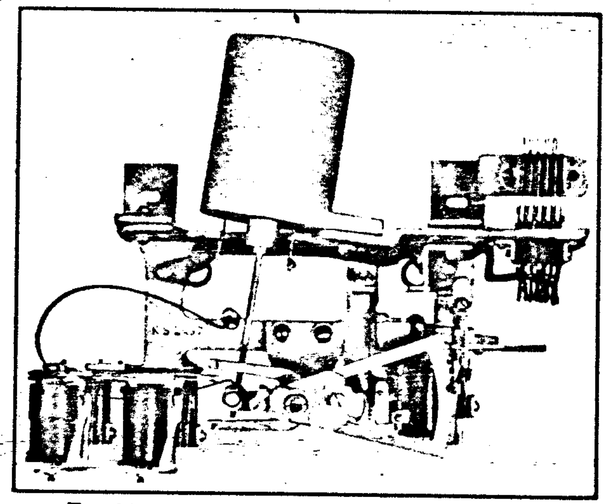


FIG. 24.—Master switch for plunger line switches.

the line-switch bank, as shown in Fig. 21. It will be remembered that the line switch is of the pre-selection type and therefore, when a trunk is connected with at a line switch, all idle line switches are immediately lined up before the next free trunk. Through the means of the master-switch bank this pre-selection is accomplished.

When a line has been connected to a trunk through a line switch, release relay *B* of the numerical switch is operated and places ground on the control trunk. This ground connection completes a circuit through the master-switch bank and the winding of the "start" relay, causing the start relay to operate and through its contact to complete a circuit from battery at the winding of the locking magnet to ground, through the super-

visory relay. The "locking" magnet is operated and thereby removes the lock lever from the engaged notch of the sector, or locking segment. This sector has ten notches corresponding with the ten contacts of the master-switch bank and, when it moves, the contact arm, or wiper, of the master-switch bank is

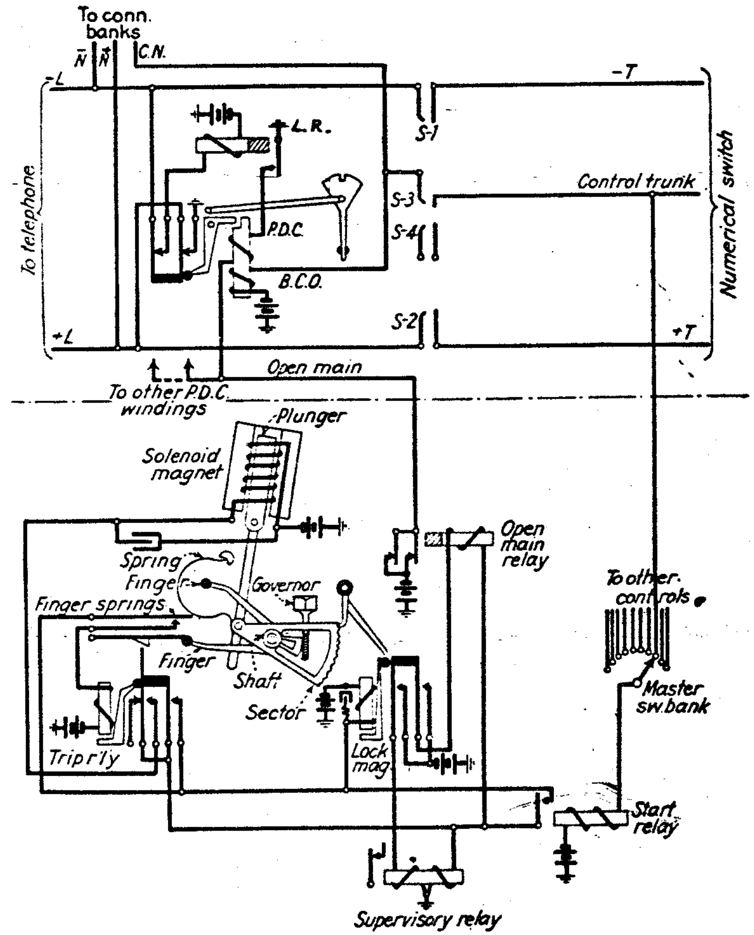


FIG. 25.—Circuit of master switch for plunger line switches.

also moved. If the next trunk in the group is not in use, no ground will be found on the corresponding contact of the master-switch bank and the start relay will be released and in so doing will open the circuit of the locking magnet, which in turn will permit the lock lever to drop back into the next notch of the sector and arrest further movement of the plunger guide shaft. If the next trunk had been busy in some other connection, the start relay would have remained operated and allowed the guide shaft to move until a free trunk, or one without ground on the release trunk, was found.

As previously stated, the sector secures its motive power from a U spring, which bears on a rear extension of the sector, the speed of motion being controlled by a governor. Provision therefore must be made for the restoration of the guide shaft when it has reached the last trunk in the group. This is accomplished by a solenoid magnet which returns the sector against the force exerted by the U spring. At the rear of, and forming extensions to, the sector are two fingers and between these, but normally out of contact, are three springs, called the "finger springs," whose function is to control the circuits for the restoration of the sector. The two upper finger springs are so placed that, when the sector has been rotated to the position of the last trunk in the group, any further movement of the sector will cause them to make contact. Therefore, when the last trunk has been selected for use, the sector will continue to rotate in the "hunting" direction but in so doing brings these finger springs together. This contact brings about the operation of the solenoid magnet. First, a circuit is closed, from battery at the winding of the trip relay, through the now closed finger-spring contacts, contacts of the trip relay and winding of the supervisory relay to ground. The trip relay operates and establishes a circuit for the operation of the solenoid magnet, from battery at the winding of the solenoid, through contacts of the trip relay, and winding of supervisory relay to ground. The trip relay also operates the locking magnet, which removes the lock lever from engagement with the sector during the restoration. Just after the reverse movement of the sector is started, the sector finger moves from engagement with the finger springs and the circuit of the trip relay is broken, but, however, provision is made to hold the springs of the trip relay in an operated position and thereby prevent the stopping of the sector before being fully restored. This is accomplished by an extension spring in the spring group of the trip relay, which engages a latch on the third finger spring. The contact springs of the trip relay are thus held in an operated position until the sector has been fully restored and the latch has been released by the lower finger of the sector. The circuit of the solenoid magnet will then be broken at the spring contacts of the trip relay, and the lock magnet will be released, provided the first trunk of the group is idle. If this trunk is engaged, the master switch will proceed, through the agency of the start relay, to "hunt" for the next idle trunk in the manner previously described.

During the hunting and restoring periods the line switches must be prevented from operating, since at such times the plungers are not properly placed before the contacts of an idle trunk. This inoperative condition of the plungers is brought about through the "open main" which supplies the battery for the operation of the *PDC* windings. Associated with each master switch and operated simultaneously with the locking magnet is an open-main relay, which, when operated, holds the battery circuits of the *PDC* windings of all line switches open, thereby preventing their operation during the time the guide shaft is in motion.

The above described line switch is known as the "fan-tail" or "pick-up" type owing to the method of operating and the design of the rear end of the plunger. The fan-shaped rear end of the plunger is notched in the center, and normally this notch engages the spline of the guide shaft, which moves the plunger from one trunk position to another, as previously described. When a plunger has been released after use, it will not be aligned with the other plungers until the guide shaft again passes the trunk position at which it was originally engaged, and the notch is permitted to register with the spline. From this explanation it will be obvious that, if a subscriber makes another call before his line-switch plunger has been again placed under the control of the guide shaft, the same trunk, as previously used, will still be available.

Self-aligning Type.—Another form of plunger line switch, which has superseded the fan-tail type, is known as the *self-aligning* type and, while its fundamental principle of operation is the same as for the fan-tail type, some of the details of operation are different. The principal point of difference appears in the method of aligning the plungers before an idle trunk in providing for the pre-selection feature. As previously stated, when a fan-tail plunger is freed after use, it is not placed under the control of the guide shaft until the notch in the fan-tail again registers with the spline of the guide shaft. In the self-aligning type, a released plunger is immediately placed under the control of the guide shaft and aligned with all the other idle plungers in the group. Figure 26 shows one design of the self-aligning plunger and guide shaft and Fig. 27 shows a complete switch. The rear end of the plunger is considerably shortened and in place of the notch is substituted a stop which projects at right angles with the body of the plunger. There is added a pair of scissor-shaped arms, each of which is free to move independently about its pivot on the plunger arm, and which are normally held in a closed position by a coil spring at the front end. At the rear end, these arms bear against the spline of the guide shaft and are held in alignment by the stop at the rear end of the plunger. When a line-switch plunger has been operated (position shown in Fig. 26), the complete member is moved forward by the plunger arm but, however,

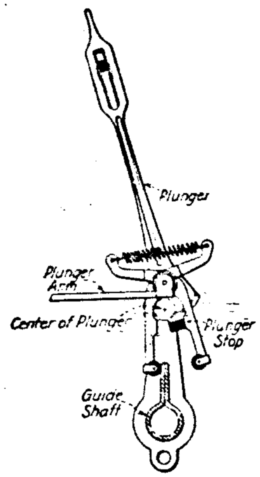


Fig. 26.—Plunger of self-aligning type of plunger line switch.

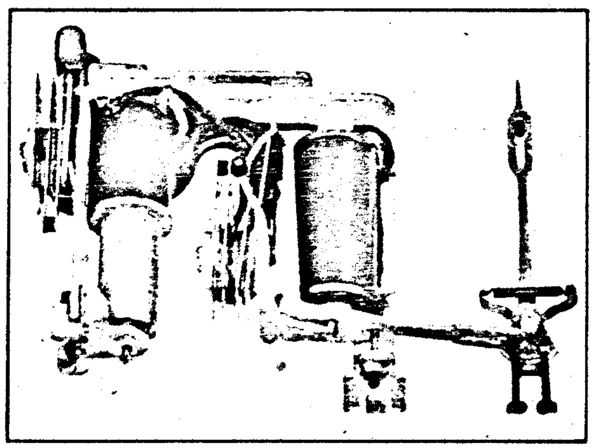


Fig. 27.—Self-aligning type of plunger line switch.

the rear ends of the aligning arms do not move forward a sufficient distance to become disengaged from the spline of the guide shaft. When the guide shaft moves, after a plunger has

been selected for use, one of the arms bears against the spline and the other against the stop on the plunger. This provides a flexibility which permits the guide shaft to oscillate through its arc of travel without disturbing the plungers already in use. As soon as a plunger is released, the coil spring, acting through the arms against the stop and spline, will immediately realign it with all the other disengaged plungers then under the control of the guide shaft. The view of Fig. 27 shows a plunger with

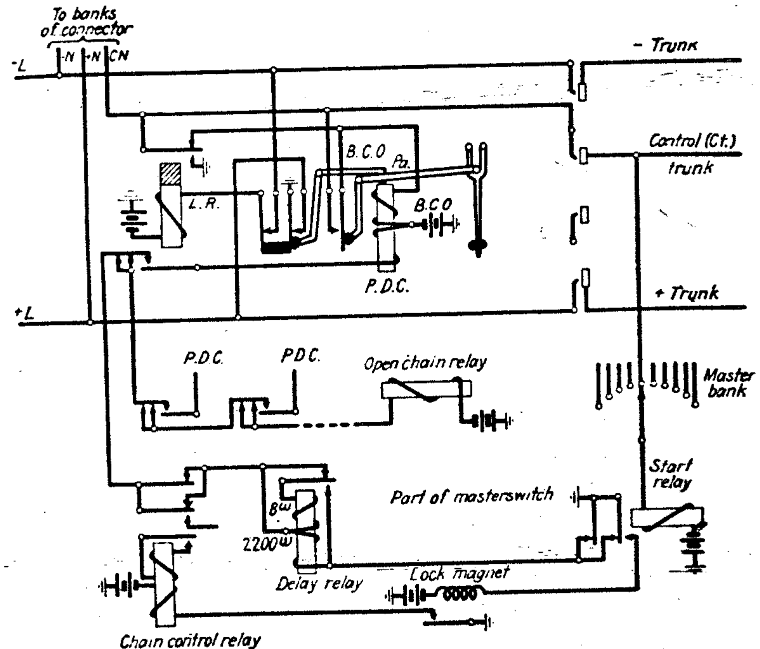


Fig. 28.—Circuit of self-aligning type of plunger line switch.

both aligning arms resting against the stop. The design of the armatures of the magnet is somewhat different from that previously described for the fan-tail type, but their operation is the same, except that the plunger armature operates a set of contact springs not required in the fan-tail type.

In connection with the self-aligning feature, several modifications have been made in the principle of the circuit of the line-switch unit to improve its operation. These modifications prevent two line switches from ever operating simultaneously and permit the line switches to pass over open-circuited trunks.

Figure 28 is a diagram of the circuit used with the self-aligning type, except that the operating parts of the master switch have been omitted, since they are the same as already described in connection with Fig. 25. At the top of the drawing will be recognized the circuit of a line switch, but differing in some respects from that already shown in Fig. 23. An additional contact has been added to the line relay *LR*, which places ground on the control normal *CN* as soon as relay *LR* operates, instead of after the operation of relay *B* of the numerical switch. This has been necessitated because a slight delay has been imposed on the operation of the plunger. The line relay also has an additional set of contacts at which the *PDC* winding of the line switch magnet is normally held open. The other normally closed contacts of this set constitute a series, or chain, circuit through all the *LR* relay contacts of the group and the winding of the open-chain relay to battery, the other end of the circuit being through contacts of the chain-control relay, 2,200-ohm winding of the delay relay and to ground through contacts of the start relay. This is a normally closed circuit, which operates the open-chain relay but does not permit the operation of the delay relay. It will be noted that all of the line-relay contacts in the chain circuit are of the double-contact type to insure against faulty contact. The open-chain relay, however, acts as a supervisory relay and, when released, operates a signal, after a predetermined delay, if any of the relay contacts fail. When the chain circuit is broken, by the operation of any line relay, the open-chain relay is released, and battery is applied to the grounded end of the chain circuit through the *PDC* winding of the line-switch magnet. The *PDC* winding, when in series with the 2,200-ohm winding of the delay relay, cannot attract the plunger, but the delay relay will start to operate, only slowly, owing to the effect of the short-circuited 8-ohm winding. When the delay relay has finally fully operated, the 8-ohm winding is placed in multiple with the 2,200-ohm winding. This relay will remain operated, and the *PDC* winding, owing to the reduction of the resistance of the winding of the delay relay, will operate the plunger armature and through its plunger close the contacts between the trunk and line conductors at the line-switch bank, causing the *A* and *B* relays in the numerical switch (not shown) to operate. The *B* relay places ground on the control trunk *CT*. This ground completes a circuit for the *BCO* winding

of the line-switch magnet through closed contacts of the plunger armature *PA*. This circuit will operate the *BCO* armature and hold the plunger armature in an operated position until the ground is removed at the numerical switches. The armature of the slow-release line relay *LR* may safely restore when the ground has been placed on the control normal *CN* by the *B* relay of the numerical switch. The line relay *LR* was disconnected by the operation of the *BCO* armature, as previously described for the fan-tail type. The release of the line relay restores the chain circuit to its normal condition. The final release of the line switch, when the connection is no longer wanted, is the same as previously described.

The master-switch operating circuit is similar to that described for the fan-tail type, except that the start relay is operated from ground at the line relay of the line switch instead of the control trunk, and the plungers of line switches are prevented from operating during the hunting period by means of the chain-control relay instead of the open-chain relay.

The self-aligning type has certain advantages over the fan-tail line switch, in that the chain circuit and delay features prevent "double connections," or two plungers operating at the same time. The delay features also prevent the selection of a busy trunk on a recall, which might occur if the plunger was allowed to operate before being properly aligned with the other idle ones of the group. The self-aligning feature provides for a more efficient use of the trunks in a group and eliminates the unsuccessful attempts to call which might occur, if a calling subscriber was repeatedly connected to a trunk which is in trouble (open).

Line-switch Unit.—Figure 29 shows the relative positions in which the master switch and line switches are actually mounted in order to function as just described. Near the top of this cut will be recognized the master switch, placed in a horizontal position, with the shaft of the sector connected to the guide shaft, at the point about which it oscillates. Immediately below is the vertical plunger guide shaft with the line-switch numbers marked on it. Just below the master switch will be seen a portion of two divisions of line switches, each switch being mounted in a horizontal position. Back of the guide shaft are the line-switch banks and associated plungers. At the extreme right and left will be seen the line-switch line relays and, between them and the guide shaft, the line-switch magnets. At the extreme top is the lower end of another guide shaft which is associated with the two upper divisions of line switches (not shown).

While only one application of the plunger line-switch principle has been dealt with in the above descriptions, other uses will be explained in a later part of this chapter.

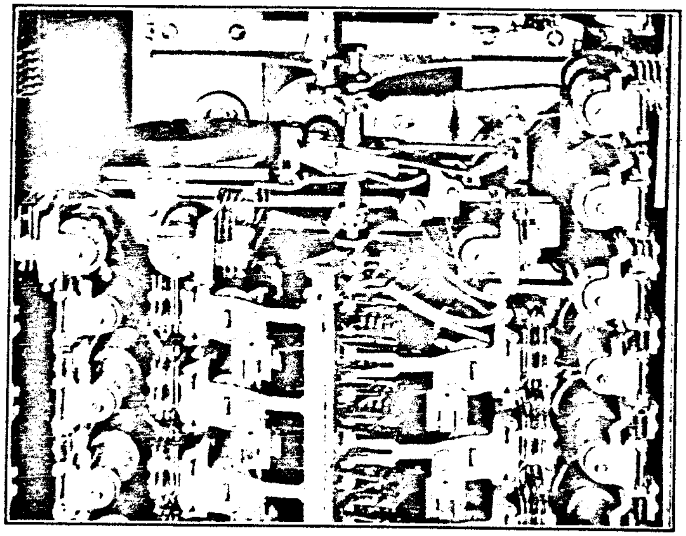


FIG. 29.—Portion of plunger line-switch board.

Rotary Line-switch Principle.—Another principle utilized in Strowger step-by-step systems is that embodied in the *rotary line switch*. This is designed for either eleven or twenty-five points, or sets of contacts. Two types of operation are provided for: "homing" or "non-homing"—that is, their wipers are either restored to a normal position after use or remain in the position in which last used. These different modes of operating are accomplished mainly through the circuit arrangements with practically no noticeable difference in the appearance of the switch mechanisms. In fact, some of the types may be used for either method of operation. The rotary switch differs from the plunger type, previously described, in that no common mechanism is employed, each switch unit being a complete operating device within itself. The plunger-type line switch is of pre-selection type while the rotary switch is operated on

the post-selection principle, that is, the selection of an idle trunk takes place after a call has been initiated.

Twenty-five-point Non-homing Type.—The switch mechanism (upper cut of Fig. 30) consists of a set of double-ended wipers adapted to be driven over their respective rows of bank contacts by means of pawl-and-ratchet mechanism actuated a step at a time by an electromagnet. The bank contacts are arranged in semicircular rows and mounted in such a manner that one end of the wipers will engage the first contacts of the rows just after the other ends of the wipers leave the last contacts. The wipers, of course, are insulated from each other and from the shaft, and their enlarged circular centers serve as collector rings to be engaged by the collector brushes which may be seen in a vertical position just below the shaft. Carried on the magnet structure are a group of interrupter springs operated by the armature which also actuates the driving pawl.

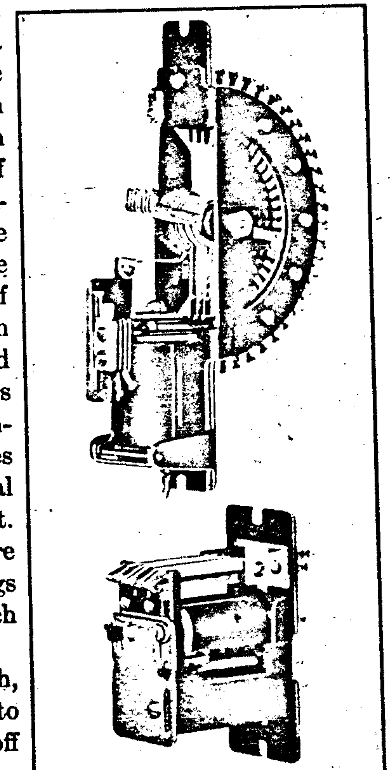


FIG. 30.—Rotary line switch (25-point)—non-homing type.

Associated with each switch, and electrically connected to it, are a line relay and a cut-off relay mounted together as a separate unit (lower cut, Fig. 30). The slow-release line relay is at the bottom but hidden by its armature. Immediately above this is the cut-off relay and at the top are shown the spring assemblies. At the left, projecting through a hole in the front plate, will be seen an extension of the cut-off relay armature which serves as an interlock with the line-relay armature. This interlock permits the full operation of the cut-off relay if the line relay also is operated, but, if the line relay is not operated, the cut-off relay can be moved only sufficiently to break all contacts at its springs but not far enough to make them. In other words, when the cut-off relay is energized and the line relay is not, all contacts at the cut-off relay springs will be open. The purpose of this will be described later.

Figure 31 is a circuit diagram of a rotary line switch. The line relay is designated *A*, the cut-off relay *B*, and the rotary magnet *Rot*. The other parts of the line switch here shown diagrammatically will be recognized from the foregoing description of Fig. 30. The line relay is operated in the usual manner by the removal of the receiver from the hook switch at the subscriber's station. Contact *X* closes first and connects the rotary magnet *Rot* through a back contact of cut-off relay *B*

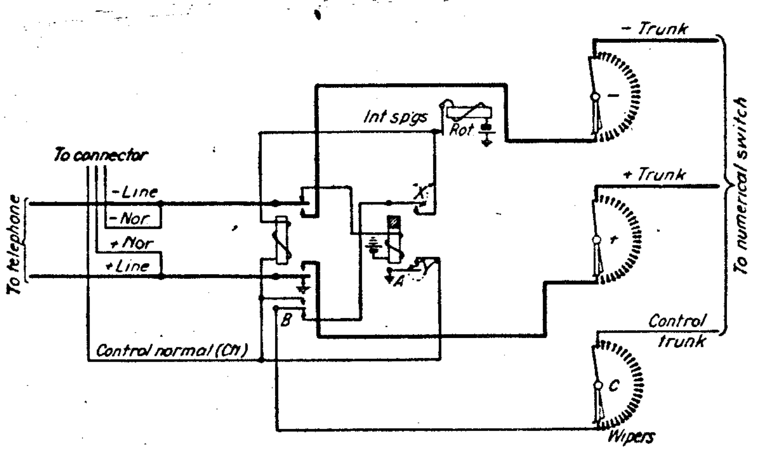


Fig. 31.—Circuit of rotary line switch—non-homing type.

to the control-trunk wiper *C*. This is followed by the closing of the ground contact *Y*, which places a guarding ground on the control normal of the connector and also ground on the winding of the cut-off relay.

Since this switch is of the non-homing type, the wipers are always resting on the multiple terminals of some trunk. If this particular trunk is busy, the control trunk will be grounded, or, if idle, it will be open. When relay *A* operates, it completes a circuit from battery through the rotary magnet *Rot* and coil of relay *B* to ground at contact *Y*. Now, if the control wiper *C* is resting on an idle trunk (open control), this circuit will cause relay *B* to operate. The magnet *Rot* cannot operate in series with relay *B* and therefore will not move the wipers. Relay *B*, when operated, opens the circuit of relay *A* and connects

its own winding to the control wiper *C*. Relay *A* is of the slow-release type and therefore will hold the ground on the winding of relay *B* until a busying ground has been placed on the control trunk at the numerical switch with which it is connected. The operation of relay *B* also removes the ground from the + line at rotary switch and connects both sides of the line through to the next switch in the connection.

If the trunk on which the wipers were resting had been busy, the control trunk would have been grounded, and this ground, through the *X* contact of the line relay, would have completed a circuit for the *Rot* magnet which did not include the coil of the relay *B*. This would have permitted the magnet *Rot* to operate, advancing the wipers to the next trunk. When the *Rot* magnet attracts its armature, it breaks its own circuit, reestablishing it again when the armature falls back. It would thus continue to step the wipers until an ungrounded control, or idle trunk, was reached, at which time relay *B* would have operated as previously described. Contact *X* of relay *A* is closed before the *Y* contact, in order to prevent a premature, or false, operation of the cut-off relay *B* when the control wiper *C* is resting on the contact of a busy trunk. The control-wiper contact is made of sufficient width to bridge the space between two consecutive contacts of the bank for the same reason. When the connection is released, relay *B* releases, and the wipers remain resting on the bank contacts of the trunk just used. This does not prevent the use of this trunk by other line switches, since in the normal condition all connections to the trunk wipers are open at relays *A* and *B*.

On an incoming call for a subscriber's line, ground is placed on the control normal, which completes the same circuit through the relay *B* and magnet *Rot* in series, as was previously established when the line relay operated. This circuit will partially operate relay *B*, but complete operation is prevented by the mechanical interlock between the line and cut-off relays, previously described. The partial operation of relay *B* opens all the circuits at its spring contacts, removing all bridges or attachments to the line at the line switch, thereby preventing connection with a numerical switch.

Eleven-point Homing Type.—Figure 32 shows an eleven-point (ten trunks and one set of home contacts) homing-type rotary line switch. While this differs somewhat in appearance from the one shown in Fig. 30, it has the same elements, differently arranged. The line and cut-off relays are mounted on a bracket at the top, and in this type no mechanical interlock is required, since when not in use the wipers always rest on a set of "home" contacts. Immediately below the line and cut-off relays is the rotary magnet with its associated armature, ratchet

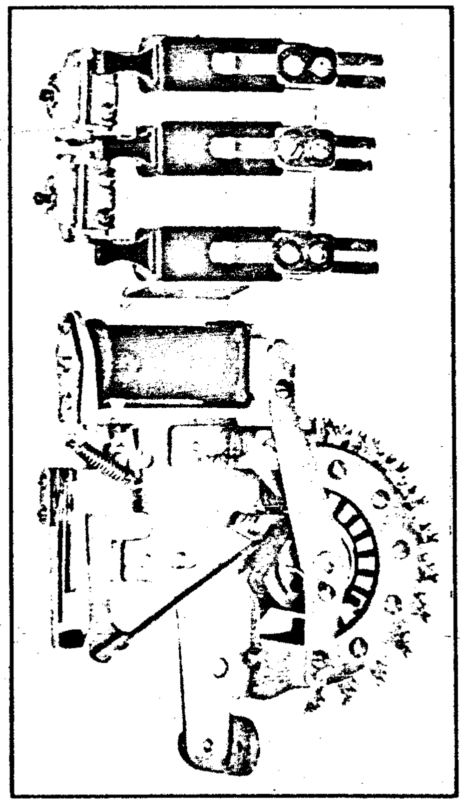


FIG. 32.—Rotary line switch (11-point)—homing type.

pawl, and interrupter springs. At the lower right are the wiper assembly and the contact bank.

A typical circuit of this type of line switch is shown in Fig. 33. When line relay *A* pulls up, it causes the rotary magnet to operate immediately. This breaks its own circuit and upon its back stroke, steps the wipers off the first, or home, position. The operating circuit is from ground, placed on the home con-

tact through contact *Y* of relay *A*, lower contacts of relay *B*, contact *X* of relay *A*, contact and winding of magnet *Rot* to battery. If ground (indicating a busy trunk) is encountered on the following control-trunk contacts, the wipers will be stepped until an idle trunk is found. The operation of the cut-off relay is the same as previously described.

On disconnection, when ground is removed from the control-trunk contact, relay *B* will be de-energized and close a circuit through its upper set of springs, which will operate the rotary magnet and cause it to drive the wipers to the home position. This circuit is from battery at the winding of the magnet *Rot*, through the cam springs, shown directly above the wipers, con-

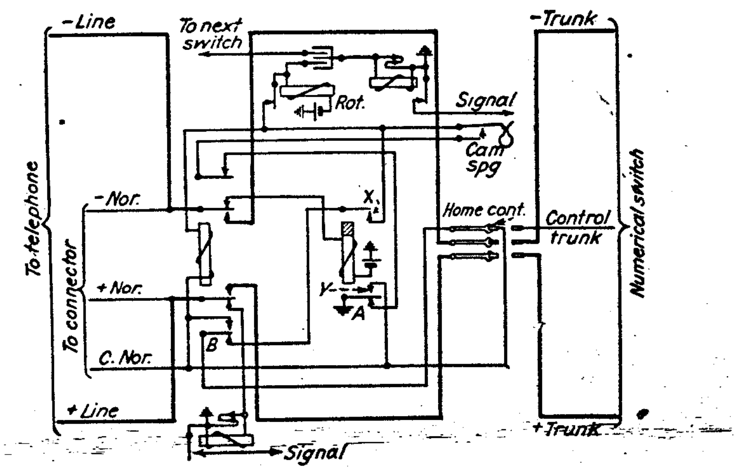


FIG. 33.—Circuit of rotary line switch—homing type.

tacts of relay *B*, and contacts of relay *A* to ground. The cam springs are operated by a cam on the wiper shaft, which causes the springs to break contact when the wipers reach the home position. The movement is always in the same direction, therefore, a rotation of 180 degrees being required for each connection. On an incoming call, relay *B* is operated over the control normal, as previously described, but no interlock with the line relay is required, since at this time the wipers are resting on the home position, and no trunk is connected to these contacts. Relay *A* is disconnected from the circuit through contacts of relay *B*. In this drawing supervisory circuits are shown connected to relay *B* and magnet *Rot*.

While the rotary switch principle has been described for use as a line switch, it will be shown later in this chapter that this principle is used in other apparatus in the system.

Line-finder Principle.—The principle of the line finder is the reverse of that of the line switch, although the purpose of each is to concentrate traffic on a smaller number of numerical switches than lines. In the line-switch system each subscriber's line is directly connected to a line switch, which selects an idle numerical switch; while in the finder system, a finder switch directly connected to a numerical switch seeks and connects with the subscriber's line. The Strowger switch and the rotary switch, the principles of which have just been described, are both employed in line-finder systems as will be explained in the portion of this chapter on Switching Apparatus.

Principles of Step-by-step Trunking System.—In a present-day manual system, trunk operators, corresponding to numerical switches in a step-by-step system, are able to reach and connect with all the subscribers' lines in a switchboard. In all except very small step-by-step systems, the line capacity of the numerical switches is such that the operation of selecting and connecting with a given line is accomplished through a series of separate numerical switches operating in tandem through intervening trunks.

The step-by-step system is essentially a decimal system, the numerical switches—selectors and connectors—each serving by a one-in-ten selection to extend the calling line, switch by switch, toward continually smaller groups of lines until finally the desired line is reached. The principle of causing a switch in response to a movement of the subscriber's dial to select a group of trunks and then automatically to select an idle one of that group has already been referred to in the preceding chapters. In the Strowger system the vertical movement of the selector shaft, in response to the dial impulses corresponding to one digit in the called number, is a numerical selection of a *group* of trunks. The rotary movement which follows is a non-numerical selection and is called the "trunk hunting" movement, since it has for its purpose merely the picking out of the *first free trunk* of the group chosen by the vertical movement. Each selector, therefore, performs one numerical selection and one non-numerical. By the time the connector is reached, however, the choice has been narrowed down to 100 lines, all

of which terminate on the connector bank. No further trunks are involved, therefore, and consequently no trunk-hunting movement is required. The connector, therefore, makes two numerical selections in response to the dial movements, one to pick out the *tens* group in which the called line terminates and the other to pick out the desired *unit* in that ten.

To make this clearer by an example: in a 10,000-line system there would be first and second selectors and connectors. In calling the number 9876, for instance, the first selector, in response to the nine impulses sent by the dial, would rise to the ninth level in which ten trunks leading to second selectors serving the ninth thousand terminated. Then the trunk-hunting movement of the first selector would pick out the first idle trunk in that group. The second selector so chosen would then, in response to the eight impulses of the dial, rise to the eighth level and then proceed by its rotary trunk hunt to pick out the first idle one of the ten trunks in that level, all of which led to connectors in the eighth hundred. The connector so chosen, in response to the seven dial impulses, would rise to the seventh level and in response to the final six dial impulses move around to the sixth set of contacts in that level. The number chosen, 9876, would thus have been arrived at by four successive one-out-of-ten numerical selections, one performed by each of the selectors and two by the connector.

Aside from the selectors, which perform single-digit selections and the connectors which usually perform two-digit selections the other automatic switches are non-numerical and do not function in number selection. They are used principally as concentrating switches to reduce the number of selectors otherwise required and to increase the efficiency of certain trunk groups.

From the foregoing it is apparent that a 100-line system would require only one numerical switch a connector; a 1,000-line system one selector and one connector; a 10,000-line system, two selectors and one connector; and a 100,000-line system, three selectors and a connector, and so on for larger systems.

One-hundred-line System.—In a 100-line system employing a connector for each line, no trunks are required, but when line switches are used to reduce the number of connectors needed, trunks must be inserted between the line switches and connectors. Figure 34 shows such a trunking system in diagrammatic form. At the left are indicated the 100 subscribers' lines divided into four groups of 25 each, each line being terminated in a line switch. The operation of the line switch has been

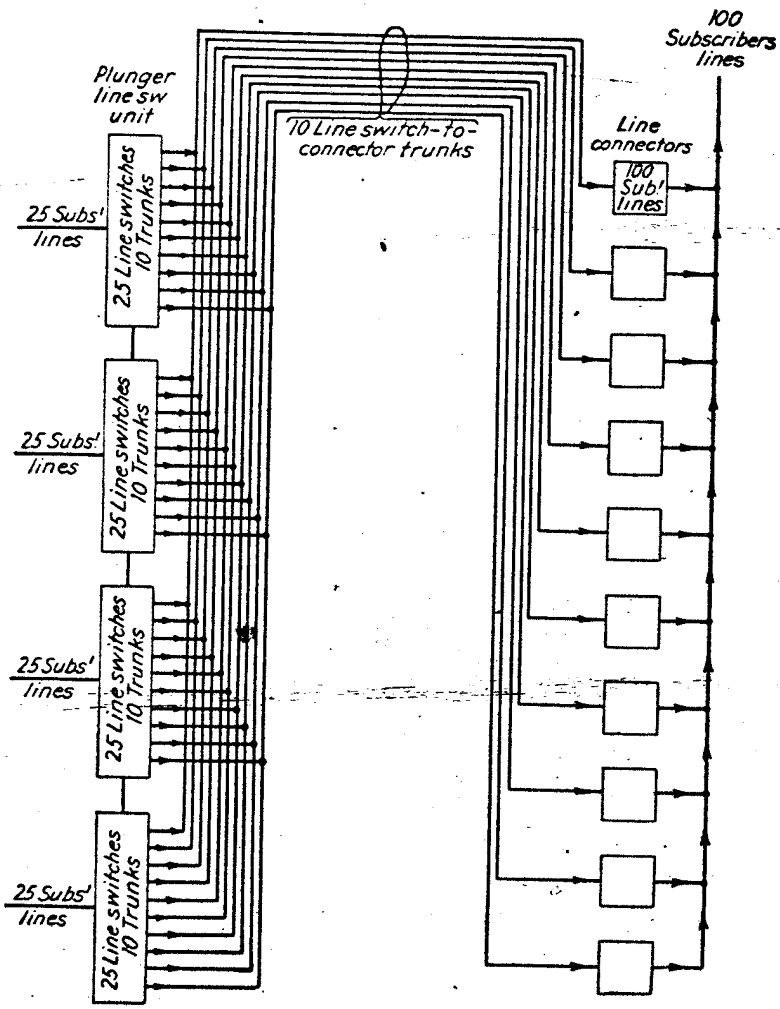


FIG. 34.—Hundred-line step-by-step trunking system with line switches.

previously described, and the apparatus for the complete unit of 100 lines will be assumed to be located within the four rectangles at the left. The line-switch unit in this case has 10 outgoing trunks, each of which is multipled to each of the four rectangles.

In practice the lines are thus divided into groups of 25 for the purpose of subdividing the unit, as will be described later. In the drawing, it has been assumed that the four groups are operated as a unit and therefore any one of the 100 lines will have access to any one of the 10 trunks. Each of the trunk lines terminates at its right-hand end in a numerical switch, which in this case is a connector. The bank of each of these connectors

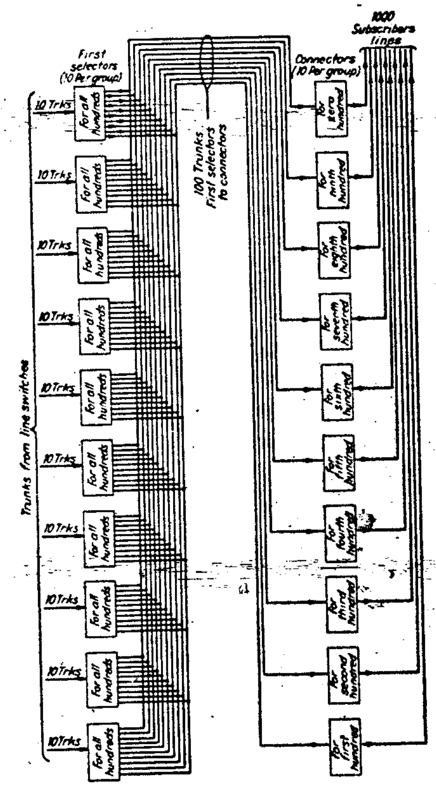


FIG. 35.—Thousand-line step-by-step trunking system.

has 100 sets of contacts, through which connections may be made to any one of the subscribers' lines. The connector switch is of the Strowger type previously described, each of the squares at the right representing a complete connector apparatus. Since each of the connectors serves the same 100 lines, the single line leading from each of them represents a multiple tap from 100 lines. These outgoing multiples are connected to the subscribers' lines at the left through the normals (not shown). Only a sufficient number of connectors are provided to meet the requirements for simultaneous connections. Each line-switch-to-connector trunk starts in switch-bank contacts, multipled together as required, at its outgoing end and terminates in the wipers of its associated connecter switch at the distant end.

One-thousand-line System.—Figure 35 shows the trunking principle employed in a system of 1,000 subscribers' lines.

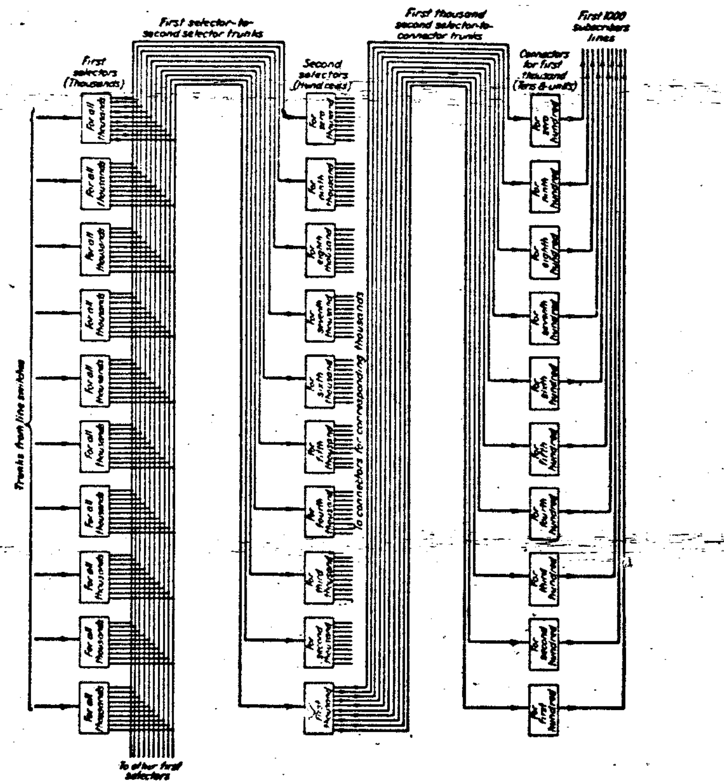


Fig. 36.—Ten-thousand-line step-by-step trunking system.

In this the line-switch units are omitted, but the trunks extending from them have been shown at the left. These trunks terminate in numerical switches, or first selectors, arranged to move vertically in response to the dial impulses corresponding to the first digit, and then to rotate automatically under control of a test circuit until an idle trunk is found. In this case, the contacts of each corresponding level of the first selectors are

multipled together and terminated in a group of connectors, each of which has access to a separate 100 lines. The arrangement of the connectors is similar to that of the 100-line system, except that in this drawing each rectangle represents 10 connectors for each 100 lines and the bank multipling is not shown. Each of the lines at the right, therefore, represents the normals for 100 subscribers' lines. While the number of switches and trunks has been designated, in practice the busy-hour traffic would determine the number to be provided. The first selectors are operated by the first, or hundreds, digit of the number dialed, and the connectors by the tens and units digits. This trunking system, therefore, provides for interconnection between any two of 1,000 subscribers.

Ten-thousand-line System.—Figure 36 illustrates the trunking principle extended to a 10,000-line, or four-digit, system. The line-switch trunks are shown terminating in first selectors as before, but in this case the first selectors perform the thousands-digit selection. The multiple banks of the first selectors are connected by trunks to second selectors, which select the hundreds digit of the called number. The trunks from the second-selector banks terminate in connectors, a group for each hundred in each of the thousands. In the drawing, the trunks extending from the second-selector banks are shown for the second selectors of the first thousand, but it is to be understood that similar groups of trunks are required for each of the other groups of second selectors. The similarity to the trunking system for a 1,000-line, or three-digit, system (Fig. 36) will be noted, provision for the additional digit being made by the addition of second selectors and their associated trunks. The actual number of trunks required in each of the various groups and the number of selector banks multipled to each group is determined by a study of the traffic in the system and, of course, must provide in all cases for the required number of simultaneous connections during busy periods.

One-hundred-thousand-line Multi-office System.—Figure 37 is a schematic diagram of a connection through a trunking system for 100,000 lines—a five-digit system. Such a system requires first, second, and third selectors, and connectors, the trunking arrangement between these being merely an extension of that described for the smaller systems. At the left are shown both primary and secondary line switches, the latter being used in the larger systems to obtain better distribution of incoming traffic and a resulting increase in trunk and first-selector efficiency, as will be described later.

This, of course, would be a multi-office system. The line switches and first selectors shown at the left would be located in the originating, or calling, office and the second and third selectors, and connectors, at the right, in either the same or some other central office. The switching train is shown for one office

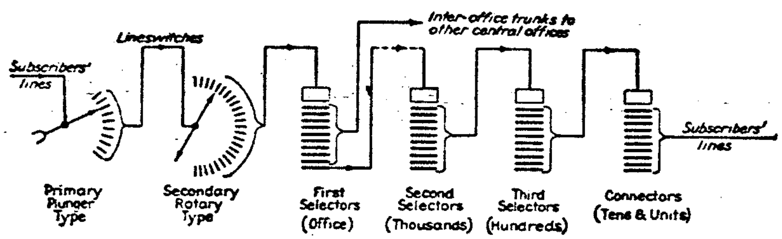


FIG. 37.—Hundred-thousand-line (multi-office) step-by-step trunking system.

only, but in a 100,000-line system nine other groups of second and third selectors and connectors would be required.

The size of the system is not limited to 100,000 lines nor is the number of digits involved in the selections limited to five. By adding selectors in the switching train a system for any desired number of subscribers' lines may be provided. Furthermore, by varying the application of the foregoing trunking principles, a trunking system meeting widely different requirements may be devised.

SWITCHING APPARATUS

The foregoing portions of this chapter have dealt mainly with the underlying principles of switch operation and trunking. The various pieces of apparatus needed to carry out the different functions of the system will now be more particularly dealt with. Many of them are based on the principles of the Strowger switch, plunger, and rotary line switches previously described, while others are designed to function in connection with such apparatus.

The Dial.—The subscribers' stations are equipped with calling devices, or dials, to enable subscribers to transmit by break-impulses the successive digits of the desired numbers. These have been dealt with in the preceding chapter.

With reference again to Fig. 2, it will be remembered that, when the dial is in its normal position, the line circuit is closed at the impulse springs *IS* and the short circuits about the transmitter and receiver are open at the shunt springs *SS*. When the finger plate of the dial is moved from its normal position in dialing, the shunt springs are immediately closed, and the impulse springs also remain closed until the finger plate starts to return under the power of its spring. As the finger plate returns to normal, the impulse springs are broken a number of times corresponding to the digit dialed, thereby transmitting break-impulses to the central office.

Plunger Line Switches.—The principle and operating circuits of the plunger type of line switch have already been described. In a large step-by-step system two line switches are often employed in tandem to extend the line to the first numerical switch, as was illustrated in Fig. 37. The first of these switches in the switching train is called the "primary" line switch.

Primary Plunger Line Switch.—Figure 38 shows a 100-line primary line-switch unit or "board." The individual line switches are mounted in four divisions of 25 each. Each division of 25 may have its own master switch or, by mechanical coupling, two, three or four divisions may have their guide shafts controlled by a single master switch. Between each of the upper and lower divisions of the unit shown in Fig. 38 is a master switch, previously shown in more detail in Fig. 29. If four

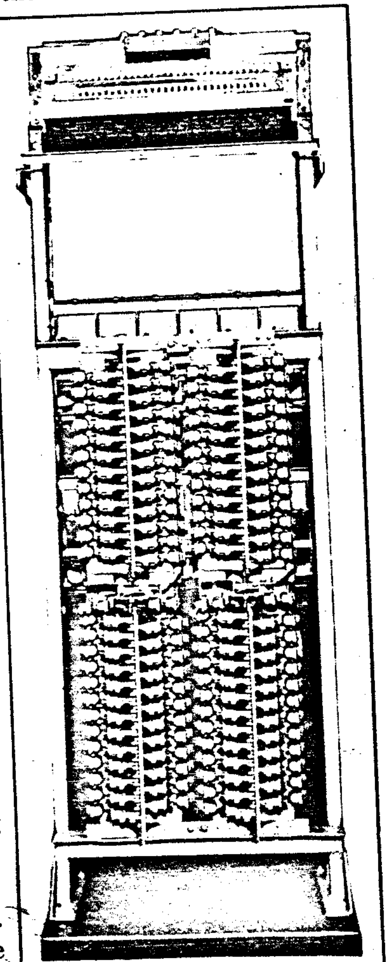


FIG. 38.—Primary line-switch unit.

master switches are provided, the two additional ones are mounted just above the two upper divisions. In the center of each division of line switches will be seen the four plunger guide shafts which control the position of the line-switch plungers. By the insertion or omission of mechanical connections between the master switches and the guide shafts, the number of line switches associated with a set of 10 trunks may be varied from 25 to 100 in steps of 25, so that there may be from 10 to 40 trunks for 100 line switches. This provides a flexible arrangement by which the trunks may be properly loaded by varying

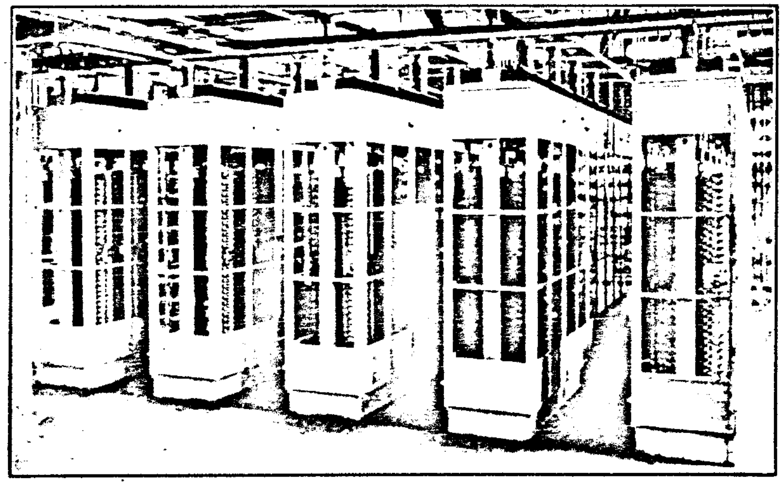


Fig. 39.—Group of primary line-switch boards.

the number of line switches associated with a given group of trunks.

The unit shown has line switches mounted on the front and connectors on the rear. Another arrangement is employed in which the connectors are mounted on separate boards and in that case line switches are mounted on both sides of the unit, providing a capacity of 200 line switches per board. In some instances where sufficient ceiling height is obtainable, two such units are mounted one above the other, giving a capacity of 400 line switches per board.

Figure 39 shows a group of line-switch boards as actually installed. The boards are completely enclosed in cases with glass panels and hinged doors, protecting the switches from dust and permiting accessibility for inspection and testing. A recent

development, providing for the mounting of the self-aligning type of line switch horizontally, is shown in Fig. 40. Two divisions of 25 line switches each are mounted per shelf with the master switch in the center. The shelves are hinged at the bottom and one is shown turned down for inspection of the wiring.

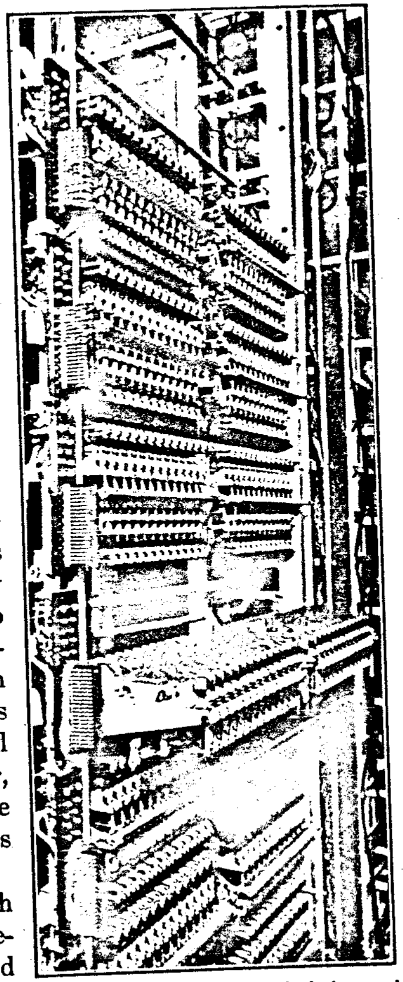


Fig. 40.—Plunger line-switch board —horizontal type.

Secondary Plunger Line Switch. The plunger type of line switch is sometimes used as a second step in the switch train between the subscribers' lines and the first numerical switches. When so used, it is called a *secondary line switch.* The operation is the same as already described for the primary plunger-type line switch and the circuit similar, except that, when a group of secondary trunks is busy, provision is made to prevent primary line switches from routing calls to secondary line switches serving that group of trunks. The use of secondaries insures better distribution of originating calls and reduces the number of first numerical switches required. However, the rotary-type switch is more frequently employed for this purpose.

Rotary Line Switches.—Both the eleven- and the twenty-five-point types already described are used as primary and as secondary line switches.

Secondary Rotary Line Switch.—When used as secondary line switches, the non-homing type is generally employed. In addition to the functions previously explained, means are provided to prevent primary switches from routing calls to any of the secondary switches serving a group of secondary trunks when all trunks of the group are busy. This is accomplished by adding a chain-relay circuit to the secondary trunks and a group busying circuit to the secondary line-switch circuits. Figure 41 shows the circuit embodying these features. The upper part of this is similar to that of the primary rotary line switch (Fig. 31), except that an additional set of contacts have been added to each of the relays *A* and *B*. In the lower part the added elements for use as a secondary line switch are shown.

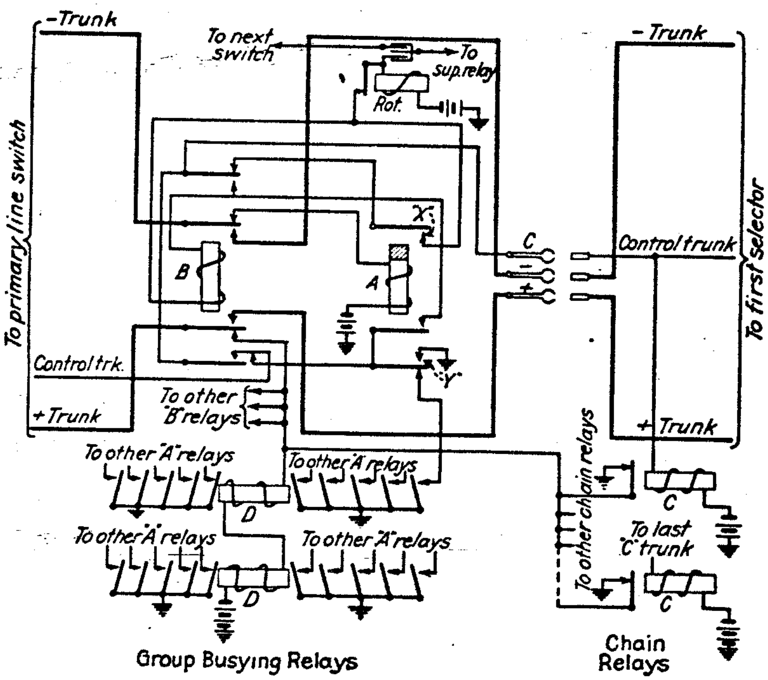


Fig. 41.—Circuit of secondary rotary line switch.

Connected to the control trunk of the outgoing-trunk circuit, at the banks of the secondary line switches, is a chain relay *C*, there being one of these for each trunk circuit in the group. The break contacts of these relays are all grounded, and the armature spring contacts are all connected in multiple and to the windings (in series) of the group busying relays *D*. This same circuit is also connected, as shown, to a normally closed contact on each of the *B* relays of all the secondary line switches associated with the group. The armature spring contacts of the group busying relays *D* are connected to ground and the break contacts to

normally closed contacts of the *A* relays, as shown. The group busying relays *D* are normally held operated by the grounds at

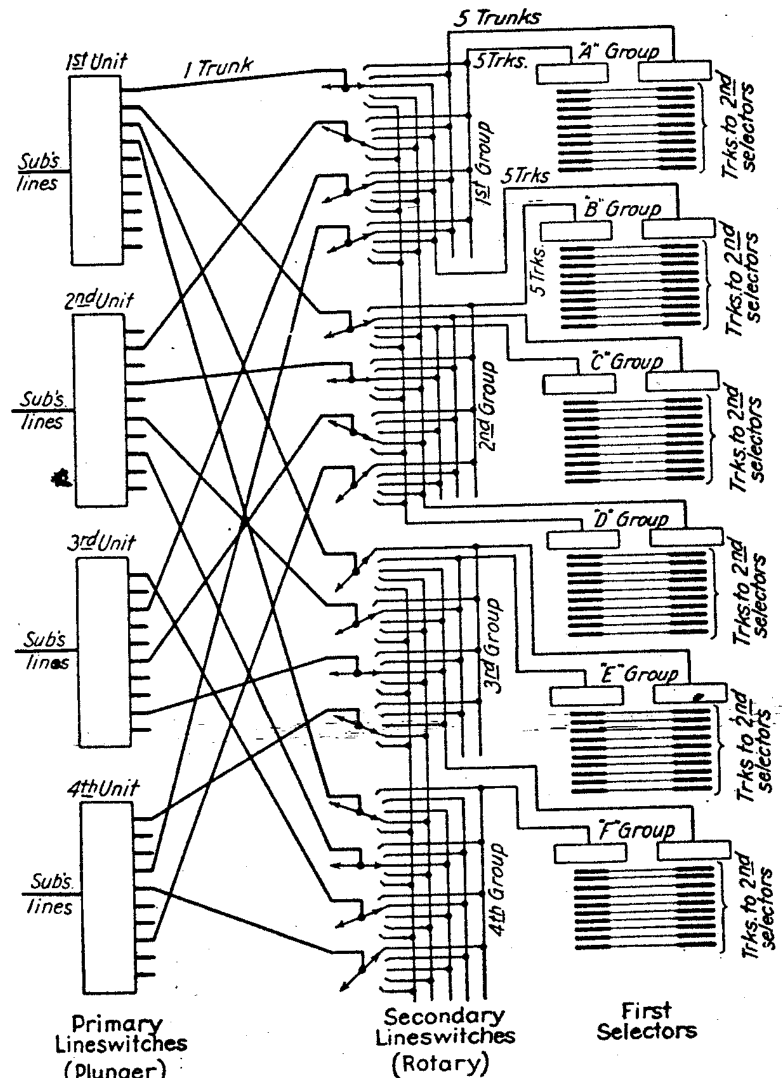


Fig. 42.—Grouping of trunks between primary line switches and first selectors.

the chain relays *C* and therefore hold the circuits to the contacts of the *A* relays open. When all the secondary trunks of a group become busy, all of the *C* relays will be operated, opening the circuit for the *D* relays. On releasing the *D* relays will close their break contacts to ground, thus making busy all of the idle trunks of this group between the primary and secondary line switches. The busying circuits are from ground at the armature spring and break contacts of the *D* relays, through the contacts of the *A* and *B* relays to the control trunks. These grounded control trunks will in turn ground the corresponding master-switch bank contacts and make the associated trunks busy. By this means, primary line switches are prevented from routing calls to groups of secondary line switches which have no available trunks to first selectors.

Grouping of Trunks between Primary Line Switches and First Selectors.—As stated, the use of secondary line switches produces better distribution of the originating calls to the first selectors and thus reduces the number of first selectors required. Figure 42 illustrates one method of grouping trunks by which this result is accomplished. At the left are shown four primary line-switch units of the plunger type, in the center four groups of secondary rotary line switches, and at the right six groups of first selectors. The lines drawn between the primary and secondary line switches represent the primary-to-secondary line-switch trunks, each line representing one trunk. At the right of the rotary line switches are the secondary-trunk multiples and the lines drawn between these multiples and the first selectors are the secondary line switch-to-first selector trunks, each line representing five trunks. Each bank contact shown on the secondary line switches therefore really represents five contacts. The banks of the groups of first selectors (shown by heavy lines) are the multiples of the first-to-second selector trunks. It will be noted that the first trunk of the first primary line-switch unit is connected to a secondary line switch in the first group, the second trunk to one in the second secondary group, the third to the third group, etc. This arrangement of connecting primary-to-secondary trunks is continued by a definite plan which results in extending not more than one trunk from a primary unit to a given secondary group. By providing each primary unit with a trunk into each of the secondary groups, all of the first selectors are made available to all of the subscribers' lines.

Since the number of switch banks multipled to a given group of trunks is that necessary to properly load the group and as the first-to-second selector trunks are in groups of ten, it is

apparent that the first-selector banks will be multipled to a number of different second-selector trunk groups. This is taken advantage of in a further distributing of the originating traffic. In the drawing, the banks of the secondary line switches are shown multipled in groups of five. The first two groups of five trunks of the first group of secondary line switches are connected to first selectors in the *A* group; the next set of five is connected to first selectors in the *B* group; the first set of the second group

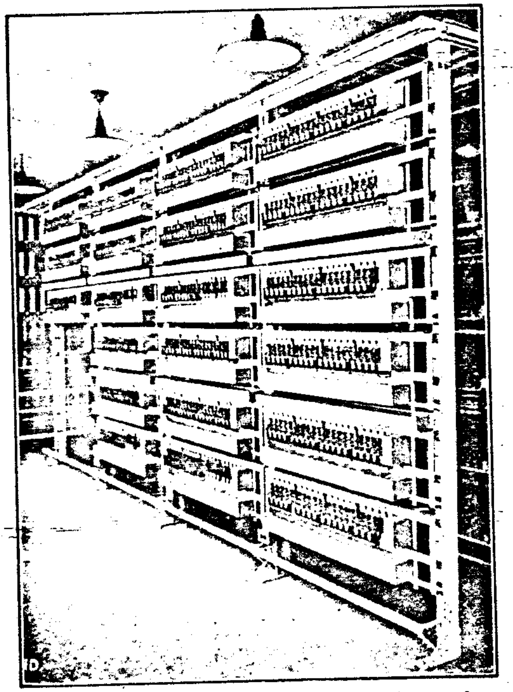


Fig. 43.—Secondary rotary line-switch boards.

of secondary line switches, to first selectors in the *B* group; the second and third sets are connected to first selectors in the *C* group; and the fourth and fifth sets are multipled through the first and second groups of secondary line switches and terminate in the *D* group of first selectors. The first and second sets of the third group of secondary line switches terminate in the *E* group of first selectors, and so on, until all the secondary line-switch trunks have been terminated in first selectors. This method of grouping the trunks between the primary line switches and first selectors produces many different routes for traffic, and an unusually heavy originating traffic in any one of the primary line-switch units will be distributed to various groups of first selectors, thereby equalizing the loads on the first-selector groups and as a result reducing the number of first selectors required to handle the traffic.

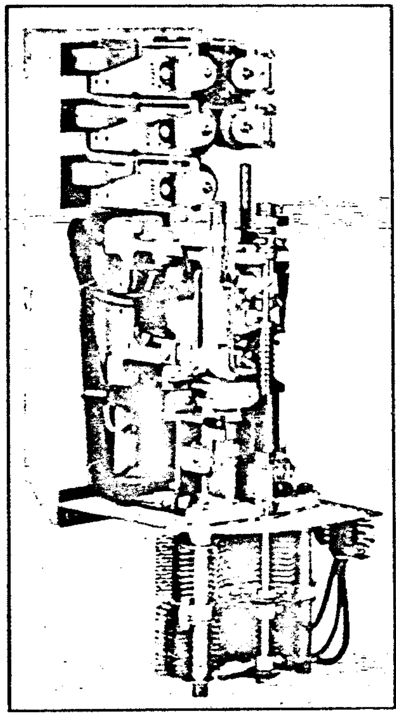


FIG. 44.—Selector switch.

Secondary Line-switch Boards.—Figure 43 shows a typical arrangement of rotary secondary line switches in an actual installation. The line switches will be seen mounted in horizontal rows in each bay of the rack. At the end of each row are the group busying relays, and the covers immediately below the switches enclose the associated line-switch relays. Between certain rows of line switches and their associated relays are mounted the chain relays for the group. These are also enclosed in metal covers.

Selector Switches.—As explained, selector switches of the Strowger type are arranged for group selecting and trunk hunting and therefore require only one selecting digit for their operation. The numerical value of the digit dialed determines the level to which the wipers are stepped, and the rotary or trunk-hunting movement is automatic.

Figure 44 shows a typical selector which may be a first, second, or third, etc., according to its position in the numerical switch train. At the top are mounted the relays of the selector; in the center is the switch-moving mechanism already described; and at the bottom are two banks of contacts, the upper called the "control bank" and the lower the "line bank." The control bank contains 100 single contacts and the line bank 100 double contacts, thus providing 100 sets of three contacts each, for

100 three-wire trunks. Just below the rotary hub will be seen a set of springs which are operated by a cam on the wiper shaft when the wipers pass the last or tenth contact of a level. The purpose of these cam springs will be described later. At the extreme lower right of the figure, at the right of the control bank, is mounted a test jack to facilitate connection with the switch for testing purposes. The remaining parts of the selector will be readily recognized from the previous description of the principle of the Strowger switch.

Operation of Selector Switch.—Figure 45 is a circuit diagram of a selector. The three wires of the trunk from the primary or secondary line switch, or from a preceding selector, are to be seen

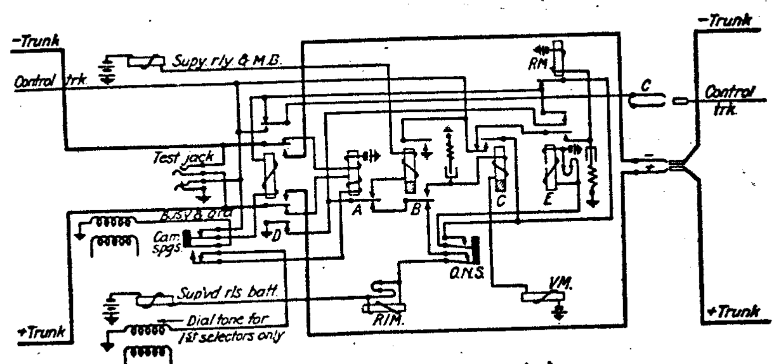


FIG. 45.—Circuit of selector switch.

at the left, and the trunk conductors extending to succeeding selectors in the train, or to a connector, at the right. The portion between is the complete circuit of the selector. The line relay *A*, release relay *B*, and series relay *C* correspond to the similarly designated relays already described in connection with the principle of operation of the Strowger switch. The rotary relay *E* automatically operates the rotary magnet *RM*, and the switching-through relay *D* connects the trunk conductors through to the next switch in the train, after the wipers have come to rest on the bank contacts of an idle trunk. The cam springs at the left are for the purpose of initially connecting the dial tone to the calling subscriber's line and also for connecting a busy tone to the calling subscriber's line after all ten trunks of a level have been tested and found busy. The function and operation of the off-normal springs *ONS* have already been described in connection with the principle of operation, although the electrical circuits here operated are slightly different.

When the selector is connected with, by a preceding switch in the train, the *A* and *B* relays are immediately operated. On a first-selector switch, the lower winding of relay *A* has in series with it normally closed contacts of the cam-spring assembly and the winding of a dial-tone transformer. This is provided to advise the subscriber by means of a distinctive tone that his line has been extended to a numerical switch (first selector) and that he may proceed to dial the digits of the desired number. The operation of relays *A* and *B* prepares a circuit for the reception of the break-impulses which are to operate the vertical magnet *VM*, and relay *B* places ground on the control trunk to replace the ground which is removed at the preceding switch shortly after it completed its operation. This ground also makes the trunk busy at all the multiple bank contacts in the preceding switch in the train.

The first break-impulse of the digit dialed momentarily releases relay *A* and permits the operation of series relay *C* and the vertical magnet *VM*, over a circuit from the grounded contact of relay *D*. The operation of magnet *VM* lifts the wiper shaft one level and subsequent break-impulses of the digit dialed will raise it to the level indicated by the numerical value of the digit dialed.

On the first movement of the wiper shaft the off-normal switch *ONS* closes its contacts and thereby prepares a circuit for the subsequent operation of the rotary relay *E* controlling the rotary magnet *RM*. Relay *E* is first operated from battery through its winding, contacts of *ONS*, contacts of relay *C* to ground at relay *B*, and when operated it is locked up through a circuit, from battery at its winding, contacts of *ONS*, interrupter contact of rotary magnet *RM*, its own upper set of contacts to ground at relay *D*. When relay *C* releases shortly after the last break-impulse of the pulsing series, a circuit will be established for the operation of rotary magnet *RM*, from battery at its winding, through contacts of relay *E*, contacts of relay *C* and to ground at contacts of relay *B*. The operation of magnet *RM* will rotate the wipers to the first set of bank contacts and at the same time break, at its interrupter contacts, the locking circuit of relay *E*. The subsequent action of relay *E* will depend upon the condition of the contacts of the control trunks, that is, whether grounded, indicating a busy condition or without

ground, indicating an idle, or free, condition. If the first trunk is idle, relay *E* will not be operated again.

The switching-through relay *D* will operate or fail to operate, also depending upon the grounded or ungrounded condition found on the multiple contact of the control trunk. If the first trunk of the group is idle, wiper *C* will be connected to an ungrounded control trunk and relay *D* will be allowed to operate. This circuit is from battery at the winding of relay *E*, contacts of *ONS*, interrupter contacts of magnet *RM*, winding of relay *D*, upper set of cam springs to ground at contacts of relay *B*. It will be noted that relay *E* is in series with relay *D* but the resistance of relay *D* is so high that relay *E* cannot operate. Relay *D* on operating will extend the trunk conductors to the next switch.

If the first trunk of the group had been busy, the same circuit would have been established but ground would have been connected to wiper *C* and thence to the upper end of the winding of relay *D* and, since the lower end of its winding is grounded at relay *B*, relay *D* would have been shunted and prevented from operating. However, with relay *D* shunted out, relay *E* would have operated and thereby closed the circuit of the magnet *RM*, causing it to move the wipers to the next set of trunk contacts. This rotary movement would have been continued until wiper *C* rested on an ungrounded contact. When relay *D* operates, it connects the trunk conductors through to the next switch and removes all bridges and attachments to these conductors. Relay *B*, being of the slow-release type, will hold ground on the control trunk until replaced by the *B* relay in the next switch.

If all the ten trunks of the selected level are found to be busy, provision is made to notify the calling subscriber and permit him to release the connection. This is accomplished by the cam-spring assembly which is so mounted on the switch frame that when the wiper shaft is rotated beyond the tenth position, its springs will be operated. This spring assembly will be seen in Fig. 44 immediately below and at the right of the rotary hub, and in Fig. 45 just below the test jack. When the cam-spring assembly is thus operated, the circuit of relay *D* will be opened to prevent it from operating, since at that time the circuit at wiper *C* will be open. At the same time a trunk busy signal will be superimposed on the telephone circuit, from ground through the winding of the busy transformer, cam springs, lower winding of relay *A*, thence to the positive trunk and the positive telephone line, through the telephone instrument, through the negative telephone line, negative trunk, and winding of relay *A* to battery.

The release circuit was originally prepared when the off-normal switch *ONS* operated, following the first break-impulse. The operation of the release has already been described, and the circuit for this operation is from battery through the supervisory relay, winding of release magnet *RlM*, off-normal springs and contacts of relays *B*, *A*, and *D*. Since relays *A* and *B* were de-energized when relay *D* was operated, the circuit was already closed at their contacts and required only the release of relay *D* to complete the circuit. During conversation or use of the connection, relay *D* is held in an operated position by the ground maintained on the control trunk. When the calling subscriber replaces his receiver on the hook switch, the *B* relay in the connector releases and removes ground from the control trunk. The removal of this ground permits the *D* relays of the selectors to release and in so doing places ground on the release magnet circuit.

It will be noted that the battery for the *B* relay was through a supervisory relay. This relay operates an alarm signal in case a selector is seized and fails to connect through to the next switch in the switching train. The battery for the release circuit was also through a supervisory relay, which gives an alarm in case a selector fails to return to normal after the release circuit has been closed for a certain length of time. Discharge circuits are also provided to protect the relay contacts when the magnet circuits are broken.

Selector Trunk Board.—Figure 46 shows an installation of selectors on a frame, or "board." The relays and operating mechanisms of each switch are enclosed in individual metal covers, with the banks, wipers, and lower portion of wiper shaft projecting below. The multiple bank contacts of the selectors are connected to terminal blocks to be seen at the upper right-hand corner of this view. The selector board illustrated is known as the "low type" and consists of two bays placed back to back, with an aisle between. The metal door at the end, above which the terminal blocks are mounted, encloses a distributing-terminal assembly. This unit is commonly called a "trunk board" and has a capacity of six shelves with twenty switches per shelf (two sections of ten) in each bay. In the figure, four shelves, of

twenty switches each, are equipped. Another type frequently employed, when there is sufficient ceiling height, is known as the "high type." In this, a greater number of shelves are employed and the bays are arranged in straight rows with aisles between, instead of back to back, as in the U-shaped units.

Connector Switches.—The connector is the final switch in the switch train and is sometimes called the "final selector." Like the selector it has two movements, up and around, and in fact is the same general type of switch as the selector, differing mainly

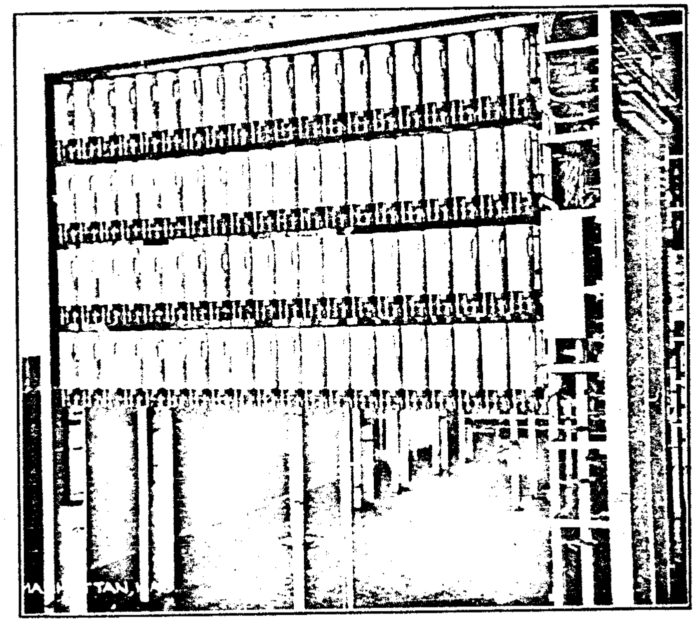


FIG. 46.—Selector trunk board.

in its manner of control. Strowger connectors are, broadly, of two types, the "individual-line connector" in which the wipers are driven by dial impulses directly to the terminals of the *individual* subscriber's line wanted, and the "trunk-hunting connector," or "P.B.X. connector," in which the wipers are driven by dial impulses to a *group* of lines serving a subscriber, after which an automatic trunk-hunting operation takes place to pick out an idle one of that group.

Individual-line Connectors.—These ordinarily have a capacity for 100 subscriber lines. They have no trunk-hunting function, both vertical and rotary movements being responsive only to dial impulses. The impulses from the dial corresponding to the tens digit raise the shaft to the level containing the line wanted and the dial impulses for the units digit rotate the wipers to engage the particular line.

Figure 47 shows a typical individual-line connector. In it, the lower contact bank is the multiple of 100 subscribers' lines instead of trunk lines as in the selectors.

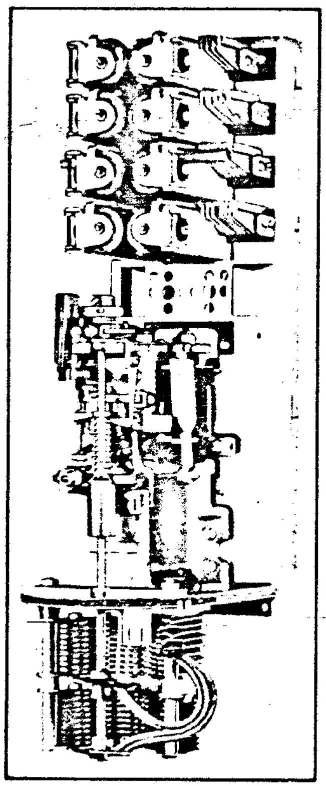


FIG. 47.—Individual-line connector.

Two-hundred-line Connector.—Some connectors are designed to serve 200 subscribers' lines. These are similar in general appearance to the 100-line connector, except that one additional relay is required in the relay group, an additional 100-line bank is provided, and the control bank has double instead of single contacts. The additional relay switches the circuit of the connector from the wipers associated with the lower 100-line bank to those associated with the upper 100-line bank. To provide for this switching, the digit 1 or 2 is included in the directory number in the hundreds place. If one break-impulse is transmitted, the connection is routed through the lower 100-line bank while two break-impulses will switch the connection to the wipers of the upper 100-line bank. This arrangement enables the use of larger trunk groups and in certain cases eliminates the use of a selector in the switch train.

Operation of One-hundred-line Connector.—Figure 48 is a circuit diagram of an individual one-hundred-line connector. The line relay A, release relay B, series relay C, and off-normal switch ONS perform the same functions as previously described in connection with the principle of the Strowger switch. Rotary relay E is connected in parallel with the rotary magnet RM and, being slow acting, remains operated during the pulsing period.

It maintains a shunt around the contacts on relay G in the operating circuit of rotary magnet RM so that, as relay G operates during the rotary movement, the operation of magnet RM will not be interfered with. Busy relay G transmits the busy tone to the calling subscriber when the called line is engaged in some other connection. It operates each time the wiper C passes or rests on a grounded control normal contact. The wiper-closing relay H connects the trunk conductors through to the line of the called subscriber after the line has been tested and found idle. It also grounds the control normal and thereby cuts off the associated line switch to prevent it from operating when the called subscriber answers. The ringing cut-off relay F operates when the called subscriber answers and cuts off the ringing current.

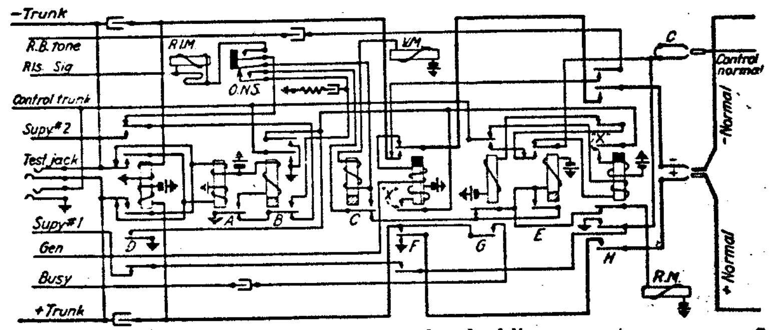


FIG. 48.—Circuit of individual hundred-line connector.

During the ringing period, it transmits the ring-back tone to the calling subscriber to advise him that the called station is being rung. This relay is of a special design with a copper slug on the armature end and a copper sleeve over the iron core, to prevent its operation by the ringing current, to reduce its impedance to ringing current, and to give it a wide range of adjustment. The back-bridge relay D supplies the talking battery to the called station and, when the called subscriber answers, it reverses the battery on the trunk and line conductors connected to the calling station. This reversal of battery serves to operate message registers and also to give supervision to manual operators on calls originating at manual switchboards.

The circuits for operating relays A, B, and C for the vertical and rotary movements have already been described. However, the features required in the operation of the connector necessitate the use of additional apparatus during the rotary movement. When the relay *C* releases after the completion of the vertical movement, a rotary circuit is established, as previously described, from ground at contacts of the *A* relay, through contacts of the *B* relay, springs of *ONS*, and contacts of relay *C*, but this circuit now extends to battery at the magnet *RM* through contacts of the *G* and *H* relays. At the contacts of relay *G*, the *E* relay is connected in parallel with the magnet *RM*. On the first break-impulse of the units digit dialed, both the relay *E* and magnet *RM* will be operated, but, since relay *E* is of the slow-release type, it will remain operated during the entire pulsing period. The operation of relay *E* shunts the contacts of relay *G* and connects the rotary circuit directly from the contacts of relay *C* to those of relay *H*. As relay *G* operates when the wiper *C* passes over a busy control normal, this prevents its interference with the proper operation of the magnet *RM* during the rotary movement.

When the line desired is reached and it at the moment is engaged in some other connection, relay *G* will operate through ground on the control normal and through its lower set of contacts will transmit the busy tone back to the calling station, over the trunk and line conductors. The relay *G*, once operated, will be retained in an operated position, until the connection has been released by the calling subscriber, being held over a circuit from battery at its own winding, through contacts of relays *H*, *E*, *G*, and *B* to ground. It will be noted that the above circuit does not include the wiper *C*, and therefore the connector cannot attempt to cut through, if the called line becomes disengaged before the release has been effected. Relays *H*, *F*, and *D* are not operated when the called line is found to be busy. The release is accomplished in a manner already described.

If the called line is free, then the relay *G* will not be operated and a circuit for the operation of *H* will be established by the release of *E*. This circuit is from ground at relay *B*, through contacts of relay *G*, lower winding of relay *H*, contacts of relay *E*, wiper *C*, control normal, bridge cut-off winding *BCO* of the line-switch magnet to battery. This circuit will operate relay *H* only sufficiently to close its contact *X*. The closing of this contact provides a locking circuit from battery at the upper winding of relay *H*, contact *X*, and contacts of relay *B* to ground. This locking circuit will complete the operation of relay *H*

which will connect the normally open negative and positive wipers to the rest of the connector circuit.

The operation of relay *H* also connects the ringing generator circuit to the called line to ring its bell. This circuit is from ringing generator (alternating current superimposed on direct current) through the upper winding of relay *F*, contacts of *F* relay, contacts of relay *H*, negative wiper, negative normal, negative telephone line, bell and condenser of telephone instrument, positive telephone line, positive normal, positive wiper, contacts of relay *H*, and to ground at relay *F*. Relay *F* will not operate so long as the condenser is in series at the telephone instrument, but when the condenser and bell are shunted by the lifting of the receiver from the hook switch, the direct current will operate relay *F* sufficiently to close its *X* contact. The closing of this contact will permit full operation, over a circuit to ground contact at relay *B*.

When relay *H* operated, the ring-back tone was transmitted to the line of the calling station, through the upper set of contacts of relay *H*, contacts of relay *F* through the telephone line, and back to ground through the *A* relay. This circuit will be opened at the *F* when it operates to cut off the ringing.

Also, when the *F* relay operates, the conductors of the called subscriber's line will be extended back to include the windings of the back-bridge relay *D*. Since the called station has answered, this relay will be operated and will reverse the battery on the calling line. The operation of relay *D* also places ground on the holding circuits of relays *F* and *H* in parallel with the ground at relay *B*. This is a precaution to prevent premature release of the *F* and *H* relays in case the *B* relay is released by the calling subscriber hanging up first. When the *D* relay operated, it also opened the release circuit at its upper set of contacts, so that the connector cannot be released until the called subscriber hangs up. This is, of course, to prevent the operation of the line switch of a called line on disconnection.

With the circuits just described, the *A* relay feeds talking battery to the calling line, and relay *D* supplies talking battery to the called line. These circuits are separated by condensers in each conductor of the trunk, so that the battery feed is of the condenser-retardation-coil type described in Chap. VIII of the preceding volume.[1]

[1] "Manual Switching and Substation Equipment," p. 250.

When the connection is no longer desired, disconnection is accomplished through the release magnet *RlM* as previously described. However, both subscribers must hang up before the connector can release, although the other switches in the switch train will be released when the calling subscriber does so. If the called subscriber hangs up first, relay *D* will be released and thereby will close the circuit of the release magnet *RlM*, at its upper set of contacts, but at this time relays *A* and *B* will be operated and hold the release circuit open at their contacts. If the calling subscriber hangs up first, the *A* and *B* relays will be released and thereby close the release circuit, but, since relay *D* would then be operated, the release circuit would be open at the upper set of contacts of that relay. Hence, relays *A*, *B*, and *D* must be released, by both subscribers hanging up, before the release of the connector can be accomplished. The other switches are held in an operated condition by ground on the control trunk and, since all grounds have been removed in the progress of building up the connection, except at the *B* relay of the connector, the release of that relay will release all the other switches. Relay *B* is released shortly after the calling subscriber hangs up.

Supervision is provided in the form of lamp signals, which are lighted in case of delay by either subscriber to hang up after a conversation has been completed. If the called subscriber should delay or fail to hang up, a circuit will be established from ground at relay *A*, contacts of relay *B*, upper contacts of relay *D*, "Supy. #2," and through a signal lamp to battery. If the calling subscriber should delay or fail to hang up, then relay *D* would release, and relays *A* and *B* would remain operated and a circuit would be established from ground at the next to lower set of contacts of relay *H*, through the lower set of contacts of relay *F*, lower set of contacts of relay *D*, "Supy. #1," and through a signal lamp to battery. This system of supervision assures that any connection being held by either the calling or called subscriber will be called to the attention of an attendant.

Connector Boards.—Connectors are mounted on iron frameworks, or "boards," in much the same manner as selectors. The relays and operating mechanism of the individual switches are enclosed in metal covers and at the end of each shelf are the connecting blocks for terminating the bank circuits of the connectors. The bank wires are terminated on one side and the

normal cables on the other. What is known as the "low-type" board has five shelves with a capacity of sixteen connectors per shelf including a test connector. Low-type boards are also made with capacities of five and eleven connectors per shelf. There is also a "high-type" board for connectors arranged as previously described for selectors.

Trunk-hunting Connector.—The "trunk-hunting," "rotary," or "P.B.X." connector, as it is variously called, is used instead of the individual-line connector for lines to subscribers' establishments having private branch-exchange switchboards requiring more than one trunk. In such cases, any one of the trunks may be used to make connections between the private-exchange switchboard and the central office. The line number of the first trunk in a group is usually listed in the telephone directory and used in dialing the private branch exchange. Incoming connections to a P.B.X. switchboard thus require the use of the trunk-hunting connector to enable the selection of an idle trunk of the group.

Trunk-hunting connectors have characteristics of both individual-line connectors and selectors in that they are operated by the dial impulses corresponding to the tens and units digits of the number called, as in the individual-line connector, and are then automatically rotated to locate an idle trunk in the group, in a manner similar to the trunk-hunting operation of the selector. They perform all the functions of individual-line connectors and, in addition, test for an idle trunk in a P.B.X. group. Since a single level has only ten sets of contacts, each switch has access to only ten trunks per level. However, a greater number may be provided for by connecting the multiple banks of the connectors in two or more separate groups.

When large groups of trunks occur, other types of trunk-hunting connectors may be employed. In one, the switch is equipped with a single vertical bank, of a type subsequently to be described in connection with Fig. 60. By means of this, the connector is enabled to test trunks in two or more levels, up to the capacity of the switch bank. Another type is equipped with a single vertical bank and with a minor switch similar to that shown in Fig. 51. In this case, the minor switch acts as a registering device and directs the connector to the levels of the required trunk group. The directory digit for the trunk group steps the minor switch to the first level of the group, whereupon the connector shaft is stepped to that level and rotated. If all the trunks in that level are found busy, the shaft is released and the minor switch then takes another step, directing the connector to the next level of the group and so on, until an idle trunk is found or all are found busy. When these types of connectors are used, the digit zero (0) may be used for the last digit or the last two digits of the directory number of the private branch exchange.

The general appearance of a trunk-hunting connector of the type first mentioned, that is, the one used for small groups, is similar to that of the individual-line connector shown in Fig. 47, except that two more relays are required, these being mounted in the blank space at the bottom of the relay mounting plate shown in that figure. Another difference is that the control

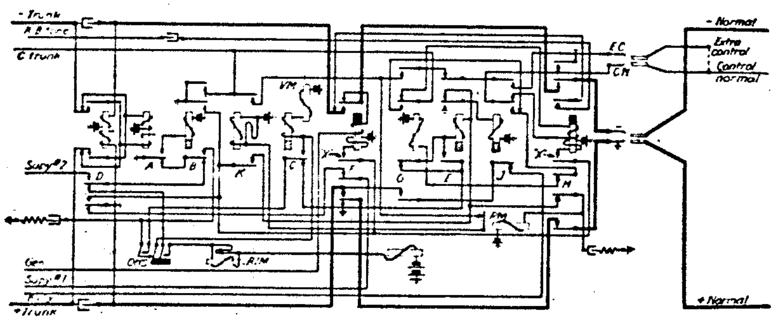


FIG. 49.—Circuit of trunk-hunting connector.

bank has double contacts instead of single ones as shown on Fig. 48.

Operation of Trunk-hunting Connector.—Figure 49 is a complete circuit diagram of the small-group type of trunk-hunting connector. Relays *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H* operate in the same manner and have similar functions to the correspondingly lettered relays of Fig. 48, except that some have additional contacts made necessary by the trunk-hunting feature. Relays *J* and *K* have been added and the wiper assembly has an additional wiper called the "extra control" *EC*. Relay *J* is operated by the rotary relay *E* and relay *K* by the busy relay *G*, their respective purposes being to provide the trunk-hunting feature and a busy signal. The extra control *EC* and control normal *CN* contacts of each P.B.X. trunk are connected together, with the exception of the last trunk in a group. In the last trunk the *EC* contact is dead. This arrangement prevents further rotation

of the switch and causes the busy tone to be transmitted to the calling subscriber when all trunks are busy. This scheme permits the assignment of trunk groups of various sizes on the trunk-hunting connectors and also enables the use of trunk-hunting connectors for individual lines.

The seizure of the switch and the vertical movement are accomplished in the same manner as in the individual-line connector. The "units" or rotary impulses from the dial operate the relay *E*, the magnet *RM* and in addition the relay *J*. The circuit for their operation is from ground at contacts of relay *A*, through contacts of relay *B*, contacts of *ONS*, contacts of relay *C*, contacts of relay *G*, and winding of relay *E*; at this point the circuit divides, one leg going to battery through the winding of relay *J* and the other through contacts of relay *H* and winding of magnet *RM* to battery. Relays *E* and *J* will operate and remain operated through the pulsing period, and magnet *RM* will operate and rotate the wipers in accordance with the break-impulses of the dial. The wipers will then rest on the contacts of the first trunk to the desired private branch exchange.

If this trunk is idle, that is, the control normal is ungrounded and connected to battery through the bridge cut-off winding of the line-switch magnet, relay *H* will be partially operated through its upper winding and will close its *X* contact. This contact will complete a circuit, which will fully operate relay *H* and connect the trunk conductors of the switch through to the negative and positive normals of the private branch-exchange trunk line. The battery from the line switch will also be connected to the extra control wiper *EC*, but this will have no effect on the operation of the switch. The remaining operations necessary to complete the connection and ring the subscriber's bell are similar to those already described for the individual-line connector.

If the first trunk is busy, that is, ground is connected to the control normal *CN* and also to the extra control *EC*, relay *G* will be operated, from ground at *CN* through contacts of relay *J*, contacts of relay *H*, and winding of relay *G* to battery. Relay *E* will release shortly after the last break-impulse, but, since relay *J* is slow in releasing, it will remain in an operated position for a short time longer and complete a circuit for the operation of relay *K*, from ground on wiper *EC*, through contacts of relay *J*, relay *E*, relay *G*, interrupter springs of magnet *RM*, and winding of relay *K* to battery. Relay *G* will operate the magnet *RM* over a circuit, from battery at its winding, through contacts of relay *H*, contacts of relay *K*, and to ground at contacts of relay *B*. It will be recalled that relay *J* was originally operated by relay *E*, which releases shortly after the last break-impulse but, however, relay *J* is retained in an operated position during the trunk-hunting period by being connected in parallel with the magnet *RM* when relay *E* released.

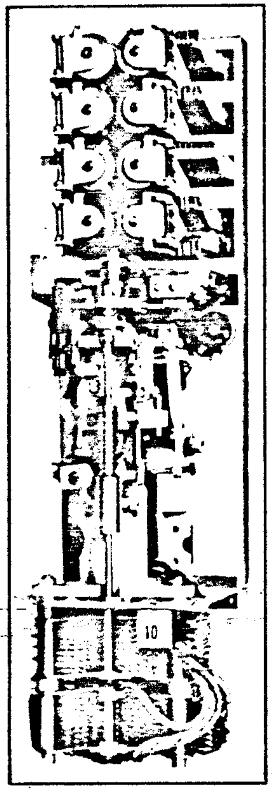


Fig. 50.—Frequency-selecting connector.

When magnet *RM* operates and steps the wipers to the contacts of the next trunk, relay *G* will be released but, if this trunk is also busy, relay *G* will be immediately operated again. Relay *G* will continue operated until an idle trunk is reached when the remaining operations of the switch will be completed as before described.

If all the trunks of a group are busy, the wipers will stop on the contacts of the last trunk of the group. The extra control *EC* and control normal *CN* contacts of this trunk are not connected together, and therefore relay *G* will operate, but relay *K* will not. Failure of relay *K* to operate will permit relay *J* to release and in so doing will complete the busy-tone circuit to the calling station.

The release of the trunk-hunting connector is the same as that of the individual-line connector previously described. The supervisory signals ("Supy. #1 and #2") are provided for the same purpose as described for the individual-line connector.

Frequency-selecting Connector.—Selective ringing for two- and four-station party lines in step-by-step systems is usually provided for by assigning the different kinds of ringing current required in the selection each to a separate connector board. Thus with four-party harmonic selection four separate groups of connector boards would be required, each provided with one of the four frequencies of ringing current. The party-line subscribers are assigned numbers which will extend the connections to the particular connector boards that are equipped with the proper frequency for ringing the bells of their respective stations. Another method is by the use of *frequency-selecting connectors*. These connectors may be used for as high as ten-party line service, the ringing selection being accomplished by an additional digit in the directory numbers. They may also be arranged for code ringing.

The frequency-selecting connector (Fig. 50) is similar in appearance to the selectors and individual-line connectors but has a frequency-selecting mechanism in the form of a minor switch, mounted directly below the group of relays at the top. An unmounted minor switch is shown in Fig. 51. It is a rotary switch, in which the wipers are returned to normal by a spring, when the switch is released.

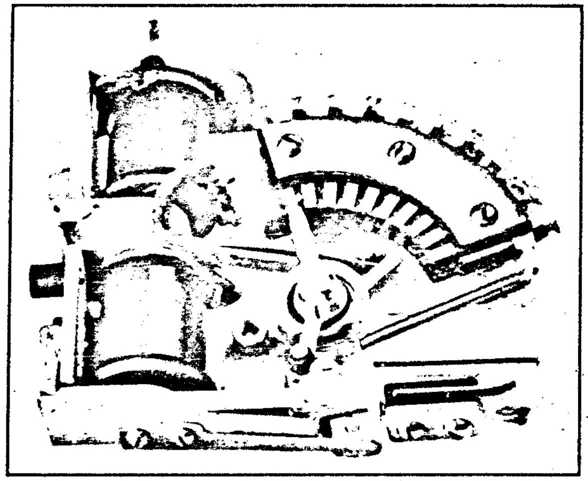


Fig. 51.—Minor switch of frequency-selecting connector.

Operation of Frequency-selecting Connector.—Figure 52 is a circuit diagram of a frequency-selecting connector, adapted for 10-party harmonic ringing over either limb of the line circuit. The line-selecting operations of this switch are the same as for an individual-line connector as previously described in connection with Fig. 48. The circuit of the frequency-selecting minor switch *J* is shown at the extreme right.

The additional digit dialed selects the proper one of five ringing frequencies and the side of the line over which it is to be sent, the minor switch being used to register this digit. The bottom level of contacts of this switch are connected to five different frequencies, contacts 1 to 5 being multipled respectively to contacts 6 to 0. The top level of contacts is divided into two groups, the contacts of each group being multipled together. The purpose of the top level is to reverse the line for the second five stations.

The circuit for the break-impulses of the last, or frequency-selecting, digit is from ground at contacts of relay *A*, contacts of relay *B*, off-normal springs, contacts of relays *C*, *G*, and *H*, and winding of minor-switch rotary magnet *Rot* to battery. Magnet *Rot* will operate with each break-impulse and rotate the minor-switch wipers to the proper contacts for the desired frequency

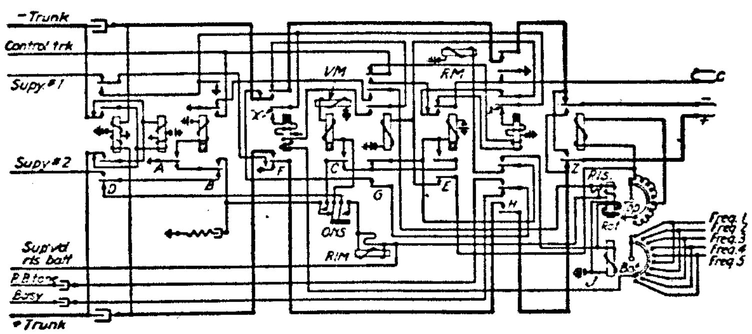


Fig. 52.—Circuit of frequency-selecting connector.

and ground connection to the line. The ringing current will then be applied to the subscriber's line, through the minor switch in the manner described for the individual-line connector. However, if the station called is in the second group, requiring the reversal of the line, relay *Z* will reverse the wipers of the switch with respect to the trunk conductors and transfer the ringing ground connected to relay *F* from the positive to negative wiper.

When the connection is no longer desired, the connector switch is released in a manner similar to an individual-line connector, except that the release magnet *Rls* of the minor switch *J* is operated and permits the switch to restore to normal, when relay *B* releases. The release of the connector is controlled by the last party to replace his receiver, but the release of the minor switch is controlled only by the calling station.

Reverting-call Switch.—In the Strowger system, provision is made to enable a subscriber on a party line to call another on the

same line, such calls being termed "reverting" calls. Although it is possible to design the switches and circuits so that a subscriber may make a reverting call by dialing the regular directory number, it has been found more economical to handle this traffic by other methods. In one method of operating, the subscriber may be instructed to call an operator by dialing a special number. The operator receiving such a call, after instructing the subscriber to hang up, dials the desired number in the ordinary way. The bell of the called station is rung, and, after waiting a few moments, the calling subscriber again removes his receiver and talks with the called party. The operator may either hold the connection and supervise the call or release it and permit the two subscribers to converse with each other by means of current derived from the first selector.

Another method employed is to assign special numbers for party-line subscribers to use when calling other stations on the same line. This information may be given either in the telephone directory or by means of an instruction card placed at each party-line telephone. This method of operating requires the use of a special mechanism called a "reverting-call switch." The subscriber first ascertains the special call number for the desired station, dials the number, and hangs up. Immediately both the bells at the calling and called stations will start to ring alternately and, when the called party answers, the bells will stop ringing, the calling subscriber will again remove his receiver from the hook switch and find the called party on the line. If after a reasonable time the bells continue to ring, indicating that the called station does not answer, the calling subscriber will remove his telephone from the hook switch momentarily and thereby disconnect the circuit and the reverting-call switch used in the connection.

Impulse Repeaters.—In the foregoing description of selector switches it will be recalled that each trunk circuit between switches consists of three conductors: two for the talking circuit and one for the control conductor. When inter-office trunks are involved, two-wire trunks are, of course, to be desired. Two types of impulse repeaters are employed to permit the use of two-wire trunks: namely, the "one-way" for use in trunks on which connections are established in one direction only, and "two-way" for trunks on which connections may be established in either direction.

Figure 53 shows an individual repeater unit which consists of a group of relays and a resistance spool mounted on a relay mounting plate, with no mechanical step-by-step progressive switching mechanism. Mounted at the lower right corner of the plate is a test jack to facilitate testing.

One-way Repeater.—Figure 54 is a circuit diagram of a one-way impulse repeater. This shows at the left the three trunk conductors, from the banks of the preceding local switch connected to the relay group of the impulse repeater. At the right is a portion of the circuit of an incoming selector at the distant central office, this being connected to the circuit of the impulse repeater by a two-wire inter-office trunk.

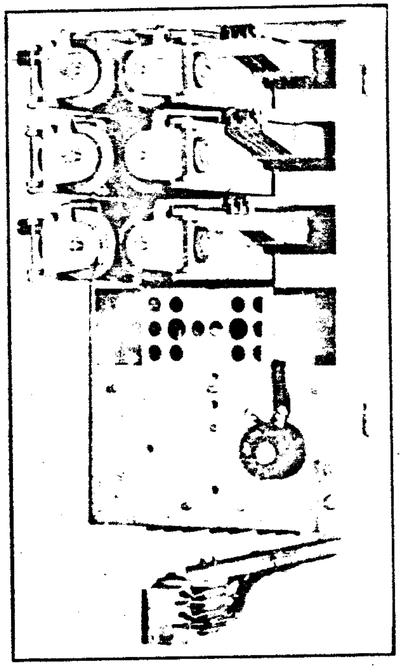


Fig. 53.—Impulse repeater.

The line relay *A* and the release relay *B* of the repeater perform functions similar to those already described, in receiving the impulse signals, guarding and holding the connection, and releasing at the end of the conversation. The shunt relay *C* shunts windings of relays *E* and *F* to reduce the impedance of the impulsing circuit. The back-bridge relay *E* operates a chain circuit for the purpose of indicating when all the trunks of a group are busy and serves as a high-impedance bridge across the trunk during conversation. The differential relay *F* operates on the reversal of current at the distant office connector and controls the operations of the reversing relay *D*. The reversing relay *D* reverses the battery to the calling station, when the called station answers, and controls the windings of relay *E*, bridged across the inter-office trunk side of the impulse repeater during conversation. The reversal of the battery on the calling line is to provide for the operation of message registers, as will be described, and

also to provide means of visual supervision in case of calls originating at manual switchboards.

When the trunk with which the repeater is associated is connected with at a local selector multiple bank, relay *A* is energized, operating relay *B* in the manner previously described. The operation of relay *B* places a guarding ground on the control trunk through one of its upper sets of contacts and prepares a circuit for the subsequent operation of relay *C* through its lower set of contacts. It also completes a circuit from battery at the lower winding of relay *F* to ground through one of its upper sets of

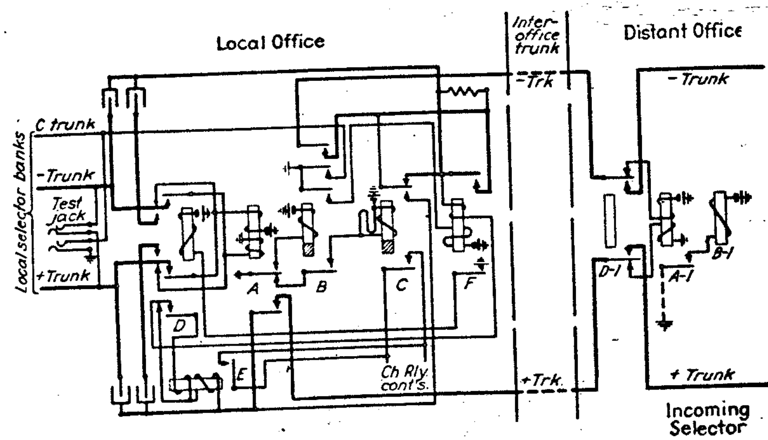


Fig. 54.—Circuit of one-way impulse repeater.

contacts. Current through this winding of relay *F* will magnetize its core but not sufficiently to cause it to operate.

An impulsing circuit has now been prepared for repeating the impulses to the selectors in the distant office. This circuit is from battery at the upper winding of relay *A*-1, upper contacts of relay *D*-1, negative trunk, contacts of relays *B* and *C*, upper winding of relay *F*, contacts of relay *D*, right winding of relay *E*, contacts of relay *A*, positive trunk, lower contacts of relay *D*-1, and lower winding of relay *A*-1 to ground. The two windings of relay *F* are so connected that the current now flowing in them will not operate the relay. Relay *E* will be operated over the above circuit simultaneously with relay *A*-1 and will close a pair of chain contacts. When all the repeaters in a group are busy, a circuit is closed through all the chain contacts in series, which operates a register. When relay *A* releases on the first break-impulse from the subscriber's dial, a circuit will be completed for the operation of relay *C*. Relay *C* is of the slow-release type and will, therefore, remain operated during the pulsing period of each digit. Relay *C*, on operating, shunts the upper winding of relay *F* and the right winding of relay *E*, thereby providing a low-impedance path for the repeated impulses. Relay *C*, also maintains the chain circuit when relay *E* releases. At each break-impulse the above circuit will therefore repeat the dialed impulses to relay *A*-1 of the incoming selector. The resistance, shown above relay *F* and bridged across the contacts of relay *C*, is to prevent the possibility of an extra impulse being sent to the incoming selector when relay *C* operates on the first break-impulse. At the end of each series of impulses, relay *A* remains operated and relay *C* releases. The digits of the required number are repeated to the *A*-1 relay by the above circuit.

When the called subscriber answers, the battery on the inter-office trunk is reversed by the connector. This reversal of current will operate relay *F*, since the current flow in its upper winding will be reversed, and both windings will then produce magnetic flux in the same direction. Relay *F*, on operating, will energize relay *D* through its lower set of contacts, and relay *D* will operate and reverse the battery feed to the calling station. Relay *D* also, when operated, increases the impedance of the bridge across the inter-office trunk by placing in series through its lower set of contacts both the right and left windings of the bridged relay *E*. This additional impedance will prevent the selectors and connector in the distant office from releasing and will also improve the voice-frequency transmitting quality of the trunk circuit. For inter-office trunks of considerable length, additional condensers are connected in multiple with those permanently in the circuit, through contacts on relay *D*.

When the connection is no longer desired and the receiver at the calling station is replaced on the hook switch, relay *A* of the impulse repeater will release. Relay *B* will shortly afterwards release and remove the guarding and holding ground from the control trunk. However, before relay *B* releases, relay *C* will be operated and prevent the opening of the chain circuit before the repeater has been entirely cleared. When relay *C* finally releases, the repeater circuit will be restored to normal. The circuit of the selectors and connector in the distant office has been held in an operated position through the lower set of contacts of relay

A and, when this relay released, the switching train in the distant office was restored to normal in a manner previously described for the selector switch and connector.

Two-way Repeater.—The two-way impulse repeater provides for repeating impulses over two-wire inter-office trunks in either direction and therefore permits the use of inter-office trunks for calls originating at either central office. However, repeaters are required at both ends of each trunk. Its use is mainly with small offices in which the inter-office traffic does not warrant the use of one-way trunks. Figure 55 shows the circuit diagram of a two-way repeater, and it is similar in design and operation to the

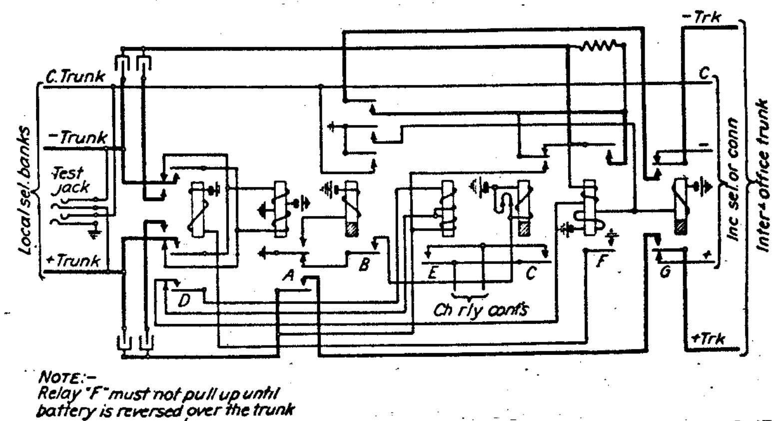


FIG. 55.—Circuit of two-way impulse repeater.

one-way repeater (Fig. 54), except that another relay, designated as relay *G*, is added to the circuit.

On outgoing calls, or calls from the local office to a distant office, relay *G* is operated from contacts of relay *B*. The operation of relay *G* disconnects the incoming selector in the local office from the trunk and also closes the trunk loop circuit to the incoming selector in the distant office through the upper winding of relay *F* and the lower winding of relay *E*. Relay *G* is of the slow-release type to insure that, on releasing from outgoing calls, the selectors in the distant office release before the incoming selector in the local office is reconnected to the trunk. This prevents the selectors in the distant office from being locked up until the called station disconnects.

On incoming calls from the distant office, the trunk wires are connected through the contacts of relay *G* directly to the incoming selector. When the incoming selector is seized, it places ground on the control trunk to make the trunk busy to outgoing calls.

Outgoing Secondary Line Switches.—When the number of trunks in a group between central offices is large, the number of such trunks required to handle the traffic can be reduced by the use of *outgoing secondary line switches*. These line switches may be of the plunger or rotary type, and they are inserted between the selector banks and the impulse repeaters. The additional annual charges for the line switches must be balanced against the annual charges for the repeaters and trunk conductors saved, in determining whether or not the use of outgoing secondary line switches is warranted.

The types and circuits of line switches used are similar to those employed for local secondaries as already described.

Two arrangements of outgoing secondary rotary line switches are used, one providing for post-selection of the trunks, and the other, pre-selection. This latter arrangement, however, does not provide for full pre-selection of trunks but does decrease the average time required for a switch to select an idle outgoing trunk. The pre-selection takes place only when all but one of the idle outgoing rotary line switches, associated with a particular outgoing-trunk group, are resting on the contacts of busy trunks. The wipers of these line switches are then rotated until at least the wipers of two line switches are resting on the contacts of idle trunks.

Switching Selector Repeater.—Briefly, a suboffice is a subsidiary office serving a portion of the line numbers nominally assigned to its main office. It is usually a comparatively small office located in the outskirts of a central-office area, where the telephone development is such as to make a separate line center more economical than to extend all of the subscriber's lines to the main office. Such an office is usually connected with the main office of which it is a subsidiary, by a group of two-way trunks, and traffic between it and other offices of the system is routed over the trunk groups of the main office. When it is desired not to trunk the local suboffice calls through the main office, "*switching selector repeaters*" are employed.

A switching selector repeater consists of a Strowger-type selector switch and an impulse repeater, with a means for switching from one function to the other, combined in one unit. It has the same appearance as a selector switch, except that the

relay group has more relays and the control bank is equipped with "extra-control" contacts similar to a trunk-hunting connector. Its functions are to complete local suboffice calls without the use of the main-office apparatus, and to extend the connections for other calls to the main-office apparatus where they are completed in the same manner as calls originated by a subscriber in the main office. Incoming calls for suboffice numbers are completed in the same manner as for subscribers' numbers in the main office, except that impulse repeaters are required in the connections to the suboffice to permit the use of two-wire trunks.

The block of numbers assigned to the subscribers' lines in the suboffice are distinguished by the first, first and second, or first, second, and third, digits, depending upon the size of the system and the size of the suboffice.

With respect to the point at which the connection is switched from the main-office trunk to the local numerical switches, three types of switching selector repeaters have been designed. One type switches on the first digit and is for use where no other numbers in the system begin with the same digit as those of the suboffice; the two other types switch on the second and third digits respectively. The type which switches on the second digit is the one which finds most frequent application in practice.

Operation of Switching Selector Repeater.—Figure 56 is a schematic diagram showing the use of switching selector repeaters in a 1,000-line suboffice, in a five-digit exchange system. The portion above the broken line is the switching equipment at the suboffice, and that below, the part of the main-office switching equipment required for use with the suboffice. At the upper left are the primary line switches to which the suboffice subscribers' lines are connected, and to the right of these are the outgoing secondary line switches. Below the line switches, from left to right, are the switching selector repeaters, local third selectors, incoming third selectors, and the connectors of the suboffice. The arrangement at the main office shows the numerical switches regularly required for a 10,000-line office in a five-digit exchange system, except that incoming first selectors from the suboffice have been added, and the fifth levels of the second selectors are extended through outgoing trunk repeaters to the suboffice, instead of to local selectors and connectors. Two-way trunks are shown between the main office and suboffice. The numbers assigned to the suboffice, in the case illustrated in the drawing, comprise the 35,000 group, and the remaining lines in the 30,000 group are served by the main office. Hence, it will be noted that at the main office the third levels of the first-selector bank are carried to local second selectors; and that the fifth levels of these second selectors are extended through repeaters to the suboffice. At the suboffice the fifth levels of the switching selector repeaters are

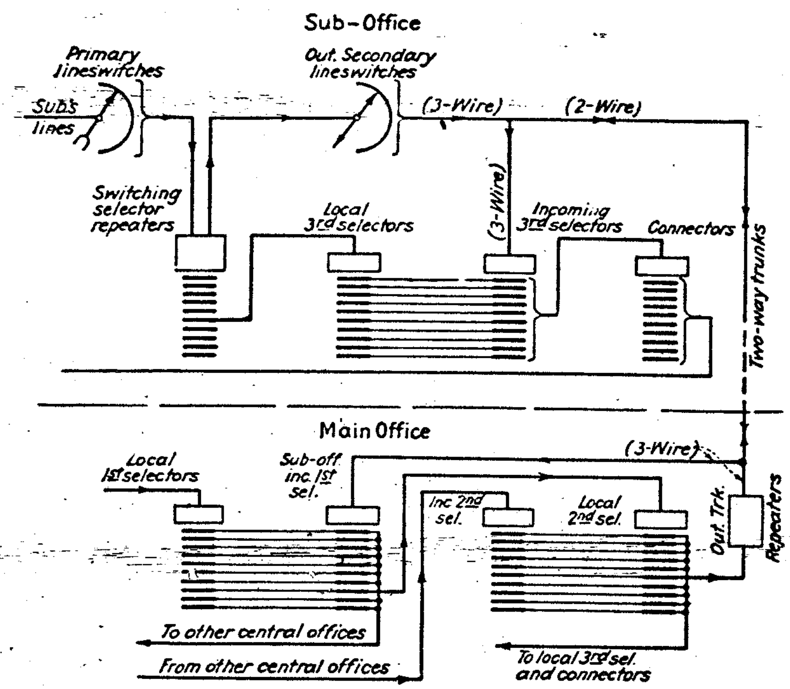


FIG. 56.—Diagram showing use of switching selector repeater.

the only ones having trunks connected, and these are carried directly to local third selectors.

When a calling subscriber at the suboffice lifts his receiver, the primary line switch extends the connection to an idle switching selector repeater, which, in turn, causes its associated outgoing secondary line switch to operate and select an idle trunk to the main office. The connection now terminates in a switching selector repeater at the suboffice and an incoming first selector at the main office. When the subscriber dials the first digit of any desired number in the system, the line relay of the switching

selector repeater receives the break-impulses and repeats them over the trunk, operating the vertical magnet of the first selector in the main office. At the same time, the vertical magnet of the switching selector repeater is also operated, and, therefore, the wiper shafts of both switches will be raised simultaneously. The incoming third selector, in the suboffice, while connected to the trunk between the two offices, is prevented from operating at this time by a cut-off relay, operated over a third wire between it and the outgoing secondary line switch. This operation is similar in principle to that of the cut-off relay of a line switch when a line is seized by a connector.

It will be noted from the groups of numbers assigned to the different offices that the first digit distinguishes between calls to distant offices and to the combined main and suboffice group, whereas the second digit is required to distinguish between calls to the main office and to the suboffice. Hence, the action of this "second-digit type" switching selector repeater, at this point, is necessarily dependent upon the first digit dialed.

If the number being called is in a distant office, the switching selector repeater wipers are stopped, by control furnished over the extra-control (*EC*) wiper, on the first contact of the dialed level, and they will remain there throughout the call, the switch acting as a repeater.

When the number being called is in either the main or suboffice, the *EC* wiper of the switching selector repeater encounters a potential on the first contact of the dialed level (the third level in the drawing), which causes the shaft to be restored to normal. On the second digit, the shaft is again elevated, this time, in unison with a second selector in the main office. The potential now encountered by the *EC* wiper will distinguish between main-office and suboffice numbers. If a main-office number has been dialed (any digit except 5), the wipers will remain on the first contact of the level, and the switch will function as a repeater during the remainder of the call.

If a suboffice number is dialed, the switch shaft is restored on the first digit exactly as before, but on the second digit no potential is encountered by the *EC* wiper, thus permitting the wipers to rotate over the contacts of the first level and seize an idle trunk to a local third selector. The operation of the switching-through relay of the selector repeater causes the opening of the loop through the inter-office trunk, thereby releasing the local outgoing secondary line switch at the suboffice and the first and second selectors in the main office.

Incoming calls to suboffice subscribers are routed in a manner similar to any other inter-office traffic. Connections for such calls are extended to either local or incoming second selectors at the main office in the usual way. When the second digit (5) is dialed, the wiper shaft of the second selector will be elevated to the fifth level and then rotated until the wipers rest on an idle outgoing trunk to the suboffice. At the suboffice these trunks are connected to incoming third selectors. The remaining digits of the number will then extend the connection to the desired suboffice line. In order to prevent the incoming first selectors in the main office from operating when a suboffice trunk is seized, the outgoing repeaters are equipped with cut-off relays, which are operated over a third wire from the first selectors, as previously described for the incoming third selectors at the suboffice.

The release of the switches involved in the switching train is accomplished by the same principle as previously described for other Strowger-type switches.

While in the above illustration the switching selector repeater has been described for use in a multi-office system, it is obvious that this apparatus can be used when only one main office is involved.

Paystation Repeater.—Paystations equipped with multi-slot coin boxes operating on either the "post-payment" or the "pre-payment" plans are used. With post-payment coin boxes no additional apparatus other than the paystation instrument is required, but pre-payment boxes require special apparatus at the central office. Pre-payment service is usually operated on the plan of requiring the deposit of a coin before calling for an exchange number and of no such deposit before calling a service or toll-recording operator. However, the circuits may be arranged so that it is necessary to deposit a coin even before calling an operator.

The apparatus required at the central office for pre-payment paystation service is embodied in what is called a "paystation repeater." This consists of a group of relays, resistances, and a retardation coil, mounted together as a unit and having the general appearance of the impulse repeater shown in Fig. 53, although, having more relays, its mounting plate is considerably longer. In order to permit the extension of calls to an operator, without first

depositing a coin, it is the usual practice to provide a special train of switches for that purpose. Paystation repeaters are usually connected in the trunks from the primary line switches associated with the paystation lines. The switches directly connected to the repeaters may be first selectors, secondary plunger line switches, or secondary rotary line switches.

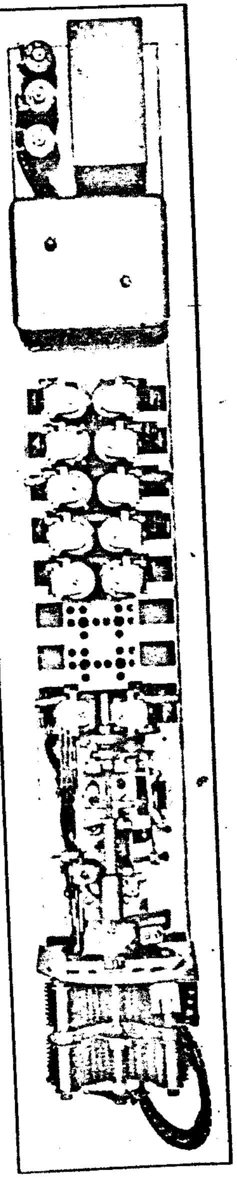


Fig. 57.—Toll transmission selector.

Toll Switch Train.—Toll calls to step-by-step subscribers are usually routed from the toll board to the central office over toll dialing trunks, and thence to the subscribers' lines through a toll switch train, consisting of special switches. The main reasons for using special switches for this purpose are to provide for the supervision of the call and control of ringing by the toll operator and also to establish the most favorable conditions for transmission. The interrelation of the operation of the different switches in the train is such that it is more convenient to describe these special switches together than as separate units of apparatus.

The toll switch train employs three types of numerical switches. These types are called "toll transmission selector," "toll intermediate selector," and "combination toll and local connector." Sometime "toll connectors" are utilized instead of the combination toll and local, but the more general practice is to use the combination type.

Toll Transmission Selector.—The toll transmission selector switch, shown in Fig. 57 with its metal cover removed, consists as usual of a relay group and switch mechanism, and in addition as shown at the top of the mounting plate, a repeating coil, transmission condensers, and resistance coils. The switch is also equipped with 400-point banks, to provide for four-wire trunk circuits. The extra equipment requires that the base of the switch be approximately twice as long as that of the regular selector (Fig. 44) and it therefore uses two selector shelves, spaced at the standard mounting distance.

The toll transmission selector functions in the same manner as a regular or local selector when hunting a free trunk to a toll intermediate selector, or a special connector, but differs in that, after the trunk-selecting operation is completed, it has additional duties to perform. It is required to repeat the break-impulses to the toll intermediate selector and the toll connector, to supply talking current to the called subscriber, and to provide for all necessary supervision. This supervision may include the collect and refund of coins on paystation calls. There are, accordingly, two classes of toll transmission selectors—one of the non-coin type and the other of the coin type.

Toll Intermediate Selector.—The toll intermediate selector is similar to a regular selector in general appearance, except that it is equipped with a 400-point bank. The functions of the switches are also similar, except that the toll intermediate selector employs four-wire trunks to extend the extra control lead from the transmission selector to the toll connector, in order to enable the toll operator to control the ringing at the connector.

Combination Toll and Local Connector.—The combination connector may be of the individual line, trunk-hunting, frequency-selecting, or of any other type suitable for use with the central office in which it is installed. The individual-line type will be used as a typical example in the following description. In appearance it resembles very closely the individual-line connector, except that an additional relay is required to provide ringing control and supervision for the toll operator.

Operation of Toll Switch Train.—Figure 58 is a circuit diagram of a typical toll train, for a four-digit central office, using individual-line combination connectors. The non-coin-type toll transmission selector circuit is shown at the upper center and left, the toll intermediate selector at the upper right, and below is the circuit of the combination toll and local connector. The relays *A*, *B*, *C*, *D*, and *E* of the toll transmission selector perform similar functions to those already described for the ordinary selector in connection with Fig. 45. Relays *F*, *G*, *H*, *R*, and *S* are additional ones. The repeating coil and condensers shown at the left of the diagram are added to produce the most favorable conditions for speech transmission. The added resistances *Y* are provided to

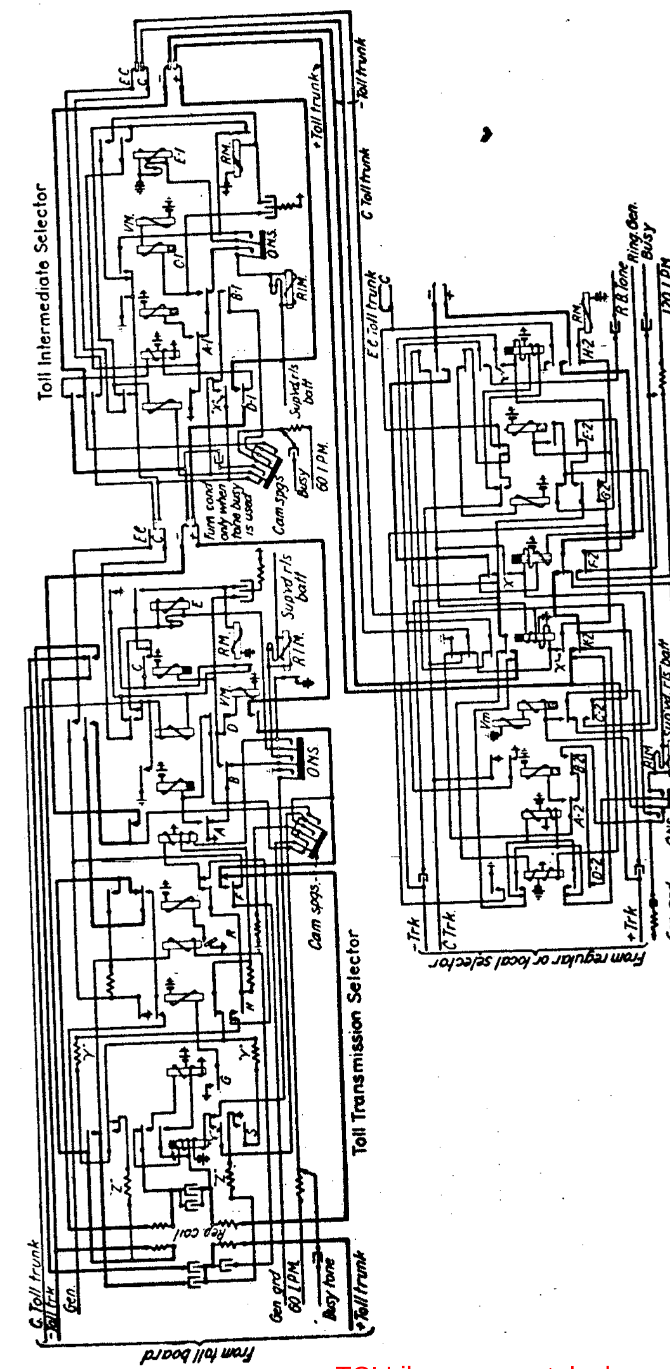


FIG. 58.—Circuit of toll train for four-digit central office.

maintain the current-flow limits of the connecting toll board, and resistances *Z* are used to adjust the trunk-circuit resistance to a standard value.

The trunk entering from the left is from the toll board, which in this case is assumed to be manually operated. The switch *ONS* and cam springs operate in similar manner to those already described for other switches but have additional contacts. The toll switch train may be equipped for either audible or visual signals at the toll board, and in this circuit diagram both arrangements are shown.

In the toll intermediate selector relays *A*-1, *B*-1, *C*-1, *D*-1, and *E*-1 perform similar functions to the relays *A*, *B*, *C*, *D*, and *E* in the ordinary selector switch (Fig. 45), except that additional sets of contacts are provided to extend the extra-control *EC* lead from the transmission selector to the connector. Relays *A*-2, *B*-2, *C*-2, *D*-2, *E*-2, *F*-2, *G*-2, and *H*-2 of the combination toll and local connector are similar to the correspondingly lettered relays of the individual-line connector (Fig. 48) and perform similar functions with some added features. Relay *K*-2 is the additional supervisory control relay.

In the present diagram (Fig. 58), the toll trunk conductors from the toll intermediate selectors are shown entering the circuit of the connector at the top, and the local trunk conductors from the regular or local selectors are shown entering at the left. The local selector trunks are connected to the last contacts on the local selector bank levels and the toll trunks to only the toll intermediate selector bank levels. Thus, the combination connectors are used for local calls only when all the regular connectors are in use, and only the combination connectors are available to the toll intermediate selectors. On calls from local selectors the combination connector operates as any other connector, but on toll calls the operation must provide for manual supervision, special talking battery, and manually controlled ringing. All the mechanical functions of these switches are accomplished in accordance with the previously described principles of the Strowger-type switch.

To complete a call from the toll board to a subscriber, the toll operator plugs a calling cord into a trunk leading to a toll transmission selector, operates the "dial" and "talk" keys, and dials the desired number. If the subscriber's line is free, a cord supervisory lamp glows, indicating that connection has been

made to the called line. When the operator is ready to ring the called subscriber, the pressing of a ringing key will cause the operation of an alternating-current relay in the toll transmission selector, which starts the machine ringing by the toll connector. The cord supervisory lamp is extinguished and the machine ringing is stopped when the called subscriber answers. When the called subscriber replaces the receiver on the hook switch, the cord supervisory lamp again lights, giving the toll operator disconnect supervision. If an all-trunk-busy condition is encountered at the toll transmission or an intermediate selector, the cord supervisory lamp flashes at a predetermined frequency (or the busy tone is received). If the called subscriber's line is busy, a different frequency of flashing (or tone) is transmitted. When a busy condition is encountered, the toll operator must release the connection and dial again. It is possible, however, for the toll operator to reach a busy line over another path, called the "verification-switch train," to check a busy-line condition, or to notify a subscriber, then engaged with a local call, that a toll call is waiting for him, but the verification-switch train is never used for completing a toll connection.

When the toll operator connects with the circuit of the toll transmission selector, relay *A* (Fig. 58) is operated, which in turn operates relay *B* and places ground on the control trunk. Relay *A* follows the break-impulses from the dial and operates relay *C* and the vertical magnet *VM*. Relay *C*, in addition to its regular functions, short-circuits the winding of the repeating coil in the negative toll trunk, to reduce the impedance of the impulsing circuit. When the wiper shaft is lifted, the off-normal switch *ONS* operates and causes the operation of relay *E*.

When relay *C* releases, after the completion of the series of impulses, the rotary magnet *RM* is energized, steps the wipers to the first-bank contacts, and breaks the circuit of relay *E*. If the first trunk is busy, ground is connected over the wiper *C* to relay *E*, which re-energizes the rotary magnet *RM*. The switch will then rotate under the control of relay *E* and action of magnet *RM* until an idle trunk is found, when relay *D* will operate in series with relay *E*; however, relay *E* does not operate. At the time relay *D* operates, the circuit of relay *A* is still maintained, and the operation of relay *D* completes the circuit of relay *A*-1 of the toll intermediate selector. The circuit for the operation of relay *A*-1 includes the upper winding of relay *S*, but this relay can only operate sufficiently to close the circuit through its X-contact, owing to current through its lower winding. The closing of the contact X completes a locking circuit for relay S.

The second series of break-impulses are repeated to relay A-1 through the action of relay A. The slow action of relay S prevents this relay from completing its operation during the pulsing period. The vertical and trunk-hunting movements of the toll intermediate selector are the same as previously described for a regular selector switch. When the relay D-1 operates, a circuit through the upper winding of relay S completes the circuit of relay A-2 of the connector, and relay D-1 remains operated through grounds on the control trunk at relays B and B-2. Relays A-1 and B-1 are now released. Ground from relay B, over the control trunk, makes the connector busy to both local and toll selectors from the instant of seizure by the intermediate selector.

The next, or tens-digit, series of break-impulses is repeated to relay A-2 through the operation of relay A. The impulsing circuit for the vertical movement of the connector is established in the standard manner, except that ground is applied to the circuit through contacts of relay K-2. Relay C-2, in addition to its usual duties, energizes relay F-2 through its upper winding, and relay F-2 locks itself up through its X contact and the upper winding of relay K-2. The upper winding of relay K-2 is short-circuited through the X contact of relay F-2. After the last break-impulse of the series, relay C releases, opens the operating circuit of relay F-2, removes the short circuit from the upper winding of relay K-2, allowing relay K-2 to be energized in series with relay F-2, and transfers the impulsing circuit to the rotary magnet RM. Relay K-2 only partially operates to close its X contact.

The last, or units-digit, series of impulses now operates relay A-2, which closes the circuit of relay E-2 and magnet RM. The operation of relay E-2 connects the busy relay G-2 through to the control wiper, opens a part of the incompleted busy flash (or busy-tone) circuit, so that no signal will be sent back to the toll operator when the wipers pass over busy lines, and short-circuits the contacts of relay G-2 through which the impulsing circuit is carried. The rotary magnet RM follows the break-impulses of the dial and rotates the wipers to the bank contacts of the called line.

When the desired line is reached, and if it is found idle, relay E-2 releases and the lower winding of relay H-2 is energized over the control wiper in series with the BCO winding of the line-switch magnet associated with the called line. Relay H-2 operates and locks up through its upper winding. Relay K-2 now operates through its lower winding and transfers its locking circuit, and that of relay H-2, to ground on the control toll trunk; grounds the control trunk from the regular local selector; separates the toll and local control trunks; and opens the circuits of relays A-2 and B-2. When the circuit of relay A-2 is broken, the circuit through the upper winding of relay S is opened. Relay S is now allowed to complete its operation through its lower winding and reverses battery from relay A back to the toll board, as well as connecting battery-feed relay G to the called line. The reversal of battery operates a polarized relay at the toll board which in turn operates a lamp and gives the toll operator "seizure supervision." Relay A now has both windings connected to the toll-board trunk conductors. After receiving the seizure-supervision signal, the toll-board operator may proceed to ring the called station.

She operates her ringing key, when ready for the called station, and the ringing current operates the alternating-current relay R. The operation of relay R energizes relay F, which removes ground from the control lead EC, thus permitting relay F-2 of the connector to release and to connect the ringing generator to the called line. A ring-back tone is connected to the toll-board trunk through relay F-2. Ground placed on the positive trunk at the toll board holds relay A operated during the ringing period. When the called subscriber answers, relay F-2 will operate and again lock up to ground on the EC lead. Relay G is now operated through the circuit of the called subscriber's telephone and operates relay H. Relay H, when operated, breaks the metallic-circuit connection between the toll board and the toll switch train. This extinguishes the lamp at the toll board and gives the operator "answer supervision." Relay A is held operated through a resistance on the toll transmission selector. During conversation, relays A, B, D, G, H, S, D-1, F-2, H-2, and K-2 are maintained in an operated position.

When the called subscriber hangs up, relays G and H release. Their release re-connects relay A to the toll-trunk and gives the toll operator "release supervision." When the toll operator disconnects the toll trunk, relay *A* restores, followed shortly after by relay *B*, which releases relay *D* and these relays remove ground from the *C* and *EC* trunks, thereby releasing relays *D*-1, *K*-2, *F*-2, and *H*-2. The release of relays *A*, *B*, and *D* completes a circuit for the toll transmission selector release magnet *RlM*. When the switch *ONS* of the toll transmission selector restores, the locking circuits of relay *S* is opened, thereby permitting relay *S* to release. The release of relay *D*-1 completes the circuit of the release magnet *RlM* of the toll intermediate selector, and the release of relay *K*-2 completes the release magnet (*RlM*) circuit of the connector. The switches of the toll switch train are now all restored to normal and are ready for use in other connections.

When all trunks are busy, or the called subscriber's line is busy, the operation of the circuit is different, depending upon whether the "tone-busy" or "flash-busy" method is employed. In the following description, the visual flash-busy method only will be considered. The flash-busy leads are connected to a source of interrupted ground, the rate of interruption being 60 per minute for the toll transmission and toll intermediate selectors and 120 interruptions per minute for the connectors. The flash busy from the connector indicates that the called subscriber is busy, and from the selectors, that all trunks are busy. Relay *D* of the toll transmission selector will operate as previously described, and, after the cam springs close on the eleventh rotary step, the first flash-busy ground impulse will fully operate relay *S* and cause the reversal of battery to the toll board and light the supervisory lamp. Succeeding ground impulses will cause the operation of relays *G* and *H*, which will alternately pull up and release, thus intermittently breaking the connection from relay *A* to the toll board and causing the supervisory lamp to flash sixty times per minute. If all trunks are busy at the toll intermediate selector, the cam springs will be closed on the eleventh rotary step and the relay *D*-1 will be operated and locked up. The operation of relay *D*-1 will open the circuit of relay *A*-1 and thereby permit relay *S* to completely operate. Succeeding ground impulses will cause the operation of relays *G* and *H*, which will cause the supervisory lamp to flash sixty times per minute as previously described. At the connector, when the wipers rest on the contacts of a busy line, relay *E*-2 will release, lock up relay *G*-2, and complete a circuit from inter-

rupted ground through one winding of relay *D*-2. Relay *D*-2 will operate and cause relay *K*-2 to operate and lock up, thus breaking the circuit of relay *A*-2. This will permit relay *S* of the toll transmission selector to operate and lock up. Succeeding ground impulses will cause the operation of relays *G* and *H*. The supervisory lamp at the toll board will flash as previously described, except that the frequency will be 120 times per minute, indicating that the called subscriber's line is busy.

Line-finder Systems.—In general, as stated earlier in this chapter, the operation of a line-finder system is the reverse of

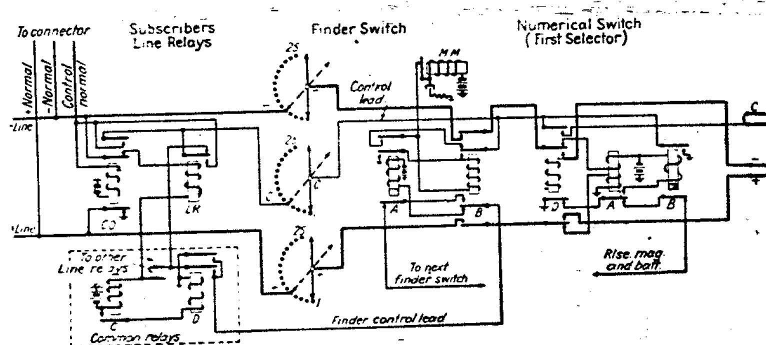


FIG. 59.—Circuit of line-finder system with 25-line units.

that of a line-switch system. In the latter system, each subscriber's line is connected directly to a line switch which selects an idle numerical switch, while in the finder system a finder switch, directly connected to a numerical switch, hunts and connects with the subscriber's line. The function of a line finder is, therefore, to seek a calling line from a comparatively large group of lines and to extend it to one of a smaller group of numerical switches. The outgoing circuit of a finder is connected directly to the incoming circuit of a numerical switch and, therefore, as soon as a calling line is connected with by a finder, the associated numerical switch is ready to receive the dialed impulses.

Line-finder System with Twenty-five-line Units.—The simplest form of line-finder system is that employing the non-homing type of rotary switch (Fig. 30), the principle of which has already been described. The subscribers' lines are directly connected to the bank contacts of the switch and, therefore, the number of lines which may be served by a group of finder switches is limited by the number of contacts in the bank level.

Figure 59 is a circuit diagram of one application of twenty-five-point rotary switches in a line-finder system. At the left are shown the subscribers' line relays for one line, one such set being required for each of the twenty-five lines in the group. Directly below are the common relays, one set for each group, for controlling the operation of the finder switches.

In the center of the drawing is shown one of the finder switches serving the group of lines. The number of such switches for the group is determined by the busy-hour originating calling rate of the group. This finder switch is a non-homing-type rotary switch, equipped with three bank levels of twenty-five contacts each. These contacts are multiplied throughout the switches of the group. The principle of its operation is similar to that previously described for the non-homing-type rotary line switch. The outgoing circuit of this switch is directly connected to the incoming circuit of a numerical switch or selector and, therefore, a selector switch is required for each rotary finder switch. At the right of the drawing is shown the portion of the circuit of a selector-type numerical switch involved in the functioning of the finder switch.

When a subscriber lifts his receiver in making a call, the line relay *LR* and the common relay *C* are operated over the subscriber's loop circuit, through contacts of the cut-off relay *CO*. Relay *C* operates the common relay *D*, thereby preparing a circuit for the operation of the finder switch. When relay *LR* operates, it disconnects the circuit leading through the contacts of the relay *D* and connects the control-bank multiple contacts of the calling line in the finder switches, to the control normal of the line. Since relay *D* has been operated, ground from its contacts will be placed on all the control-bank contacts of the finder switches, except those of the calling line, from which ground was disconnected by the operation of relay *LR*. This has established an identifying condition at the finder-switch banks, since ground has been placed on the control-bank contacts of all lines except the calling line.

The operation of relay *D* energizes relay *A* of the finder switch, through the finder control lead and contacts of relay *B*. Relay *A* closes a circuit for relay *B* and the motor magnet *MM* in series, from ground at relay *A* to battery at the winding of *MM*. It also connects a point between relay *B* and *MM* to the control wiper *C*. The operation of relay *B* and magnet *MM* will depend on the condition at the contacts on which wiper *C* is resting. It will be remembered that all contacts except those of the calling line were connected to ground when relay *D* operated; therefore, if the wipers are not resting on the contacts of the calling line, ground will be encountered. This ground will cause magnet *MM* to operate but prevent the operation of relay *B*. The magnet *MM* operates and steps the wipers to the next set of contacts and will continue to operate until contacts without ground—that is, contacts of the calling line—are reached. In this position, since the ground has been removed, relay *B* will operate, and magnet *MM* will not attempt to move its wipers, as this magnet cannot operate in series with the winding of relay *B*.

Relay *B* on operating will extend the positive and negative conductors of the calling line to the first selector, disconnect the winding of relay *A*, close a part of the finder control circuit to the next finder switch, and disconnect the control lead from relay *A* and connect it to ground through contacts of relay *A*. This ground, through the control-bank contacts and contacts of relay *LR*, will cause the cut-off relay *CO* to operate. Relay *A* is of the slow-release type to prevent the removal of ground from the control lead until another ground has been placed on this lead at relay *B* of the first selector.

Relay *CO* on operating will disconnect the *LR* and *C* relays from the line circuit and connect the control normal to the control lead. When relay *C* is disconnected, it will in turn restore relay *D* and thereby disconnect the finder control lead, unless relay *C* is held operated by some other line in the group attempting to call. When relay *B* of the finder switch operated, as the wipers connected with the calling line, the subscriber's line circuit was extended to the first selector. Relays *A* and *B* of the first selector then operated and placed the guarding ground on the control lead, and through contacts of relay *CO* also on the control normal. Relay *B* of the finder switch was also locked up through the same ground. After obtaining the usual dial tone from the first selector, the calling subscriber may proceed to dial the number desired. When the first selector has operated and extended the connection to the next switch, relay *D* of the first selector has operated and connected the control lead through to the *B* relay of the next numerical switch in the train.

Since the non-homing-type rotary switch is used with this system, the release of the connection restores relay *B* of the finder switch and leaves the wiper on the bank contacts of the line just released. If this subscriber should make another call before this particular finder switch has been selected for some other connection, the wipers will not be moved and the connection will be extended merely by the operation of relay *B*.

Incoming calls are extended to the subscriber's line in a manner similar to that used in line-switch systems. When the normals of the line are connected with at a connector, the cut-off relay is operated over the normal control. This relay disconnects the calling equipment from the line and places a guarding ground on the control lead, thereby grounding the control-bank contacts at the finder switches.

Line-finder System with 200-line Units.—Another system, more generally employed, utilizes both rotary and Strowger-type switches, which permits the use of 200-line groups. In this system, the apparatus is divided into three distinct groups: namely, the subscribers' line relays, the finder switches, and the group distributor equipment. These three groups operate as a unit, each having certain definite functions to perform in the extension of the calling line to the associated numerical switch.

Two relays of standard type, line and a cut-off, are required for each line, these being the only central-office apparatus associated individually with the lines. The manner in which they operate depends upon whether the call is originating or incoming. On an originating call, the line relay operates to "mark" or identify the calling line in the finder-switch banks; to start the operation of the associated distributor equipment, which in turn assigns a pre-selected finder to hunt for the line; and to prepare the circuit of the associated cut-off relay, so that it will operate as soon as a finder switch connects with the calling line. On an incoming call, both the line relay and the cut-off relay are operated in series over the control normal from the connector; the line relay has no functions to perform, but the cut-off relay disconnects the distributor circuit from the line relay to prevent operation of the finder switches.

The finder switch, two of which are shown in Fig. 60, is a Strowger-type switch. Each is equipped with three 200-point banks and associated sets of wipers. The top bank carries the contacts of the control trunks, and the two lower banks the line contacts. By means of two separate sets of line wipers, the switch covers twenty lines on each level, the control wipers testing

the lower and upper control contacts alternately until a calling line is found. The capacity of this type finder switch is, therefore, 200 lines. The relay group and operating mechanism are provided with a metal cover (not shown).

In addition to the standard banks and wipers, the finder switch is also equipped, as shown in Fig. 60, with a single wiper mounted on the wiper shaft, for operating over a special ten-point vertical

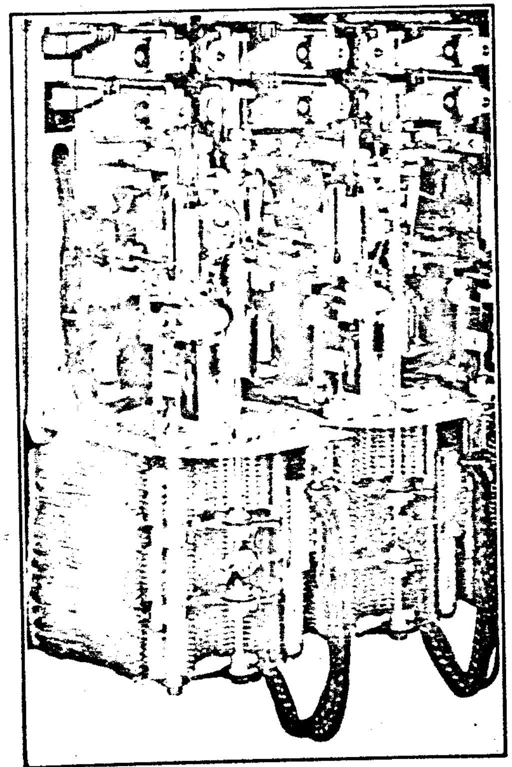


FIG. 60.—Line-finder switches—200-line units.

bank. This wiper breaks contact with the special vertical bank when the switch starts to rotate. It enables the finder switch, in the vertical movement, to determine the level to which a calling line is connected, the level of the calling line being marked on the corresponding contact of the vertical bank. The wiper shaft is elevated to this level, hunts over the horizontal bank, and connects with the calling line.

The finder switch is pre-selected by group-distributor equipment. Only one finder switch in a group may hunt at one time, and, as soon as a calling line is extended to a numerical switch, the common equipment is released for use in the next call. The release of the finder switch is under the control of the numerical switch with which it is directly connected, and the finder therefore releases immediately following the release of other switches in the switching train.

A principal feature of this system is the application of "preferential hunting" by means of a multiple reversal between the banks of two associated groups of line-finder switches. The lines, although arranged in groups of 200 on the banks of the finder switches, are actually served in 100-line groups under normal traffic conditions, each 100-line group having its individual

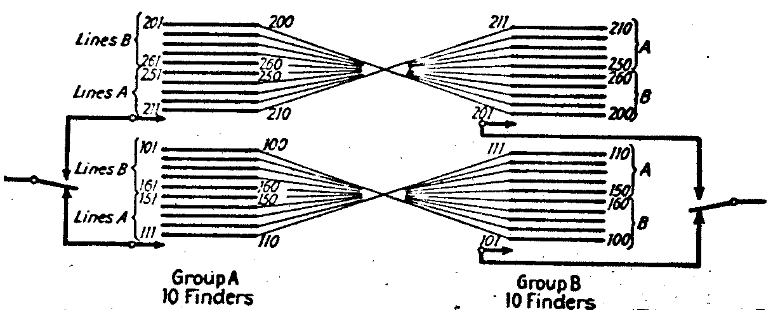


FIG. 61.—Multipling of line-finder switch banks.

allotment of line-finder switches. However, the 200-line grouping is established whenever the traffic in a 100-line group becomes abnormal to the extent that its allotment of finder switches is momentarily inadequate. The finder switches of the associated 100-line group are then assigned, by means of the group-distributor equipment, to serve the two 100-line groups until the traffic in the overloaded group again becomes normal.

The principal advantage of this arrangement of line grouping is that the individual lines of the two associated 100-line groups may be so transposed in the banks of the finder switches that the finder switches of neither group are required normally to hunt in the upper five levels. This results in the establishment of a uniform and minimum hunting time and reduces the possibility of lines in the lower levels "stealing" a finder switch from lines in the upper levels.

Figure 61 shows one method of effecting the transposition by means of a complete vertical and horizontal reversal between the banks of the two 100-line groups. By this arrangement, the lines farthest from the starting position of the finder switches of one group are given a more advantageous location in the other group. In the drawing it will be noted that numbers 111 to 150 and 211 to 250 (standard Strowger switch-bank numbering) form

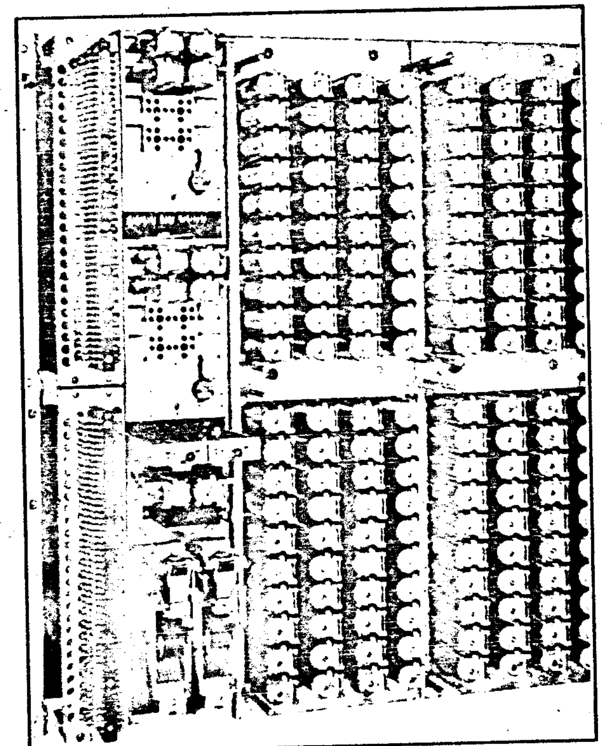


FIG. 62.—Group distributor and portion of line-relay equipment.

a 100-line group accessible to the finder switches of group *A* through the levels 1 to 5, inclusive. In a similar manner, except for a reversal in the direction of numerical sequence, numbers 161 to 100 and 261 to 200 form a second 100-line group accessible to the finder switches of group *B* through the levels 1 to 5, inclusive. Therefore, under normal traffic conditions, the finder switches serve the two 100-line groups without searching in the upper five levels. However, this arrangement of lines provides for the serving of the entire 200 lines by either group of finder switches whenever conditions require it.

The group-distributor equipment is shown in the left portion of Fig. 62, the right portion being a part of the subscriber's line relay equipment. The complete relay equipment consists of 200 sets of line and cut-off relays provided with metal covers. The group-distributor equipment shown is for 200 lines and consists of a five-level non-homing-type rotary switch and associated relays for each 100 lines, with two common keys mounted near the center. One of the keys provides a means for cutting out of service either group-distributing equipment temporarily, for testing or repair purposes. The other key is provided for routine testing of the distributor and finder switches.

A group distributor is associated with each 100-line group. Under normal conditions, each serves its own group of lines, but, in case either group of finder switches becomes completely occupied, the two group-distributor equipments are so interconnected that either may serve both groups. The calls are then picked up in the order in which they occur or, in the case of simultaneous calls, in the order in which they appear in the banks of the finders. As soon as a finder switch in the busy 100 group becomes free, calls in that group will be again served by the associated group-distributor equipment. This team-work feature operates automatically and is a safeguard against a group of 100 lines being left without finder switches in case of trouble or a busy condition in the group.

Figure 63 is a circuit diagram of a 200-line unit line-finder system. In the extreme upper center is shown one subscriber's line relay equipment in each of the 100-line groups *A* and *B*. Above the horizontal dash line are two line-finder switches, one for each of the groups *A* and *B*. Each group is often equipped with ten of these line-finder switches, although, as a matter of practice, the originating calling rate should determine the actual number to be provided. In the center, below the line relay equipment, are shown one set of switch-bank contacts for each finder switch, and immediately below these, two special ten-point vertical banks, one for each of the finder switches. The bank contacts of all the lines would be multiplied to all the switches in the groups, as previously described, in connection with Fig. 61, and the special vertical banks shown would be multipled to the other finder switches of each group. At the extreme left is a

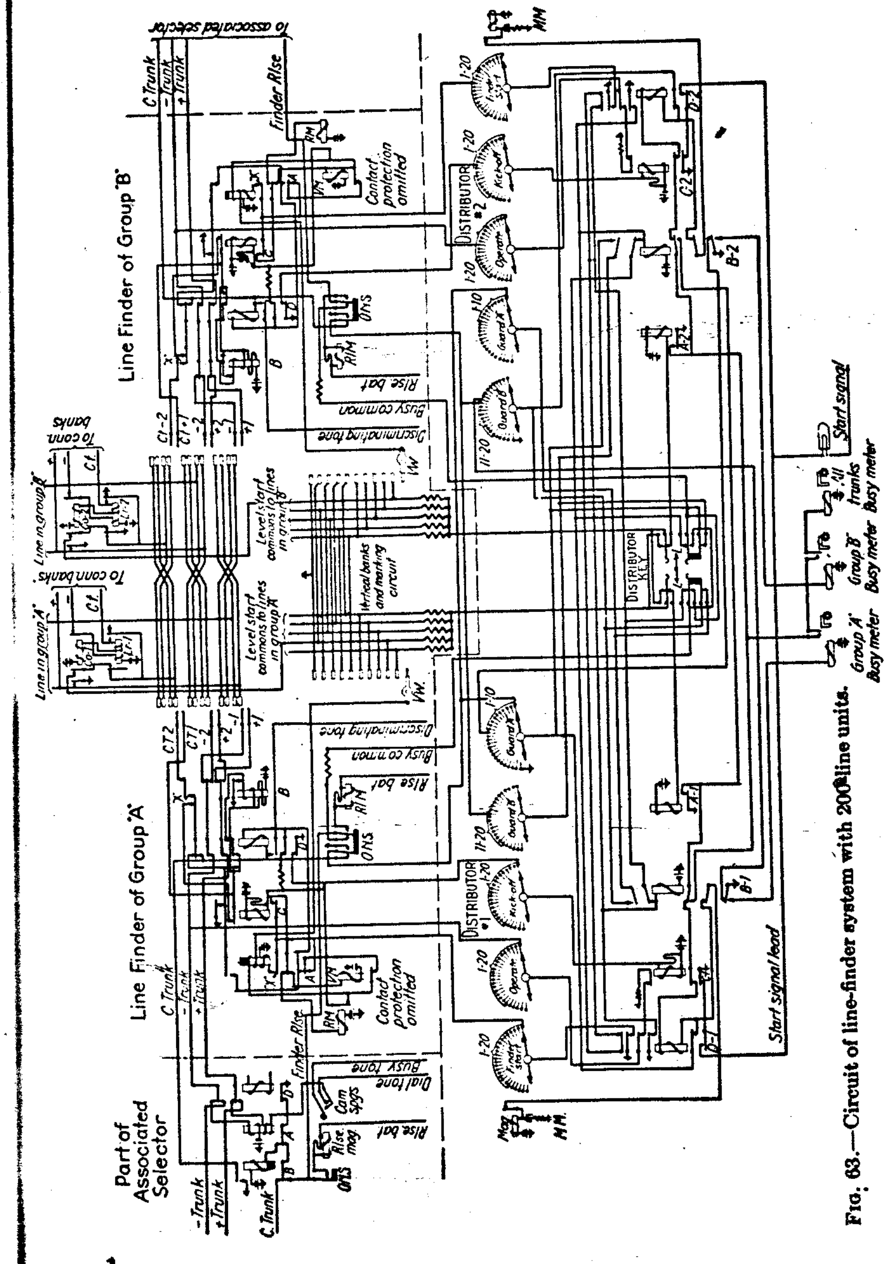


FIG. 63.—Circuit of line-finder system with 200-line units.

part of the numerical switch (usually a first selector) shown connected to the finder switch. Each of the ten finders in each of the groups would have corresponding numerical switches. Below the dash line are the two group-distributor equipments, one normally associated with each of the groups *A* and *B*. Immediately below this line are the non-homing-type rotary switches, each with five levels of bank contacts, and below these are the associated relay groups. In the lower center of the drawing will be seen the key for cutting out of service either one of the distributor equipments, and below this is the meter equipment for determining the adequacy of the line-finder switches provided.

The operation of the system, briefly, is as follows:

A ground from the line relay of the calling line starts the operation of the group-distributor equipment. A ground is placed on a lead to a pre-selected finder switch through the banks of the distributor switch, causing the finder switch to start its hunting operation. The finder switch steps vertically to the level of the calling line and then rotates until its wipers rest on the bank contacts associated with the line. As soon as the finder switch connects with the calling line, the group-distributor switch steps ahead and pre-selects a finder switch for the next call in the group. The distributor switch will not stop on the contacts of a busy finder, and, if it pre-selects a finder switch which later becomes busy (due to switchman testing), the distributor switch then steps to the next idle finder switch.

Only one finder switch in each 100-line group may hunt at one time, but, however, one finder switch in a 100-line group may hunt simultaneously with a finder switch in the associated 100-line group, provided that both 100-line groups are segregated at the group-distributor equipment. When two calls occur simultaneously in the same group, the call on the lower level, or, if on the same level, then the call nearest to the starting point, will be selected by the first finder switch. The other call waits until a second finder switch is started, which takes place as soon as the first finder switch connects with the nearest line. The waiting time is very short and the delay is therefore inconsequential.

Figure 64 shows a line-finder switchboard. This is of the "high type" and shows the finder switches mounted in the left bay. The right bay contains the distributors at the left and the subscribers' line relays at the right. All the switches

are shown with the metal covers in place, the different parts of the distributors being enclosed by three separate covers for each two 100-line units. Each group of twenty sets of line and cut-off relays is enclosed by a separate cover.

This board has an equipment capacity for 800 lines with 10 finder switches, for each 100-line group. The two lower shelves here are equipped with only 8 each. Low-type boards are also used for this equipment, in which case the boards have a capacity of 600 lines each.

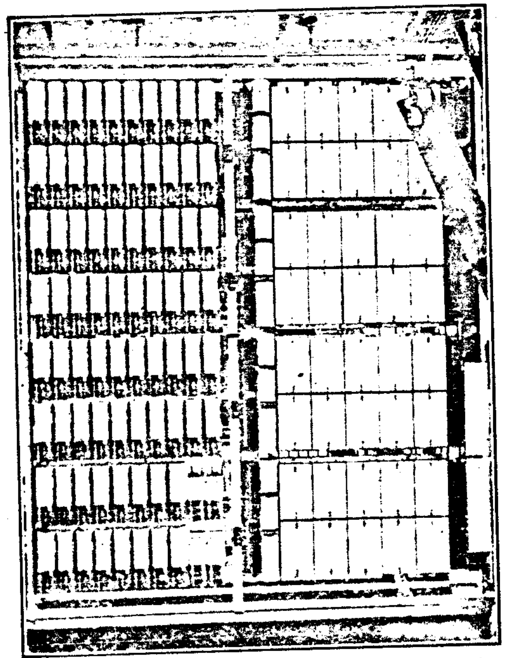


FIG. 64.—Line-finder switchboard.

Measured-service Systems.—Two methods of charging for local telephone service are in common use: namely, the flat-rate method and the measured-service method. Local measured service may be subdivided into message-rate and coin-box service. In the apparatus previously described, the flat-rate method has been assumed, except that the apparatus required for handling coin-box service has been mentioned in connection with the paystation repeater. Strowger step-by-step apparatus may be readily arranged for individual and two-party-line measured service, with slight modifications and additions in the circuits of certain apparatus and the addition of registering equipment. The arrangement generally employed for individual-line service requires message registers, located at the central office, and additional relays, and bank contacts in the line switches. The additional relays are usually mounted in the vacant space shown at the top of the line-switch board in Fig. 38 when this type of board is used; in other cases a separate rack of the relay type is employed. The two-party-line service requires special trunk repeaters, in addition to the apparatus required for individual-line service.

Message Registers.—For recording the number of completed messages or, more properly, completed local-exchange connec-

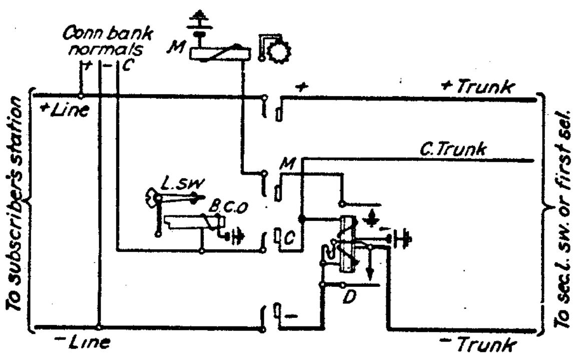


FIG. 65.—Circuit of individual-line registration—reverse-battery method with plunger-type line switch.

tions, as a basis of charging the subscriber for service, message registers of the type shown in Fig. 185 of the preceding volume on manual equipment[1] are used. They are either mounted on racks similar in design to the standard line-switch uprights, provided with a metal casing and glass doors, or on standard unit-type relay racks.

Two methods of providing for message-rate service on individual lines are employed. One is known as the "reverse-battery" method of registration and the other the "booster-battery" method.

Individual-line Reverse-battery Method.—The reverse-battery method may be adapted for use with either the plunger- or rotary-type line switches. With both types of line switches,

[1] "Manual Switching and Substation Equipment," p. 201.

units equipped for message-rate service may be used for flat-rate lines by changing the method of connecting and omitting the message registers.

Figure 65 shows the essential parts of the plunger-type line-switch circuit used in the reverse-battery methods, and the additions required to provide for registration. At the left is the line to the subscriber's station, at the right the trunk to the secondary line switch, or first selector, and at the top the message register *M*. In the center of the drawing at the left are portions of the line switch, and at the right the additional relay *D* required for registration. The line-switch portion shows merely the bridge cut-off winding *BCO* of the line-switch magnet, the plunger, and one set of four bank contacts. With reference to Figs. 25 and 28, it will be noticed that one pair of contacts in the line-switch banks was not used, and these contacts (*M*, Fig. 65) are now employed for the message-register circuit.

The line switch operates to extend the connection to the next switch, in the manner already described and, in addition, prepares the circuit of the message register *M*. Ground over the control lead from the next switch in the train energizes the *BCO* winding of the line-switch magnet and the upper winding of relay *D* in multiple with it. Current also flows through the lower winding of relay *D*, which is connected in the negative trunk lead, but, however, relay *D* will not be operated at this time, as the magnetic fields of the two windings are opposed. When the connection has been extended to the called line and that subscriber has answered, current flow is reversed in the trunk conductors, so that relay *D* will then operate. Relay *D*, on operating, short-circuits its lower winding and places ground on the message-register circuit. It is held operated by its upper winding after its lower winding has been short-circuited. Register *M* is operated, its magnet remaining energized as long as the connection is held, even if the current in the line conductors is again reversed. This prevents more than one registration for a call.

Since the operation of the register is dependent on the reversal of battery in the negative trunk, "busy," "don't answer," and "aberrated" calls, on which no reversal occurs, will not be registered. Likewise, "official" or special calls may be made without registration by arranging the circuits, so that on answering the current flow will not be reversed in the trunk conductors. The non-inductive resistance, connected in multiple with the lower winding of relay *D* and the copper sleeve placed over the core, is to maintain transmission at a normal standard when relay *D* is not operated on non-registered calls.

Figure 66 shows how the rotary line switch, described in connection with Fig. 31, is adapted for message registration by the reverse-battery method. When arranged for registration, the rotary line switch requires four bank levels, an additional set of contacts on the cut-off relay, and an additional relay. The operation will be understood from the description just given for metering with the plunger type of line switch.

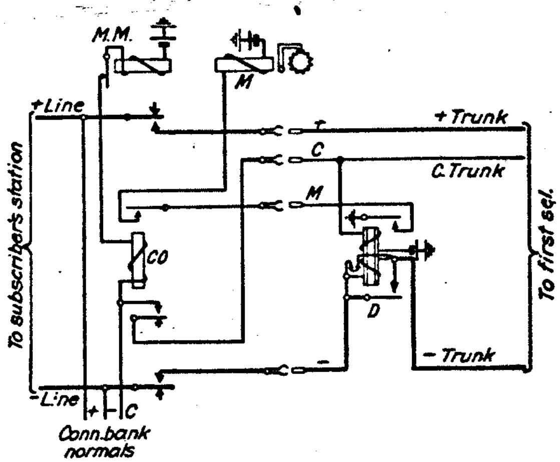


Fig. 66.—Circuit of individual-line registration—reverse-battery method with rotary-type line switch.

Individual-line Booster-battery Method.—In the booster-battery method of message registration on individual lines, while the primary control of registration is dependent upon the battery reversal, the actual registration is accomplished over the control trunk of the line switch by approximately doubling the potential of the current flowing through the winding of the message register. Additional bank contacts, additional relays, and also a special booster battery are required with this method. This principle of registration can be applied to either plunger- or rotary-type line switches, but a description in connection with the plunger type will suffice.

The essential parts of the circuit are shown in Fig. 67. Here the message register is connected directly to the normal control.

Its characteristics differ from the one previously used, in that it will not operate on the regular central-office battery voltage (48 volts) but requires approximately double voltage (93 volts). Relay *D* is operated on the battery reversal as before but performs slightly different functions. The operation of the line switch is as previously described.

When ground is connected to the control lead by the next switch in the train, it does several things. It completes a local circuit through the *BCO* winding, it closes a circuit through the upper winding of relay *D*, it closes a circuit for relay *C* through the lower set of contacts of relay *D*, and it closes a circuit for the register *M*. Relay *D* does not operate at this time because

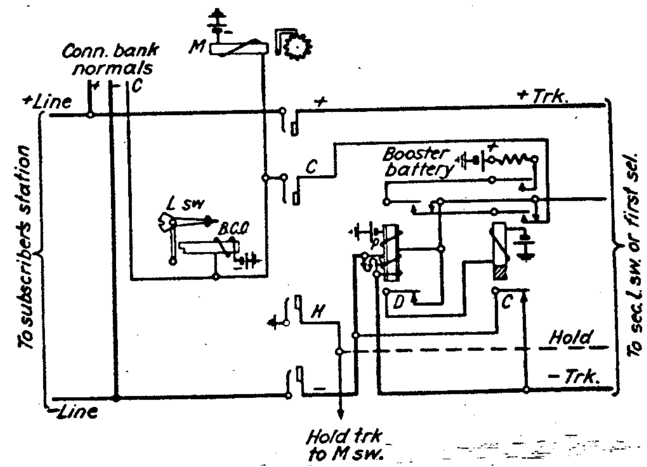


Fig. 67.—Circuit of individual-line registration—booster-battery method with plunger-type line switch.

of its opposed windings and the meter *M* does not operate because of insufficient voltage. Relay *C*, however, operates and disconnects the control lead of the line switch from the control lead to the next switch, through a set of break contacts, and reconnects these leads through a set of make contacts, and break contacts of relay *D*. Relay *C*, at its upper contacts, also connects the booster battery to an open contact of relay *D*, thereby preparing the register circuit for operation when relay *D* subsequently operates on the battery reversal. When the called subscriber answers, relay *D* will operate, open the control lead of the switch ahead, and connect the booster battery to the control lead of the line switch. The double voltage now connected to the winding of the register *M* will cause the register to operate. Also, when relay *D* operates, the circuit of relay *C* is opened. However, owing to its slow-release feature, relay *C* will hold the booster battery connected in the register circuit for a period long enough to cause the register to operate. When the relay *C* releases, the booster battery is disconnected, the control lead of the line switch is reconnected to the control lead of the trunk, and the short circuit replaced on the lower winding of relay *D*, thereby holding it in an operated position until the connection is released. Register *M*, after once being operated, is held by the regular battery voltage until the line switch is disconnected.

As in the case of the reverse-battery method, "busy," "don't answer," "aberrated," and "free" calls will not be registered.

Two-party-line Registration.—Measured service for two-party lines in the Strowger system requires two meters and two control relays for each line, these being individual to the line and associated with the line switch. The subscriber's telephone circuit at one of the stations is so arranged that ground is connected to the positive line wire through the shunt springs when the dial is off-normal. The other station on the line is connected in the standard manner. Special trunk repeaters are also required for two-party measured service, one in each outgoing trunk from the line switches. These, called "two-party message-rate line repeaters," each consist of a group of relays similar in appearance to the impulse repeater shown in Fig. 53, but with more relays. This service may be given with either plunger or rotary types of line switches but will be here described in connection with the former.

Figure 68 is a diagram of the circuits. The two meters *M*-1 and *M*-2 and the two relays *S*-1 and *S*-2, which control their operation, are shown below the line switch. The repeater, interposed in the trunk between the primary line switch and the secondary line switch on the first numerical selector, comprises the group of relays at the right of the diagram.

The repeater has two separate sets of functions to perform: it acts as an impulse repeater in transmitting the dial impulses to the numerical switches; and it acts to associate the proper meter or register with the line switch when the subscriber dials, to operate the selected register when the called station answers, and to hold it operated until the connection is released. Only

the latter, or metering, functions will be described here since the repeater functions have been previously explained.

Relay *C* determines which meter is to operate. If it is energized, the resistance *R* will be included in the meter circuit through relays *S*-1 and *S*-2 in series, from battery at *S*-1 to ground at the contacts of *J*. Relay *S*-1 will not pull up through this resistance; hence only *S*-2 will operate, to complete the circuit through meter *M*-2. If relay *C* is not energized, resistance *R* will be short-circuited, causing both *S*-1 and *S*-2 to pull up and thus close the circuit of meter *M*-1. Relay *S*-2 is of the slow-operating type in order to delay the placing of the ground on the register circuit until *S*-1 has operated, when resistance

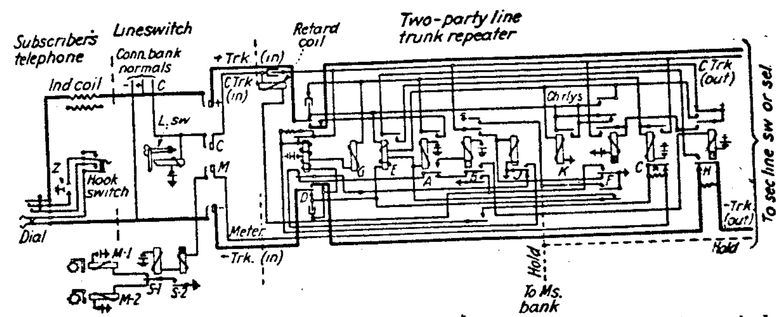


FIG. 68.—Circuit of two-party line registration—with plunger-type line switch.

R has been short-circuited. On disconnection, however, relay *S*-2 must release before *S*-1 to prevent false registration.

The "meter" circuit is held closed at the contacts of relay *D* until that relay is released on disconnection, regardless of whether relay *C* is operated or not and, therefore, whichever one of the registers is operated will remain in an operated position until the circuit is opened at the line switch. The circuit of relay *C* is controlled through contacts of relay *E*, and, if ground is connected at the calling subscriber's telephone when dialing, relay *E* will be operated through its lower winding and in turn operate relay *C*. When relay *C* operates, it is locked up to ground on the control trunk (out) and removes the short circuit from resistance *R*, thereby permitting register *M*-2 to be operated, when relay *D* subsequently operates. However, if the station with no ground connection is calling, then the current flow in the two windings of relay *E* will produce opposed magnetic fields and prevent relay *E* from operating; hence, relay *C* will not operate to remove the short circuit on resistance R, and, therefore, register M-1 will be operated when relay D operates.

"Reverting-call" switches are usually provided in party-line systems, but, since the installers and repairmen frequently use them for ringing tests and bell-adjustment purposes and since revertive calls made by subscribers are comparatively few, means are provided to prevent registration on such calls. The reverting-call switches employed in measured-service systems must be so designed that, when one is selected for use, direct ground will be removed from the (out) control trunk of the two-party-line repeater and ground through a resistance substituted, thus permitting relay J to operate and prevent registration by removing the ground from the meter circuit.

COMPLETE EXCHANGE SYSTEMS

As in manual practice, an automatic exchange to serve a specified local community may comprise one or more offices. Several typical arrangements of central-office equipment will be described in order to illustrate the actual applications of the different forms of step-by-step switching apparatus to the purposes of a small single central-office exchange, a full-sized single-office exchange, and a large multi-office exchange. A system utilizing what is known as the "director"[1] will be described for multi-office exchanges. Mixed systems having both manual and step-by-step central offices and small community systems will also be explained.

Three-digit System.—Dial systems serving less than a thousand and more than a hundred subscribers' lines may be referred to as three-digit systems, since the line-designating directory numbers have but three digits each. Party-line numbers, when frequency-selecting connectors are used, require an additional digit to select the ringing frequency.

Schematic Diagram of Three-digit System.—Figure 69 is a schematic diagram of the central-office apparatus and wiring for a typical three-digit exchange system. It is assumed that this exchange is equipped to render service to individual, private branch exchange (P.B.X.), and party-line subscribers, and that provision is made for toll service to and from the subscribers.

[1] The word "director" is registered as a trade mark of the Automatic Electric Company.

All of the outside lines would terminate on a main distributing frame M.D.F., as shown at the left, where they would be cross-connected to the central-office equipment. The switching equipment would consist of primary plunger- or rotary-type line switches, first selectors, and connectors. Testing facilities, information desk, toll-board equipment, and the necessary power plant would also be provided for the operation and maintenance of the system. The line switches would be cross-connected to the subscribers' lines at terminal blocks on the connector boards, and

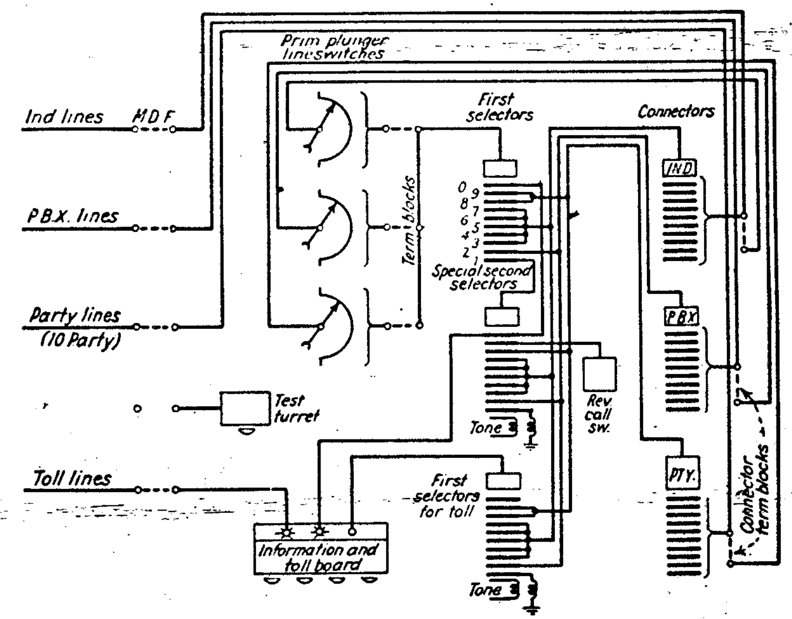


Fig. 69.—Schematic diagram of three-digit system.

the first selectors to the line switches at terminal blocks on the line-switch boards. In the drawing, separate groups of line switches have been shown for each of the different classes of lines, although in a very small office the line switches might all be in one group. Regular selectors are shown for the trunks from the toll board, since a special toll switch train would not usually be used in an office of this size.

The subscribers' dials would have their number plates marked with numerals only, as shown in Fig. 7 (left), since the simplest form of dial numbering meets all requirements of a small, single-office system. On the drawing, only one symbol has been shown for each type or group of apparatus, but it is to be understood that a sufficient number of each, connected by the proper number of trunks, would be provided to handle the traffic during the busy-hour period.

The first selectors are the first numerical switches involved in a connection, and, therefore, the general description of the system may well start at that point, it being remembered that, whenever a subscriber calls, his line switch acts automatically to connect his line to a first selector.

The first-level bank contacts of the subscriber's first selectors are shown connected to special second selectors. These special selectors are similar to the first selectors, and in addition to providing facilities for connections to information, etc., are utilized to prevent a subscriber from securing a wrong number when a false preliminary break-impulse has been transmitted, in removing the receiver from the hook switch or by any other cause immediately prior to dialing. Thus, when a subscriber dials after a false impulse has been transmitted, the special second selector will respond. The multiple connector-trunk banks of the two groups of switches are similarly connected, and, therefore, the subscriber will be connected with the correct number regardless of whether or not a false preliminary impulse has been received. The first-level bank contacts of the special second selectors are connected to a distinctive tone, which will be transmitted to the subscriber, in case two false impulses have been received. The subscriber, on hearing this tone, will hang up momentarily, releasing the connection to the first selector and thereby restoring the switches which have been improperly operated.

The second level of the first selectors is reserved for P.B.X. lines, and its contacts are therefore connected to P.B.X. or trunk-hunting connectors. Therefore, in the system shown, P.B.X. numbers will all have 2 as a first digit. The third to seventh levels, inclusive, are for individual lines, and the trunks from these levels terminate in individual-line connectors. The eighth and ninth levels are for party-line numbers, the trunks from these levels terminating in party-line frequency-selecting connectors. The tenth or 0 level is used for calls to the special-service operator, or for toll, and is multipled through the first and special second selectors, terminating at manually operated positions. The ninth level of the special second selectors is used for revertive calls and, therefore, terminates in reverting-call switches. These switches are connected with and ring the desired station when the proper code is dialed.

The first selectors for toll are for extending incoming toll calls to the step-by-step subscribers' lines and are only accessible to the toll operators. The bank contacts of these selectors are multipled to the first and special second selectors and therefore the toll operator, by dialing, may reach any subscriber in the system. The outside toll lines are extended through the main distributing frame to the toll operators and there provision is made for handling both incoming and outgoing toll calls.

The multiple banks of the connectors, of each type, are shown connected directly to the main distributing frame and are there cross-connected to the respective outside lines. The normals from the connectors to the line switches are cross-connected at the connectors.

The test equipment is connected to the main distributing frame, at which the necessary cross-connections may be made to provide for the testing of the equipment.

An actual connection may now be explained. Assume that a subscriber on one of the party lines is calling station 456. The calling line, it will be noted, extends through the M.D.F. to contacts of terminal blocks on a party-line connector board and thence to the associated line switch. Since a plunger-type line switch has been assumed, the plunger of his switch will be standing before the contacts of a trunk to some idle first selector. When the subscriber lifts his receiver in making his call, the plunger will operate to extend his line to the operating relays of the chosen first selector. He will then hear the dial tone and proceed to dial the digits of the desired number.

The first digit (4) of the dialed number will cause the first selector to step its wipers up to the fourth level and therefore to the terminals of a group of trunks leading to connectors serving the *fourth* hundred group of lines. The wipers will then rotate in trunk hunting and will finally stop on a trunk leading to an idle connector in that group. This selection of a trunk, from the first selector to an idle connector, takes place after the dial finger plate has returned to normal and while the subscriber is again rotating it for the second digit.

The second digit (5) of the number will step the wipers of the selected connector up to the fifth level, where they will stop, awaiting the dialing of the third digit. The fifth ten of the fourth hundred has now been selected. As the digit 6 is dialed, the connector wipers will be rotated over the fifth bank level until the sixth set of contacts is reached, and, if the called line is not busy, the connector will switch through and extend the connection through the M.D.F. to the called station.

As soon as the connector stops rotating, the ringing current will be applied and the bell rung. At the same time the ring-back tone will be connected to the calling subscriber's line, to notify him that the connection has been made and that the bell

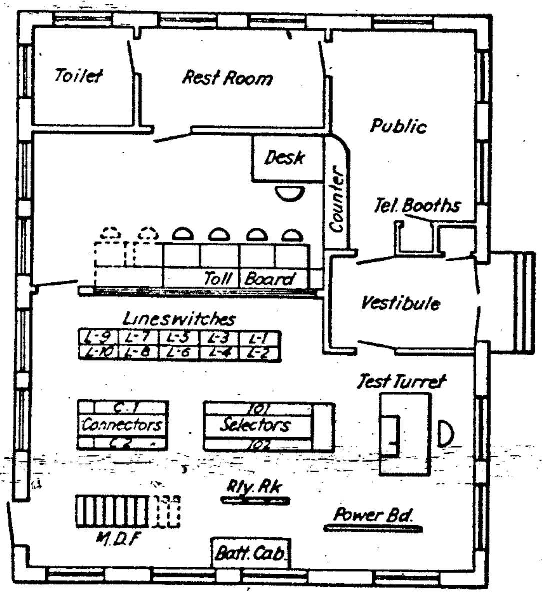


Fig. 70.—Typical floor plan for three-digit system office.

is being rung. When the called station answers, the bell will stop ringing, the ring-back tone will cease, and the connection is ready for use. If the line called had been busy, the connection would not have been extended beyond the connector and the calling subscriber would have been advised of the busy condition by a distinctive "busy tone."

When the subscribers hang up, the various pieces of apparatus used will be disconnected and made available for other connections, with the exception of the calling subscriber's line switch, which is permanently associated with his line. At the time the calling subscriber hangs up, the first selector will be

released and restored to normal, and the line-switch plunger released. The connector, however, will not be released until both subscribers have hung up.

Typical Office Floor Plan of Three-digit System.—Figure 70 is a typical central-office floor plan for a three-digit system, showing how the apparatus of the preceding schematic diagram might actually be installed. By comparing this with the schematic diagram, it will be seen that the subscribers' line cables would be run from the M.D.F. to the connector boards, and the normals from the connector terminal blocks to the line-switch boards. The line-switch-to-first-selector trunk cables would extend from the line-switch boards to the first-selector boards, and the first-selector-to-connector trunk cables would be carried across the aisle between the first-selector and connector boards. Since this is a relatively small exchange system, the central-office building would provide accommodations for dealing with the public, and space for such facilities is shown on the floor plan.

Four-digit Systems.—Dial systems serving less than ten thousand and more than a thousand subscribers' lines are called *four-digit systems*, since all the numbers involved in the line selection may be expressed in four digits. As before, party-line numbers, when frequency-selecting connectors are used, require an additional digit to select the ringing frequency. Such systems are usually the largest served by a single central office, although at times this capacity is exceeded by the use of some five-digit numbers for individual and P.B.X. subscribers' lines. Frequently suboffices are found to be economical; and, at times, other main offices are established before the ultimate capacity of the four-digit system is reached.

Schematic Diagram of Four-digit System.—Figure 71 is a schematic diagram of the central-office apparatus and wiring for a typical four-digit single-office exchange system. It is assumed that this particular exchange would render service to individual, P.B.X., two- and four-party city, and ten-party rural line subscribers, and measured service on individual, P.B.X. and two-party lines. Provision, of course, is also to be made for toll service.

The switching equipment would consist of primary plunger-type line switches, secondary rotary-type line switches, first selectors, second selectors, and connectors. Rural selector

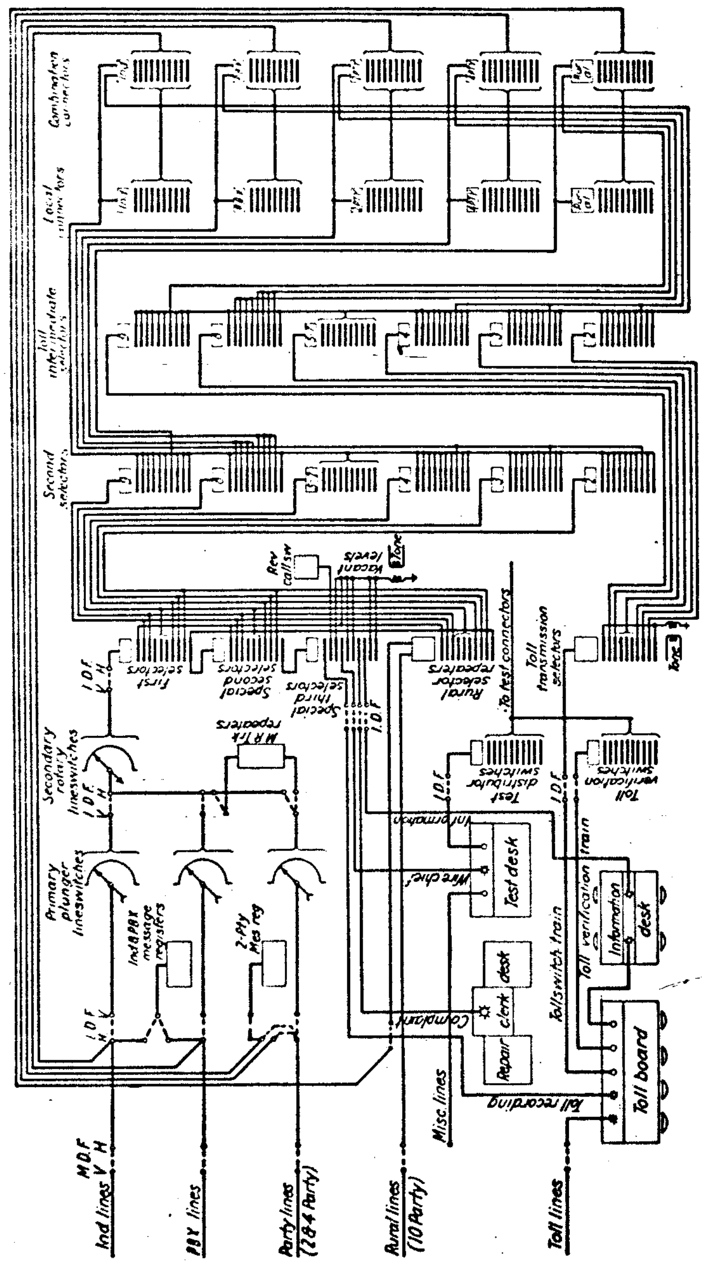


FIG. 71.—Schematic diagram of four-digit system.

repeaters would be provided for the rural lines and meters and associated registering equipment for the measured-service lines. A complete toll switch train, consisting of toll transmission selectors, toll intermediate selectors, and combination toll and local connectors, would be provided in an office of this size. Also, in an office of this size, an intermediate distributing frame would be installed to afford flexibility in the use of the apparatus and economy in cabling. In order to facilitate the testing, test-distributor and test-connector switches would be included. The subscribers' dials would have simple number plates, that is, those with numerals only (Fig. 7, left).

All subscribers' outside lines are shown terminating at the M.D.F. From there all are cabled to the I.D.F., with the exception of the rural lines, which are run directly from the M.D.F. to the selector repeaters. The primary line switches are connected to the vertical side of the I.D.F. where they are cross-connected on the incoming side to subscribers' lines and on the outgoing side to secondary line switches. On the drawing, the I.D.F. terminals are shown in separate groups in order to simplify the diagram, but in practice they usually would be mounted on the same frame. In some cases, however, a separate trunk intermediate distributing frame is used.

The line switches have been assigned by groups to the different classes of lines. The message registers are shown connected to the vertical side of the I.D.F. where they are cross-connected to register terminals of the subscribers' lines, on the horizontal side. The registers for individual lines and P.B.X. trunk lines are shown in one group and those for two-party lines in another. Since the two-party measured-service lines also require special trunk repeaters, these are shown connected between the horizontal and vertical sides of the I.D.F. where they are cross-connected to the line circuits as required. Other terminals are also shown at the I.D.F. which permit direct cross-connection for the four-party lines between the primary and secondary line switches.

The secondary line switches are shown in one group and connected between the horizontal and vertical sides of the I.D.F., where they are cross-connected as required. The first selectors, shown in one group, are connected to the horizontal sides of the I.D.F., where they are cross-connected to the secondary line switches. A method of arranging for the distribution of incoming traffic between primary line switches and first selectors, when secondary line switches are employed, has previously been described in connection with Fig. 42, and this or a similar method would be employed in the central office shown in the diagram.

The rural selector repeaters are shown connected direct to the M.D.F., since it has been assumed that line switches would not be required for the rural lines. This apparatus is merely a combination of a selector and repeater, acting as a selector on originating calls and as a repeater on incoming calls to the rural-line stations. The rural lines in the case illustrated have been assumed to be operated on a ten-party line selective basis. It will be noted that the selector repeaters have the same position in the numerical switch train as first selectors.

The first selectors, in a four-digit system, respond to the first or thousands digit of the dialed number. The first level of their bank contacts is connected to special second selectors, as previously described for the three-digit system, but, in this case, special third selectors are also provided. A false preliminary impulse would operate the first selector and connect the circuit to a second special selector, and a second false preliminary impulse would in turn connect the second special selector to a third special selector any further false impulses, usually owing to incorrect operation by a subscriber, would connect a distinctive tone to the line. The other corresponding bank levels of the first and special second selectors are multipled, so that a subscriber will secure the correct dialed number when false impulse has been received.

The "service lines" are connected to the bank levels of the third special selectors and therefore three digits are required to call information, the toll operator, or the test desk. In the arrangement as shown, the call number for the toll operator would be 110, information operator 113, etc. The levels of the rural selector repeaters are also multipled in the same manner as the first selectors, thus giving the rural subscribers access to the same switching train as the city subscribers.

The four-digit system requires second selectors, these operating on the second or hundreds digit of the called number. Therefore, the trunks from the first-selector banks terminate in second selectors. The second level of the first-selector banks terminates in second selectors capable of extending connectors to the various hundreds in the second thousand numbers of the exchange, the third level to numbers in the third thousand, and so on for the rest of the levels up to and including the ninth. The fifth, sixth, and seventh levels are shown grouped together, since all of the lines in these groups are of the same class, namely, individual lines. The tenth, or 0, level of the first-selector switches is not used in the system shown and the contacts are connected to a distinctive tone, to advise calling subscribers, when this level is connected with, that some error has been made. Experience has shown that in a single-office system it is not advisable to use subscribers' numbers commencing with the numeral zero (0), unless absolutely necessary to secure the desired capacity.

The trunks from the banks of the second selectors terminate in connectors, which are segregated according to the different classes of lines, and also, of course, according to the different hundreds of the directors numbers. It will be noted that the bank levels of the various groups of second selectors are not all multipled in the same manner. This, of course, is due to the plan of assigning blocks of numbers for the different classes of lines. The bank levels of the second-selector groups designated as 2, 3, and 4 are all similarly connected, and it will be noted that all except the third levels are grouped together and terminated in local, and combination local and toll, individual-line connectors. The third levels are likewise multipled and terminated in P.B.X. or trunk-hunting connectors. The bank levels of groups 5–7 are all grouped together and these are connected to individual-line connectors. The different bank levels of group 8 are variously connected. The first and tenth (0) levels are shown terminating in individual-line connectors, the second to fifth levels, inclusive, in four-party connectors, and the sixth to ninth levels, inclusive, in two-party connectors.

In the system illustrated, the city party lines are served by the arrangement in which a different frequency of ringing current is connected to each of the four connector boards serving party lines. Therefore, party-line stations must be assigned numbers corresponding to the connector boards having the proper ringing current.

The bank levels of group 9, with the exception of the fourth level, are connected to individual-line connectors; the fourth terminates in rural-line connectors. The rural-line connectors are of the frequency-selecting type and therefore require an additional digit in the directory number, to ring the proper station. It will be noted, from the above, that two methods of serving party lines are illustrated. The arrangement of the wiring of the switch-bank levels shows that the assignment of numbers to the various classes of lines is as follows:

Hundreds	Thousands							
	2	3	4	5	6	7	8	9
0	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.
9	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	2-pty.	Ind.
8	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	2-pty.	Ind.
7	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	2-pty.	Ind.
6	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	2-pty.	Ind.
5	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	4-pty.	Ind.
4	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	4-pty.	Rural
3	P.B.X.	P.B.X.	P.B.X.	Ind.	Ind.	Ind.	4-pty.	Ind.
2	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	4-pty.	Ind.
1	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.

The bank levels of the connectors for each class of lines are grouped together and connected to the terminals of the respective lines on the horizontal side of the I.D.F. The party-line connector banks are shown connected to group terminal blocks on the I.D.F., where cross-connections are made to the proper line circuits. These connections between the connectors and the I.D.F. constitute the so-called "normals."

The switching train for incoming toll connections consists of switches and trunks, previously described as the "toll switch train." The toll transmission selectors are connected to the toll board through the I.D.F., where the necessary cross-connections are made. The second to ninth bank levels of the toll transmission selector are connected to toll intermediate selectors, and it will be noted that these trunks are arranged in the same manner as the first-to-second selector trunks. The trunks from the toll intermediate selector banks terminate in combination local and toll connectors. The combination connectors may be used for local connections when all the local connectors in any given group are busy, at the same time keeping the toll switch train free from the local switch train. The method of accomplishing this was explained in connection with the circuit diagram of the toll switch shown in Fig. 58.

Access to the subscribers' lines, from the test desk, is provided for by the test-distributor switches and test connectors. The test distributors are connected to the test desk through the I.D.F. and their bank levels are connected to test connectors in

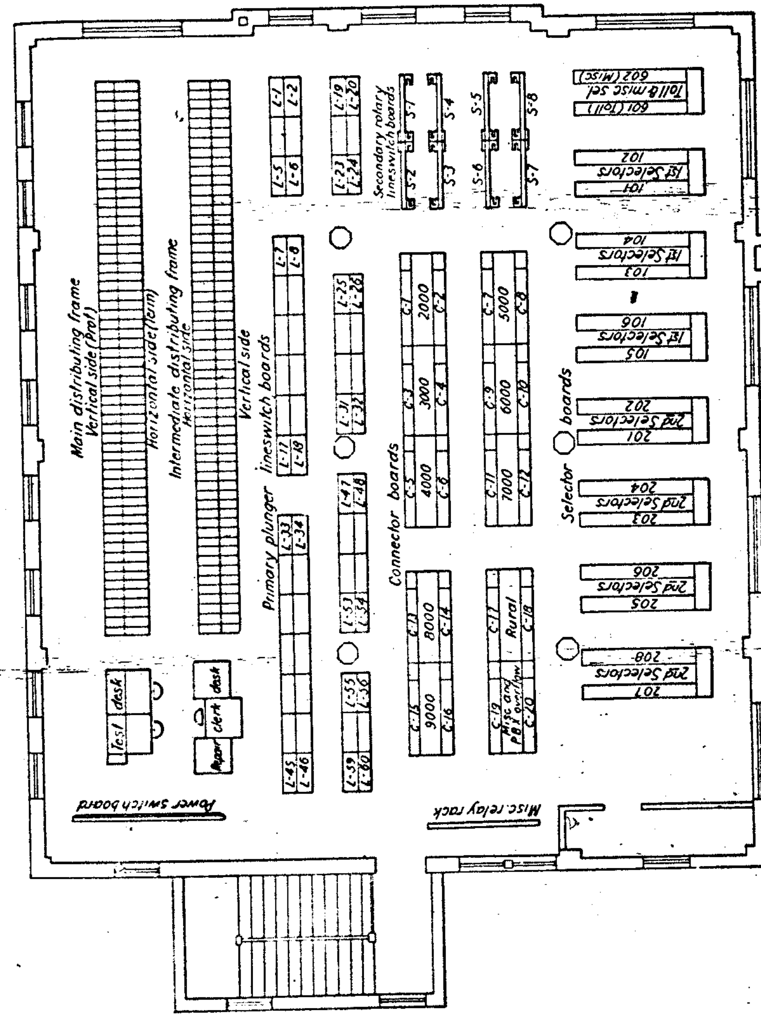


FIG. 72.—Typical floor plan for four-digit system office.

the various hundred line groups. The circuit of this switch train is so arranged that a test connector can be connected with a subscriber's line even though the line may be busy at the time, and, when so connected, a complete metallic circuit with no attachments or bridges is made continuous from the desk to the line of the subscriber.

The toll board is provided with "verification circuits" which terminate in verification switches. The bank levels of these switches are multipled with the bank levels of the test-distributor switches, thereby giving the toll operators access to the test connectors. This switch train is ordinarily used to verify "busy" or "don't answer" conditions but also permits the toll operator to advise a subscriber, then busy on a local call, that he is wanted on an incoming toll call, when such procedure is deemed advisable. The verification train, however, is never used for toll connections.

Typical Office Floor Plan of Four-digit System.—Figure 72 shows how the various apparatus units of the preceding schematic diagram might be arranged on a central-office floor plan. The power switchboard, seen near the test and repair-clerk desks, is the only portion of the power plant in the switch room, the remainder of the power equipment being elsewhere in the building. The toll board and information desk are also installed on another floor. While this floor plan shows an orderly and convenient arrangement of the apparatus, it is obvious that, on account of the relatively small sizes of the switchboard units, floor areas of widely different shapes may be economically utilized for the installation of such equipment.

The outside cables terminate on protectors on the vertical side of the M.D.F. The subscribers' line cables extend between the horizontal side of the M.D.F. and the horizontal side of the I.D.F. The primary line switches are connected by cables to terminals on the vertical side of the I.D.F., and the secondary line switches are cabled between the horizontal and vertical sides of the I.D.F. The secondary line-switch-to-first-selector trunks are cabled from the horizontal side of the I.D.F. to the first-selector boards. The first-to-second-selector trunk cables terminate at the second-selector boards. The second-selector-to-connector trunks are cabled from the terminal blocks on the second-selector boards and terminate at the connector boards. The normals of the subscribers' lines are cabled from terminal blocks at the connector boards to the horizontal side of the I.D.F., where they are connected to the respective subscribers' line terminals. From the above description of the cabling, it will be observed that the apparatus has been arranged

so as to require a minimum average length for the various cable runs. This is a fundamental consideration in the planning of central-office installation, on account of its effecting a considerable saving in first cost.

Six-digit (Multi-office) System.—In larger city exchanges, served by several central offices, the switch train is somewhat more complicated than for a single-office exchange. It may be divided into two separate parts: one for office selection and the other for subscriber's line selection within the office. The numerical switches involved in the train are therefore classed in two groups: "office-code" switches and "station-code" switches. As explained in Chap. II, the number of numerical switching steps required for the office code depends on the number of offices ultimately planned for the exchange. Line selection within each office is usually on the basis of four-digit numbers, although additional digits may be required for party-line selection. The requirement of any scheme of numbering is, of course, to provide a sufficient number of digits in both the office and station codes to accomplish the selection, first among the total number of offices and then among the total number of subscribers in any office so chosen.

In the present case, it will be assumed that the central offices are arranged for a four-digit station code, similar to the four-digit system just described for a single office, and that the office code will require two digits, designated in the telephone directory by letters rather than numerals. The subscribers' telephones will, therefore, be equipped with dials having number plates with both letters and numerals as shown in Fig. 7 (right). Since the case now to be considered is a six-digit system, the directory numbers will be made up of two letter digits for the office code and four number digits for the station code. The office codes would consist of the first and second letters of the names of the various central offices. This arrangement, as explained in the preceding chapter, would provide for sixty-four theoretical office codes, but in actual practice the number of codes usable would be smaller, owing to the fact that suitable common names in the English language do not permit the use of all the possible letter combinations.

Schematic Diagram of Six-digit (Multi-office) System.—Figure 73 is a schematic diagram of one of the central offices in a multi-office exchange system. It is assumed that this office will

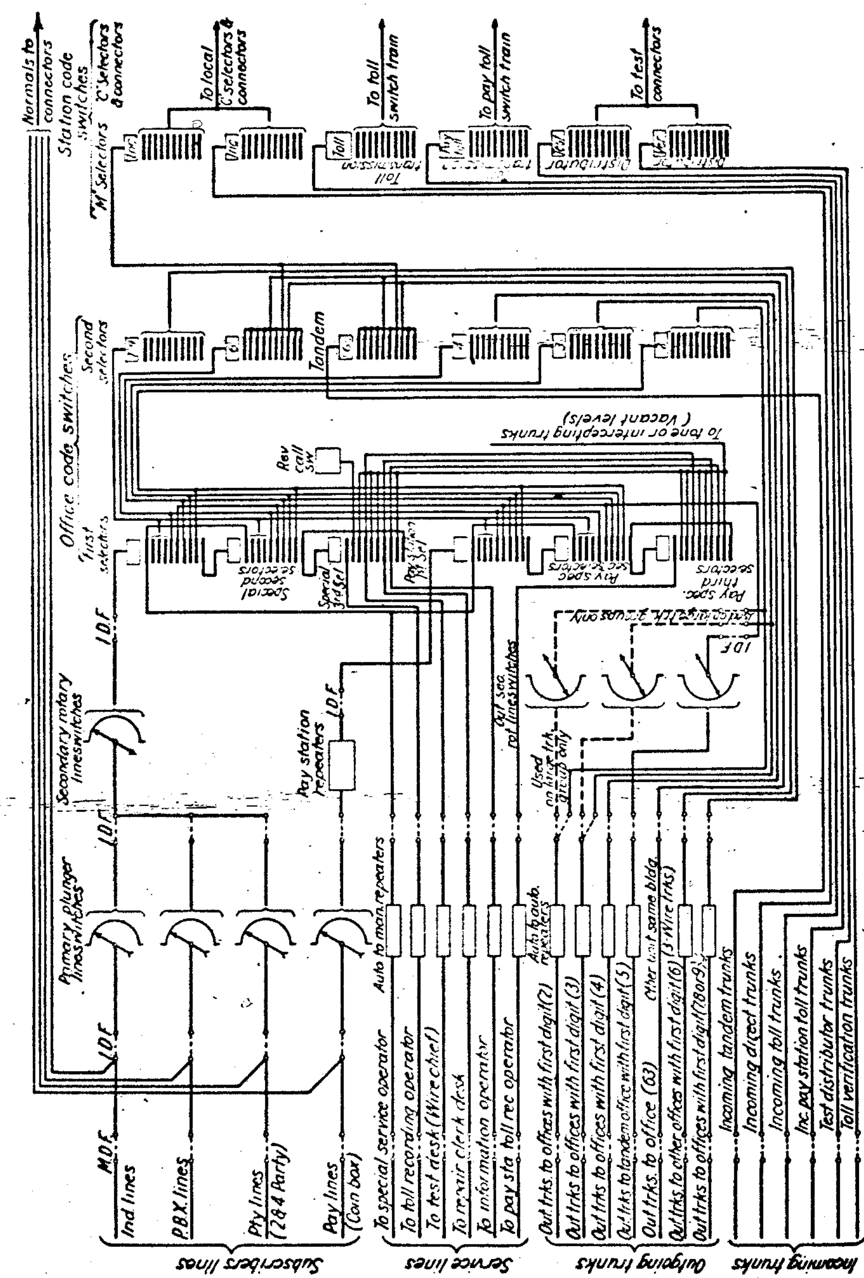


Fig. 73.—Schematic diagram of six-digit (multi-office) system.

render service to individual, P.B.X., two- and four-party, and paystation subscribers. The service charges might be on a flat-rate or measured-rate basis, but, however, the method of charging is not material, as this diagram is intended primarily to illustrate the office-code portion of the switch train. Since a four-digit central-office system was described in connection with Fig. 71, the station-code switch train is, in large measure, omitted from this diagram. It will be remembered that the "station-code switches" are the ones in the switch train which complete connections with lines in their own office, whether the calls originated in their own or any of the other offices. Of the station-code switches only the "incoming" or "M" (thousands) selectors are shown at the extreme right of the diagram, it being understood that the "C" (hundreds) selectors and connectors beyond these perform the hundreds, tens, and units selections as already described for the single-office, four-digit system.

In the upper left portion is shown the non-numerical switch train for the subscribers' lines served directly by this office, the normals of these lines extending across the top to the right. The non-numerical portion of the local switch train is shown terminating in first office-code selectors. The paystation switch train requires special repeaters, and the special selectors are slightly different from the regular type to permit toll-recording and "service" calls to be made without the necessity of first depositing a coin. Furthermore, it is assumed that the paystation lines would not be provided with secondary line switches.

Below the paystation lines are the toll-recording and service lines. In the case under consideration, it has been assumed that centralized information and testing facilities would be provided, and located in one of the other central offices of the exchange system; therefore they are not shown on this drawing.

Below the service lines are the outgoing and incoming inter-office, tandem, and toll trunks. The outgoing trunks and service lines are provided with impulse repeaters to permit the use of two-wire outside trunk circuits.

The bank levels of the first office-code selectors and the special second selectors are multipled, as previously described. The first level of the first office-code selectors is carried to special second, and that of the special second to special third, selectors for the purpose of providing facilities for connections to information, etc., and for absorbing false preliminary impulses. The tenth, or 0, bank level of the first selectors is connected to trunks to the service operator. The other office lines, including the recording trunks, are taken off at the bank levels of the special third selectors. A special switch train for paystation service is provided, consisting of first, special second, and third paystation selectors. The bank levels of these switches are multipled to the corresponding bank levels of the switches just described, except that separate paystation toll-recording trunks are provided and connected to the tenth, or 0, level of the special third paystation selectors. This is to provide special identification for paystation lines and to advise the recording operator, by a "class-of-service" tone, of paystations to which toll service is denied. The vacant levels on the special third selectors are shown extending to a source of distinctive tone or to intercepting trunks. The intercepting trunks terminate at operators' positions and provide means for advising subscribers when improper connections have been made.

The second to ninth levels of the first and special second selectors are multipled and are connected to correspondingly designated groups of second office-code selectors, with the exception of the fifth level, which is connected through outgoing secondary line switches and trunk repeaters to the group of trunks designated as "Out. trks. to tandem office with first digit (5)." In the system illustrated, it has been assumed that a group of two or more offices is so located, geographically, that trunks may be extended from the office shown to one of the offices of the group, called a "tandem office," and from there connections would be extended through the regular inter-office trunks to the other offices of the group. It is, of course, necessary to assign offices of this group, names whose first letter is associated with the digit 5 on the dial number plate, that is, each must begin with the letters *J*, *K*, or *L*. The second office-code selectors in this case, therefore, would be in the tandem office of the group. The group of trunks from the office shown to the tandem office would then carry all the outgoing traffic from the originating office to the several offices of the tandem group. This feature has been introduced to illustrate how tandem trunking may be accomplished when the offices of a group are so geographically located and named as to make such an arrangement economical.

The bank levels of the second office-code selectors, designated as 2, are grouped together and connected to the outgoing trunks marked as "Out. trks. to offices with first digit (2)." Of course, there would be a separate group of trunks for each of the offices with the first digit (2). These trunks have been shown connected in two different ways at the intermediate distributing frame. One arrangement consists of the regular cross-connection at the I.D.F., while another alternative arrangement includes outgoing secondary line switches in the circuits. As previously stated in the description of outgoing secondary line switches, their use would be determined by a study of the annual charges. The bank levels of the second office-code selectors, designated as 3, 4, and 7–9, are shown connected in the same manner as just described.

The office shown in the diagram is assumed to be in the same building with another full-sized unit, and therefore an arrangement of incoming tandem trunks serving the two offices is shown. The third and fourth bank levels of the second office-code selectors, designated as 6 and "Tandem 6," are multipled together respectively, the third levels being connected to outgoing trunks designated as "Out. trks. to office 63" and the fourth levels to the local "M" selectors. The outgoing trunks to the other office (63) would terminate on incoming "M" selectors in that office, and, since the two offices are in the same building, the trunk repeaters are omitted and three-wire trunks used. The switch train from the local "M" selectors is not shown, but it would be the same as already described in connection with Fig. 71. The two offices in the same building would be 63 and 64 or, using central-office names, they might be NEwton and MIchigan respectively. The other bank levels of these second selectors are grouped together and connected to outgoing trunks designated as "Out. trks. to other offices with first digit (6)."

The incoming-trunk groups shown at the lower left of the diagram and marked "Incoming direct trunks," "Incoming toll trunks," "Inc. paystation trunks," "Test distributor trunks," and "Toll verification trunks" each terminate on either "M" selectors or distributor switches shown at the right. The switch train for each of these classes has been previously described in connection with Fig. 71.

The diagram for each of the other offices in the exchange system would be similar to the one just described, only differing in the office-code switch train, to provide a switching arrangement, which would be proper for the inter-office trunking system required for each of the respective offices.

Director System.—In the description of the six-digit multi-office exchange system, it will be recalled that two examples of tandem trunking were illustrated: one for incoming tandem trunks and one for outgoing tandem trunks. These arrangements provided for using only one tandem office in certain connections, although with a three-digit office code the same principle might be extended to include two tandem offices in a connection. It will also be remembered that, in order to provide for tandem trunks, certain restrictions were imposed on the selection of office names, that is, the first letter of the office name had to correspond with the letters associated with certain numerical digits of the dial number plate. This limitation of free use of office names frequently makes it difficult to apply the tandem principle to the extent which the geographical location of central offices and the volume of traffic between the offices would normally warrant. In certain instances the difficulty inherent with the use of office-name codes has been overcome by assigning predetermined office code numerals, or letters and numerals, in place of the first letters of the central-office name, but, however, this method has not had a very extensive use. Another disadvantage of the fixed-code system is the low efficiency of certain switches and their associated intra-office trunks, since numerical switches must provide for paths in the office-code switch train to accommodate all the combinations of the numerical equivalents of the letter codes used, and this frequently results in vacant levels on many of the office-code selectors. The simplest way to overcome these difficulties appears to be to *dissociate the fixed office-code numbering system from the trunking system* and to substitute "directing" numbers for the office codes, thereby permitting the switch trains to be designed for a more efficient use of both switches and trunks. A system designed to accomplish this, and which has other advantages, utilizes an arrangement of apparatus known as the *director.*

The director equipment consists of Strowger-type switches, rotary- and minor-type switches, relay groups, and impulser. It is inserted in the switch train between the non-numerical switches and the first office-code switch and dissociates the calling subscriber's line from the numerical switch train until the connector has completed its rotary movement. The complete number dialed by the subscriber is registered and stored and then sent with translated directing digits for the office code, and with the same station-code digits as dialed by the subscriber. However, since the incoming and outgoing circuits of the director are kept separated, the translated office code is sent shortly after the directory office code is dialed and before

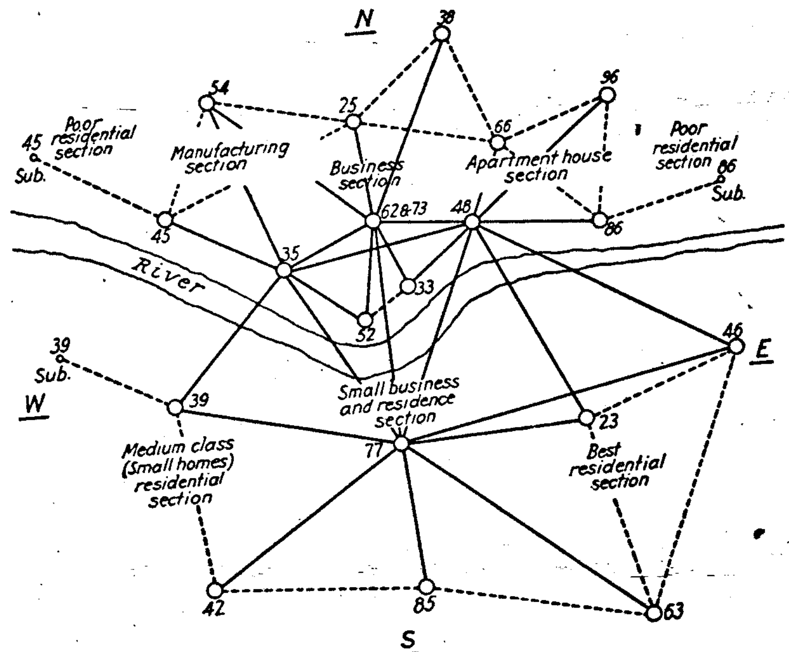


Fig. 74.—Inter-office trunk routes for tandem trunking.

the complete station-code digits are registered. This enables the director to complete its work and release shortly after the subscriber dials and last station-code digit. The dissociation of the telephone directory office code from the trunking system has several advantages in addition to permitting inter-office trunk routing in the most economical manner. It takes advantage of the efficiency obtainable by the use of larger trunk groups, provides a simple means of re-routing calls as traffic conditions change, and serves a useful purpose in facilitating the transition from manual to step-by-step operation. The choice of office names is simplified, since trunk routing is no longer a factor in their selection.

Before describing the details of the director, it may be well to consider some of the possible economies in the use of translated directing digits in the exchange trunk plant.

Tandem Trunking.—Figure 74 is a diagram of a hypothetical six-digit multi-office exchange system. The larger circles represent the central offices, and the smaller circles suboffices of the main offices with which they are shown connected. The solid lines are the trunk groups required with tandem trunking, and the dotted lines are the inter-office trunk groups used only for connections between the central offices at which they are terminated. These lines indicating trunk groups are shown as straight lines between the points which they connect, but in practice they would follow established subway or cable routes and therefore frequently deviate widely from air-line courses. The central offices are numbered, for convenience, with the numerical equivalents of the first two letters of the office names, since it is assumed that the central offices would all be named.

On the diagram, twenty central offices are shown. With the ordinary step-by-step system using direct trunks from each office to each other, there would be required at each office nineteen groups each of outgoing and incoming trunks, except that the number might be slightly reduced by the selection of office names to permit tandem trunking as explained in connection with Fig. 73. With the substitution of translated digits for the directory office codes many of the trunk groups are made to serve several central offices and thereby reduce the total number of separate groups, as illustrated on the drawing. In the case assumed, four tandem trunking centers have been utilized and these are located at offices 35, 48, 62, and 77. It is not always necessary that the tandem centers be located at central offices, but for convenience they have been so located in this case. The tandem-trunking system, of course, does not preclude the use of direct trunks between any of the central offices in the system, when that method would be more economical.

Figure 75 is a schematic diagram of the tandem-trunking plan required for this hypothetical exchange. It will be used to illustrate a connection between a calling station in office 38 and a called station in office 42. The main central portion of the diagram shows the arrangement of tandem selectors at the four

offices used as tandem centers. At the left are the office selectors and directors at the originating office, and at the right are the station-code switch train of the terminating office.

The directory office code for the called subscriber will be the letter equivalent of 42, since the called station is in office 42. However, as the call is to be routed through offices 62 and 77 (see map) the director at the originating office will translate this code into a *directing code* 3-2-9, the numbers of which correspond to the bank levels of the office selector at the originating office

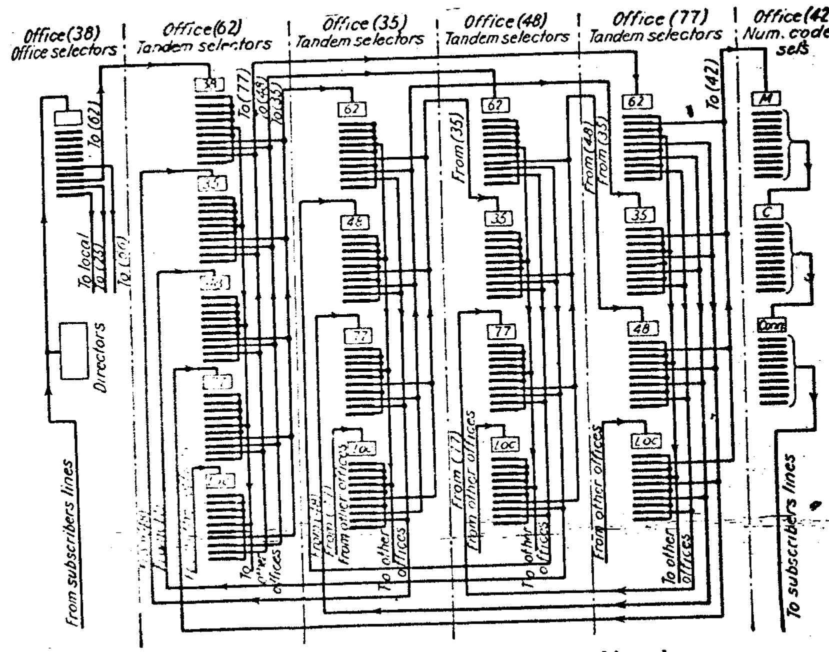


Fig. 75.—Schematic diagram of tandem-trunking plan.

and of the tandem selectors in the chain necessary to reach the terminating office. Thus the first digit 3 operates an office selector and steps it up to the third bank level connected with a trunk to office 62. At office 62 the tandem selector responds to the second digit 2 and extends the connection over a tandem trunk to office 77, where the last digit 9 steps the tandem selector to the ninth level and extends the connection over a trunk to the station-code switch train at office 42. At office 42 the "M" and "C" selectors and a connector are operated by the station-code portion of the desired number and thereby extend the connection to the line of the called subscriber.

This diagram also shows all possible trunk combinations which may be established at each of the four tandem centers. The numerals placed on the switch symbols indicate the offices at the outgoing end of the trunks. For example, at office 62 the top selectors are designated 38, which means that they are connected to trunks from office 38; the next is marked 35, which indicates that they are associated with trunks from office 35, and so on for all except the bottom group. The bottom selectors in each office are marked *Loc* to indicate that they serve the local office and all other offices tributary to each of the tandem switching centers.

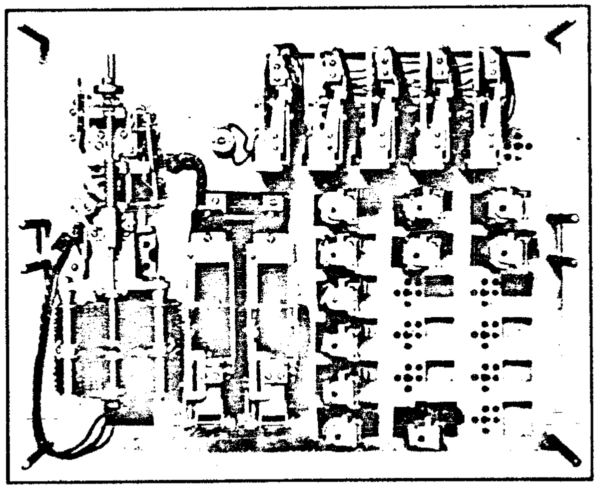


Fig. 76.—Director—front view.

The selectors 38 at the top in office 62 would ordinarily be in this group but have been shown separately to illustrate the tandem switch train used in the specific case explained.

By comparing Figs. 74 and 75, any assumed connection may be traced through the trunking system. As an example; assume that a subscriber in office 96 is calling a number in office 85. The calling office is tributary to 48 and the normal routing for such a call would be through tandem centers at offices 48 and 77. The first tandem selector used would be one of the lower groups of office 48, and the connection would be extended through an office selector at 96 over a trunk to 48, where a tandem selector would be stepped up to the fourth level, and connected by a

trunk to a tandem selector in office 77. At that point, the tandem selector would be operated to connect with the bank level assigned to trunks to office 85.

In the exchange system illustrated, it will be noted that only first office-code selectors are required at the tributary offices and that all the tandem selectors in the system are located in the offices 35, 48, 62, and 77. In a larger system where more

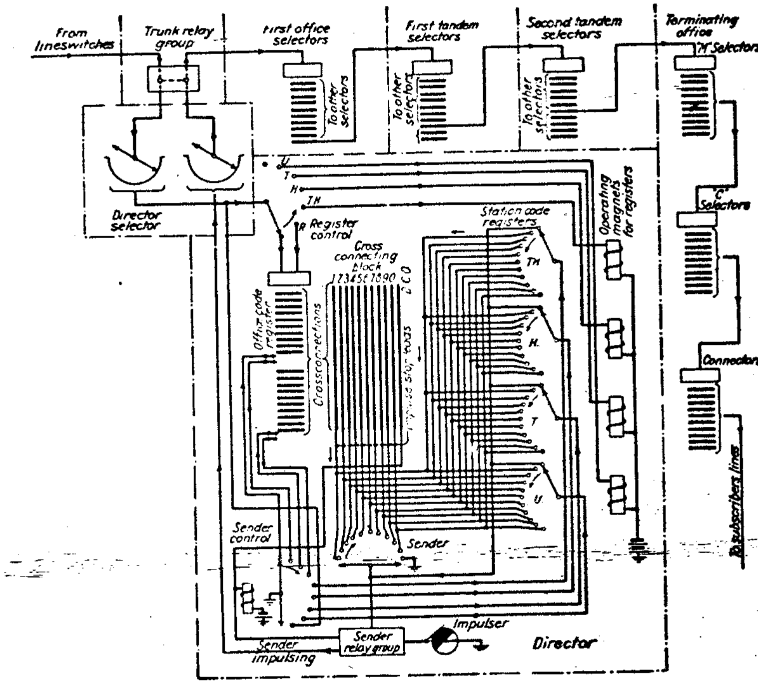


Fig. 77.—Schematic diagram of director system.

than ten groups of outgoing trunks would be needed at any of the offices, then first and second office-code selectors would be provided.

Director Apparatus.—Figure 76 is a front view of a director with the metal cover removed, and Fig. 77 a schematic diagram of a director circuit, which also shows a "director selector," and a tandem switching train. By comparing these two figures, the corresponding pieces of apparatus will be readily recognized. In Fig. 76 the "office-code register" is at the extreme left; across the top are, first, the "register-control" switch and then the four "station-code registers." For party-line service requiring five digits, a fifth register would be provided and mounted in the blank space at the extreme right. At the right of the office-code register are the "sender" and "sender-control" switches, and at the right of these are mounted the various relay required in the circuits of the director.

The office-code register is a Strowger type switch with a four-hundred-point bank, which registers the office-code portion

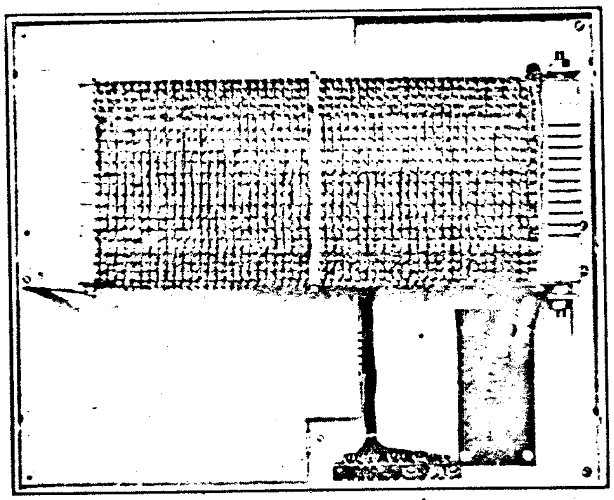


FIG. 78.—Director—rear view.

of the directory number. In the particular form shown, provision is made for registering a two-digit office code, however, the system may be arranged for a three-digit code, as will be described later. The register control is a minor-type switch, which controls the registration of the dialed digits and the impulser circuit of the sender. The station-code registers are also minor-type switches and are used to register the numerical digits of the called number. The sender and sender control are rotary-type switches. The sender transmits the translated directing digits to the switch train; and the sender control arranges for the transmission of these digits in the proper order and at the correct time and also serves to control the release and disconnection of the director when the complete office and station codes have been transmitted to the switch train.

In the central portion of Fig. 77 will be seen the elements of the director just identified and also the cross-connecting board,

which is mounted on the rear of the director. Figure 78 shows a rear view of a director, with the cross-connecting board and all the cross-connections in place. At the extreme upper left of Fig. 77 is a trunk from the line switches, shown passing through the "trunk relay group" and terminating in the first office selector. Immediately below the trunk relay group is the "director selector." This is a non-homing rotary-type switch similar to that shown in Fig. 30. At the bottom of the diagram is indicated its associated relay group and an impulser. The director selector has four bank levels but only two levels are shown, to represent the separate registering and transmitting circuits.

At the top of the drawing are the first office selectors and first and second tandem selectors, and at the right is the local switch train of a terminating office.

Operation of Director.—When the calling subscriber lifts his receiver, his line circuit is extended to the trunk relay group in the regular way. At this time, only the control trunk lead is extended through to the first office selector, and the associated director selector is connected to the trunk relay-group circuit. The director selector operates in similar manner to a rotary line switch and places its wipers in contact with the bank terminals of an idle director. When this operation has been completed, the subscriber receives the dial tone and proceeds to dial the directory digits of the desired number.

The first digit of the office code raises the wiper shaft of the office-code register to the level corresponding to the numerical equivalent of the first office letter, over a circuit through the wiper and bank contacts of the register control. The register control, after the completion of the first impulse series, steps its wipers to the second, or "rotary," contact position of the bank. The second digit dialed rotates the wipers of the office-code register to the bank contacts corresponding to the numerical value of the second digit. The office-code register wipers now rest on the bank contacts corresponding to the numerical value of the *directory* office code. The particular code is immaterial, since it is to be translated to *directing* digits appropriate for the switches required in routing the connection to the desired office. The subscriber continues to dial the station code, and the registration and retransmission of these digits will be described later.

The separate bank contacts of the office-code register (400 contacts in all) are each connected permanently to one of the

400 terminals shown in Fig. 78 on the upper and lower portions of the cross-connection block. In the center of the cross-connecting block are eleven "digit bus-bars" which on Fig. 77 are represented by the office-code register. Each of these bus-bars is provided with projecting terminal lugs, so that any one of the bank terminals may be cross-connected to any one of the digit bars. On Fig. 77 the first ten of these bars are numbered from 1 to 0 respectively, indicating the number of break-impulses that will be transmitted from the respective bars. The eleventh bar, at the right, marked *DCO* (digit cut-off) is for use when the number of directing digits is less than four, the total for which this particular director is designed. Some offices may require only one directing digit, while others may need two, three, or four. (In certain designs of directors as many as six are provided for.)

This cross-connecting block on the back of the director provides means, as will be seen, for translating the office-code *directory* digits dialed into any arbitrary one-, two-, three-, or four-digit *directing* code. The dialed digits of the directory office code will set the office-code register in a certain position, this position determining the digits of the directing code to be sent out according to the cross-connections that have been made between the bank contacts on the office-code register and the digit bus-bars.

Let us assume that the four wipers of the office-code register have been set in certain position by the vertical and rotary movements of its shaft in response to the two digits of the *directory* office code dialed. If now it is assumed that the upper one of the bank contacts so chosen had been cross-connected to digit bar 1, the next bank contact to bar 3, the next to bar 5, and the last, or lower one, to the *DCO* bar, then the two-digit code dialed will have been translated to the three-digit directing code 1-3-5 and these latter digits will be the ones sent out from the director.

When the last directory office-code digit is registered, then through a level of the register control (not shown) the impulser will be connected to the sender relays, to transmit the directing digits at the same time the station-code digits are being registered. This dual operation is made possible by the line-switch-to-first-office-selector trunk, which is broken at the trunk relay group, the left level of the director selector being connected to the line-switch side and the right level to the first office selector, as indicated on the drawing by the vertical dotted lines through the rectangle designated as the "trunk relay group." The grounded wiper of the sender control is resting on its first bank contact which is connected to the top wiper of the office-code register, and, since this bank contact is cross-connected to bus-bar 1, ground will be connected over the first "impulse-stop" lead to the first contact of the sender bank. The impulser, previously having been connected to the sender relay group, will cause the sender to move its wipers over the bank contacts. However, the ground, encountered on the first bank contact, will cause a relay, of the sender relay group, to operate and short-circuit the impulsing circuit. Therefore only one impulse will be transmitted over the "sender-impulsing" circuit. This impulse, through the bank contacts and wiper of the right level of the director selector, will elevate the wiper shaft of the first office selector to the first level. This selector will then rotate and connect with a free trunk to the first tandem selector. The sender switch will continue to rotate over its bank contacts, and, when the ten "impulse-stop" bank contacts have been passed, it will close a circuit for the operation of the sender-control switch. The sender control will then step its wipers to its second bank contact and connect ground to the second wiper of the office-code register. The register bank contact on which this wiper is resting is cross-connected to digit bus-bar 3. The sender will start to rotate its wiper and transmit three break-impulses before the sender impulsing circuit is short-circuited. These three impulses will now elevate the wiper shaft of the first tandem selector to the third level, at which point the wipers will rotate and connect with an idle trunk to a second tandem selector. The sender continues to rotate its wiper and, after passing the tenth impulse lead, will again operate the sender control to move it to the next position. In the same manner as before, the second tandem selector will be operated to the fifth level and connect with a trunk to the terminating office. The director shown is capable of transmitting four directing digits, but, since only three are required for the connection desired, the fourth must be eliminated. When the sender completed its third rotation, the sender control was operated to the fourth position, connecting with the fourth wiper of the office-code register. The bank contact on which this wiper is resting is cross-connected to the *DCO* bus-bar and it will be noted that this bus-bar is connected to the operating magnet of the sender-control switch. The grounded wiper of the sender control will, therefore, cause the sender control to move from the fourth contact and the sender switch will not rotate. The transmission of the directing digits has now been completed and the connection has been extended to the "M" selector of the desired office.

It will be recalled that, simultaneously with the transmission of the directing digits, the director has been receiving and registering the station-code digits of the called station. This registration is accomplished by means of the register control switch and the station-code registers. After the directory office code was registered, the wiper of the register control was moved to the third bank-contact position. In this position the thousands or first digit of the dialed number operates the thousands station-code register and moves its wiper to the contact corresponding to the dialed digit. The hundreds, tens, and units digits are registered in the same manner, and, if party lines requiring five digits are served by the system, a fifth register would register the additional digit. After receiving the station digits, the register control wiper is moved to a dead contact and remains there until the director is released and disconnected. Another level of this switch (not shown) continues to hold the impulser circuit connected to the sender relay group.

It will be noted on the drawing that the multiple contacts of the station-code registers are connected to corresponding "impulse-stop" leads and thence to the bank contacts of the sender switch. After the sender control was operated to cut off the last directing digit, which would normally be transmitted through the fourth, or lower, brush of the office-code register, its wiper was moved to a contact connected to the wiper of the thousands register. In this position ground, through the wiper and contact of the sender control and the wiper and contact of the thousands register, would be connected to the correspondingly numbered impulse-stop lead. The sender would again rotate and cut off the impulsing when the grounded bank contact is reached, thereby transmitting to the connected "M" selector, at the terminating office, the thousands digit of the called number. The "M" selector would be operated and extend the connection to a "C" selector. This same operation would be repeated for each of the station-code digits of the desired number, and the switch train in the terminating office would be extended to the

line of the called subscriber. The director has now completed its work and is ready to be released and made available for use in directing other connections.

After the sender-control switch disposed of the last, or units, digit, its wipers were moved to a contact, which has connected to it a circuit extending through the director selector to the trunk relay group. Ground connected to this circuit, through the wiper of the sender control, operates a relay in the trunk relay group, which extends the circuit (shown by the horizontal dotted line) directly from the line switch to the first office selector, and disconnects the circuits to the wipers of the director selector. This disconnection of the director selector in turn provides for the disconnection of the director.

All of the switches in the director, with the exception of the sender and sender-control switches, are provided with release magnets (not shown) and, when the director selector is released, these magnets are all operated simultaneously, thereby restoring the office-code register, operating the register control to its first position, and returning the wipers of the office-code registers to their normal positions. The sender switch is rotated to its normal position, if for any reason it has not already done so, and the sender-control switch is stepped to its normal or first position. The director is now completely restored and is in a position ready for use in directing another connection. The director selector is a non-homing type of rotary switch, and therefore its wipers remains in the position in which last used.

The director system is capable of handling all classes of traffic and provides for all special or irregular calls. In cases of calls for "dead" or unused office codes, or when a subscriber delays unduly in completing the dialing of a number or does not dial a complete number, the director will route the call to a special-service operator and then release. Provision is also made for extending the "class-of-service tones" to the toll or special-service operators.

Busy keys and test jacks (not shown in the schematic diagram) are provided to enable the attendants to remove a director from service temporarily, to make routine or special tests.

Mixed Systems.—Where there are both manual and automatic central offices in the same exchange, the completion of connections between subscribers in one kind of office and those in the other presents a special problem. This is a problem which nearly always occurs in the conversion of a multi-office system from manual to machine switching, as there is nearly always a considerable period during which some of the offices are operating on the manual basis while others have been cut over to the automatic. In making such connections from manual to automatic or *vice versa*, a fundamental requirement has been adopted quite generally: namely, that either the manual or automatic subscriber shall be able to make his call in the usual way (manual or dial) regardless of which class of subscriber he is calling. Thus, the subscriber need not, and frequently does not, know the type of office to which the called subscriber is connected, all numbers being listed in the telephone directory in the same manner.

One of two methods may be employed in extending connections from manual to step-by-step offices. In one, the "A," or answering, operators' positions in the manual office are equipped with dials, and the operator receiving the call selects an idle trunk to the office desired and dials the station-code portion of the number. In the other, special apparatus is installed in the step-by-step office, and the call is extended to that point by either the call-circuit or straightforward method of trunking. The equipment at the step-by-step office in this case consists of special manually operated positions, commonly called "cordless B" positions. The incoming trunks from the manual offices terminate at these positions which are equipped with sending-key sets. The cordless "B" operator, when advised of the number desired, sets up the station-code digits on her key set which then acts, in lieu of a dial, to extend the connection through the step-by-step switching apparatus to the called station.

Two methods are also available for extending connections in the other direction, that is, from step-by-step to manual offices. In one, a number of station-code switches, sufficient to handle the traffic from the step-by-step offices, are installed in each of the manual offices. The other method utilizes special manually operated incoming-trunk positions at the manual offices. The method used depends upon the ultimate plan of the system, although the latter is the one more frequently employed. In the second arrangement, the special trunk positions are provided with the complete subscriber's multiple, and the incoming trunks from the various step-by-step offices terminate in plug-ended circuits. The key shelves are equipped with visual

illuminated number-display apparatus called "call indicators," and, hence, these positions are termed "call-indicator" positions. Associated apparatus is provided at each manual office which registers and stores the station-code portion of the number dialed by the calling subscriber.

Call-indicator Positions.—Figure 79 shows a call-indicator position of a manual multiple board. It is equipped with forty-eight incoming-trunk circuits from step-by-step offices. The trunks from a particular office are distributed among the

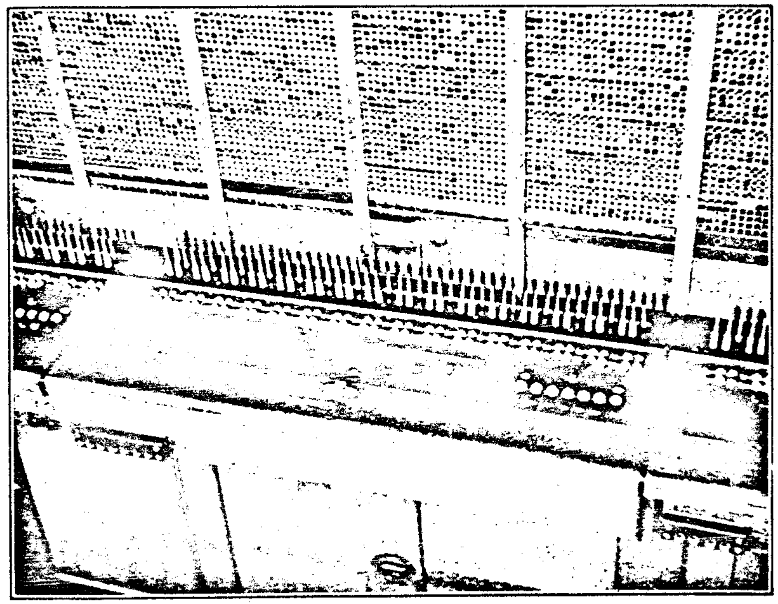


Fig. 79.—Call-indicator switchboard position.

various incoming positions, providing for better distribution of the incoming traffic and facilitating night service by permitting subgroups of trunks from all the offices to be consolidated on a few call-indicator positions. The trunks terminating at the unoccupied positions are made busy by special busying circuits, so that the step-by-step switching apparatus will not attempt to distribute calls to them.

The plugs of the incoming trunks are shown in a single row on the plug shelf at the rear of the key shelf. Associated with, and in front of, each of these plugs are two supervisory lamps, one the assignment lamp and the other the disconnect lamp.

In front of these and at the center and left portions of the key shelf are two call-indicator display panels. The one at the left is the reserve panel, and the one at the center the regular panel. The object of providing duplicate panels is to enable the operator to continue to operate with the reserve panel, in case one or more lamps burn out in the regular panel during the busy period of the day. Each panel has a frosted-glass top plate, below which are four groups of ten lamps each with a transparent number plate above each lamp, each group representing the ten numerals for each of the four digits. The calling number is displayed by lighting one lamp in each group, and in the illustration the number 9753 is shown displayed.

In manual offices serving party lines, a fifth group of display lamps is sometimes required. The lamps of this group indicate the party-line designation following the display of the four digits of the number. A certain time interval is required to either display the party-line suffix or to definitely indicate an individual-line number.

In the right portion of the key shelf is a lamp and key panel. The central office at which this view was taken has seven register sets for each operator's position and the seven lamps in a row are associated with these register sets. One of the lamps is illuminated when a number is displayed, thereby indicating the particular register set on which the number is registered. In front of the first lamp at the left is a plunger-type key called the "assignment" key. The circuit of this key is so arranged that, if a number is displayed and no trunk-assignment lamp lights, the operator, by depressing the key, will cause the disconnect lamp of the assigned trunk to light, thereby directing her to the proper trunk to use in completing the connection. The plunger-type key in front of the seventh lamp from the left is the "stepping" key and is used by the operator to move the display control switch off the contacts of a register set which is showing an aberrated or incomplete number on the display panel. This key enables an operator to free an aberrated number from her position and continue to complete normal connections. Busy-back jacks are mounted below the multiple for transmitting a busy tone to the calling subscriber in case the called line is busy.

Figure 80 is a schematic diagram of call-indicator equipment and its circuits. At the top of the drawing is a portion of a group of incoming trunks from a step-by-step office. Each of

the trunks has an associated relay group, which in addition to providing for the usual automatic ringing and supervisory functions, has additional relays for extending the break-impulses of the dialed number, through register selectors to register sets. Below the trunk relay groups are shown the register selectors. These selectors are non-homing-type rotary switches and serve to associate an idle register set with an incoming trunk. One register selector is required for each incoming trunk and the bank

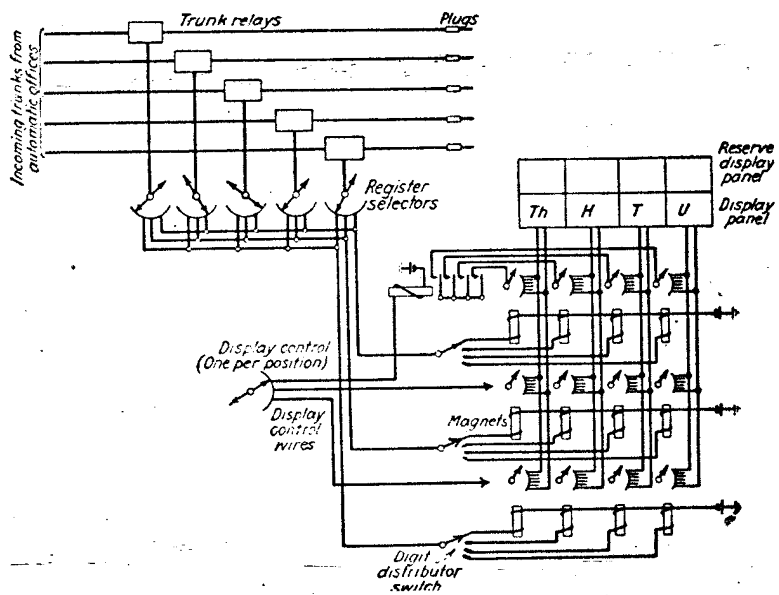


Fig. 80.—Schematic diagram of call-indicator equipment.

contacts are multipled and terminated in the wipers of the digit distributor switches. At the right of the register selectors are the display panels at the switchboard positions. The regular and reserve panels are shown for one position. Below the display panels are the register sets which are mounted on a standard rack in the terminal or apparatus room. Three of these sets are shown, but in practice from six to eight are associated with each switchboard position. The register switches of these sets are of the minor-rotary type and are therefore restored to normal after the set is released. The digit distributor switches (one per register set) are also minor type and serve to connect the dialing circuit with the proper digit registers as the impulses are received.

At the left of the register sets is shown one of the display control switches. This switch is of the non-homing rotary type (one per position) and it is controlled by the availability of the operator; that is, when an operator has disposed of a connection and is free, this switch transfers to her position another call which at that time may be stored on another register set associated with her position. However, if no calls are waiting, this switch does not operate. The controlling relay for transferring the registered call to the display panel is shown at the left of the upper register set. One of these relays is required for each register set.

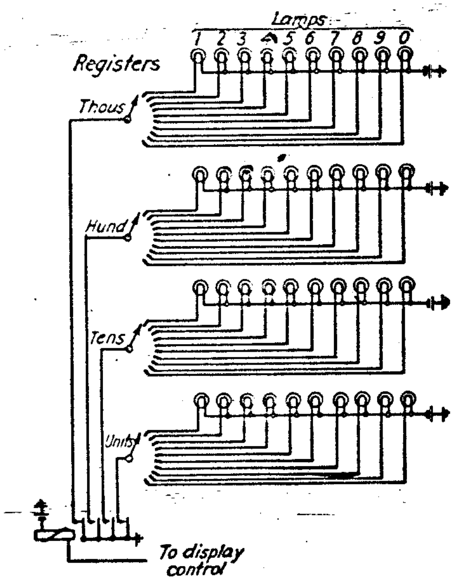


FIG. 81.—Wiring of display-lamp circuits.

Figure 81 shows in a little more detail the method of wiring the number lamps of the display panel to the register bank contacts. When the controlling relay is operated by the display control switch, ground is applied to each of the wipers of the register switch, and through the contacts on which the wiper are then resting, to the proper number lamps in the display panel and to battery. This causes to be displayed before the operator the numerical digits which have been stored on one of the register sets. At the same time, the assignment lamp, associated with the plug of the incoming trunk, lights and indicates the particular trunk to be used in completing the connection.

Cordless "B" Positions.—Figure 82 is a photograph of several cordless "B" switchboard positions utilized in extending connections from manual offices to a step-by-step office. Associated with the switchboard positions, but located elsewhere in the building, are senders, and sometimes sender finders, for allocating senders to the positions, for transmitting the digits set up on the key sets, to the step-by-step switching apparatus of the office. The sections of the switchboard are of one position each and, in order to facilitate operation and the observation of signals, both the key shelf and trunk face panel are placed at an angle, the face panel having about twice the angularity of the key shelf.

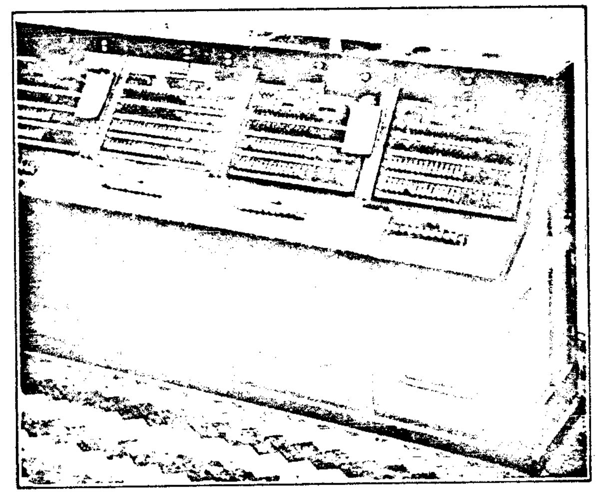


FIG. 82.—Cordless "B" switchboard positions.

In the center of each key shelf are the digit-sending keys and immediately above them a cancel key. When an error has been made in the operation of the digit key, the cancel key is depressed, thereby erasing the incorrect number and permitting the correction of an error without again pressing the assignment key associated with the incoming trunk. At the left of each position is mounted a glass-covered instruction-card panel. These positions each have a capacity of fifty trunks of which in this case thirty are equipped. The face panel has five horizontal rows of keys and lamps with a designation strip below each row. The four lower rows have changeable designations for trunk numbers, while the top row has fixed designations. In each of the two lower rows are fifteen plunger-type keys and lamps associated with the incoming trunks. The plunger keys are the trunk-assignment keys and are pressed immediately after the operator has received from an "A" operator the number called and has assigned the trunk, but before the number has been registered on the sender-key set. The assignment key serves to associate a sender with the position. The associated lamps are the supervisory lamps, and in this case the "one-lamp" type of supervision is employed. In this method, the lamp remains lighted while the trunk is in use and flashes if an "A" operator plugs into the wrong trunk or one on which the assignment key has not been pressed. The lamp is extinguished when the trunk is disconnected, but the cordless "B" operator is not involved in the disconnection, since it is accomplished automatically. The third and fourth rows of the face panel each comprise fifteen two-position lever keys associated with the correspondingly positioned trunk-assignment keys and supervisory lamps in the first two rows. When a key lever is moved downward or toward the operator, the associated trunk is removed from service and the supervisory lamp lighted. The upward position of the key is for the purpose of converting the associated incoming trunk to an emergency call circuit when the regular call circuit is out of service. In this case also, the supervisory lamp lights and remains lighted while the trunk is used as an emergency call circuit. The top or fifth row contains keys associated with the local operation of the positions, such as disconnecting a faulty call circuit or grouping call circuits for night service, calling a supervisor and disconnecting sender finders.

While the above illustration and description are for the call-circuit method of operating trunks, the straightforward method is equally applicable with a similar type of equipment.

Small-community and Rural Systems.—Step-by-step central-office equipment has been adapted to the needs of small-community and rural-district exchanges serving from a few subscribers up to several hundred. These small exchanges may be "attended," that is, looked after by someone in constant attendance, or they may be "unattended" and supervised from a near-by city exchange or toll center. The latter method of operating is assumed in the following description. In many instances, several small unattended exchanges are supervised from the same point. Toll, information, and special-service

calls are handled through the supervising center, so that a twenty-four-hour service is furnished which otherwise might not be warranted in certain small communities. The unattended offices are visited by maintenance employees at predetermined intervals to check up on the operation of the equipment and correct any non-standard conditions that may have developed.

Similar switching apparatus operating on the general principles already described for larger offices are employed in these small exchanges. The main differences are in the arrangement and mounting of the apparatus and in the addition of remote-control apparatus for maintenance supervision. Certain of the local equipment must also be arranged to function automatically, as, for example, that for charging the storage batteries. The subscribers' stations are usually served by party lines.

Two general methods of serving small communities by step-by-step equipment are employed by Automatic Electric Company and styled by that concern as "full-automatic" and "semi-automatic" respectively. Each of these general methods is subject to various modifications to meet special local requirements.

Full-automatic Operation in Small Communities.—With the full-automatic method of operation, the central-office switches are controlled by dials at the subscribers' stations as in larger step-by-step exchanges. The subscribers' dials have simple number plates with numerals only, as shown in the left-hand cut of Fig. 7.

The common-battery method for both talking and signaling is used, thus requiring storage batteries and means for charging them. The "floating" method of charging, explained in Chap. VII, is used, the charging being automatically controlled by the voltage of the battery and in some instances by ampere-hour meters. Either rectifiers or motor-generator sets may be employed for charging, depending on the type of power supply available.

The telephone stations are ordinarily arranged for ten-party service with code or harmonic ringing, thus requiring the use of frequency-selecting type connectors. Reverting-call switches are provided to handle calls between stations on the same line. The ringing current may be supplied by rotary ringing machines but, on account of the small current required, the vibrator type of equipment is most commonly provided. These unattended offices are also equipped with apparatus for the transmission of alarm signals to the supervising center, as will be described later. The subscribers secure connections in the same manner as previously explained for the larger systems, the switching operations being in no way affected by the method of supervision employed.

Semi-automatic Operation in Small Exchanges.—This is really a remote-control method of operation, the control of the central-office switches being exerted by a distant operator rather than by the subscribers themselves. This operator, located at an associated city office, is known as the "control" operator. She merely ascertains the wishes of the calling subscriber and establishes the connection by means of a dial or key set connected to the unattended exchange over a control trunk. The control trunk is used by the subscriber in telling the control operator the connection desired, and by the control operator in setting up the connection. This trunk is not used in the actual connections between subscribers. After dialing, the operator disconnects from the control trunk and exercises no further supervision on the local connection she establishes.

This method of operating may be employed in small scattered communities to eliminate the necessity of maintaining operators at points where there is insufficient traffic to keep them busy. Sometimes such offices are installed when the associated city exchange is manually operated, but where it is planned to change the entire system to full-automatic operation at some later date, at which time the semi-automatic offices will be changed to full-automatic operation.

These exchanges generally operate with local battery transmission and magneto signaling requiring, therefore, local batteries and hand generators at the substations, the generator being used to signal the control operator and to release the connection after completion of conversation. The central-office equipment comprises line switches and numerical switches and is similar to that just explained for full-automatic unattended exchanges, except that a semi-automatic type of numerical switches is required. Toll trunks, usually the two-way type, are provided between the unattended office and the control center and such other toll centers or exchanges as the local conditions and traffic warrant. Provisions are made, by remote-control means, for converting any one of the toll trunks to a control trunk in case the regular control trunk becomes inoperative, and an emergency

operating set is usually installed at the unattended office for use when, for any reason, all of the trunks to the control center are out of service.

When a subscriber removes his receiver from the hook switch and turns the hand generator to make a call to another local station, the line switch operates and extends the connection to a numerical switch or connector. A relay in the numerical switch operates and extends the connection to the control trunk. If the control trunk is busy, the line switch will not operate until the trunk is free. This trunk, when seized, causes a signal to be displayed before the control operator. The control operator answers the signal by operating a key associated with the trunk and connects her listening and dialing circuit. After ascertaining the number desired, she dials and releases her circuit from the control trunk by restoring the key. When the operator dials the desired number, the numerical switch previously used at the unattended office in extending the connection to the control trunk receives the break-impulses and operates to extend the connection from the calling line to the line of the called subscriber. Ringing current is then applied to the line, or if the called line is busy, the busy tone is transmitted to the calling station in the usual manner. When the numerical switch completes the selecting functions, the control trunk is released and made available for use in connection with other originating calls.

Reverting calls are completed by the operator who dials a code number to signal the wanted station, after instructing the calling subscriber to hang up and wait for a moment.

Outgoing toll calls or calls for other exchanges are handled in the same manner as a local connection, except that the control operator, instead of dialing a subscriber's number, dials a pre-assigned number to connect the line of the calling subscriber to a toll or other exchange trunk extending to the proper operator.

Incoming toll or other exchange calls to subscribers are completed in the same manner as in full-automatic operation, since the unattended exchanges are provided with numerical switches capable of reaching any subscriber's line in the exchange.

Rural-line Operation.—The rural lines are practically always operated on the multi-station basis, with code ringing. These lines may be operated by the full-automatic or the semi-automatic method as may be desired, but the following description will be for the full automatic.

The local-battery method of telephonic transmission is generally used, and the subscribers' stations are equipped with local-battery magneto instruments provided with dials having the simple number plate. The central-office switching equipment consists of line switches, selector repeaters, and connectors, according to the requirements of the individual exchange. On account of the frequent long length and character of rural lines, "simplex" dialing is quite often employed. In one arrangement of this, the dialing circuit is established by connecting one of the impulse springs of the dial to ground and the other to the center tap of the ringer coils and by connecting the line relay at the central office to the center tap of the line repeating coil. Thus the dialing impulses are sent over both sides of the line in parallel with a ground return.

The subscribers secure connections to other stations in the same general manner as previously described for full-automatic or semi-automatic operation in small-community systems. Calls for another party on the same line are usually made by the subscriber's signaling the code of the desired station by means of his hand generator.

Safeguards and Alarm Signals.—Since the unattended community exchange depends upon supervision from a distant point, the maintenance methods are somewhat different from those in the larger attended exchanges, and it is desirable to provide remote-control means and additional safeguards to insure the continuity of service.

The self-aligning type of plunger line switch affords means for enabling a subscriber to free himself from a defective trunk circuit. The inter-office trunks to the city exchange or toll center are so arranged as to enable a subscriber to connect with one even though one or more of them may be in trouble. The incoming ends of these trunks at the toll center or city exchange are under constant supervision but, however, certain classes of faults, as for example open conductors, do not give an indication until connected for use. This contingency—of being unable to get through—is guarded against by using a "trunk-busying" circuit which is arranged to busy the first trunk after it has been used, so that the next call must take the second trunk. Thus a subscriber, by recalling, is always able to get free from a faulty trunk and reach an operator, or other central-office switching apparatus, as long as any of the trunks are working. Special

forms of intra-office trunk multipling also are employed to distribute the traffic, so that recalls will not be routed through the same switching apparatus. When duplicate ringing sets are provided, the circuits are so arranged that, if trouble should develop on the set in service, it will be removed from service automatically and the other set substituted.

In order to facilitate the supervision of these offices from a distant point, various alarm signals are provided to indicate when a non-standard condition occurs at the unattended office, such as a blown fuse, lack of ringing current, improper operation of the charging equipment, or line permanents. These signals are transmitted to the supervising office over one of the regular inter-office trunks. The signal received does not indicate the character of the fault and the attendant then dials a pre-assigned "test" number to connect with the supervisory equipment at the unattended office to obtain further details. The alarms are divided into two classes: "emergency" alarms indicating conditions which prevent the continuation of service or the proper functioning of a major unit of apparatus, and thus requiring immediate attention, and "regular" alarms for non-standard conditions which do not seriously impair the service and may, therefore, be cleared when convenient. After dialing the test number, the attendant will hear a tone signal if the alarm was of a regular nature and will not hear any tone if the alarm was of an emergency character.

Sectional Mounting Frames.—A type of mounting frame and method of wiring for small unattended office equipments, which provides for flexibility in growth and for complete enclosure against dust and mechanical injury, has been developed and standardized. The frames are of "sectional" type, after the manner of sectional bookcases. The sections or units are designed for mounting numerical switches, line switches, and other groups of apparatus and all the circuits for each shelf are wired to terminal blocks before leaving the factory. Each section is therefore completely self-contained, so that, in installing them, it is necessary only to place them in the desired positions and make the proper cross-connections between their respective terminal blocks.

Such a switchboard is shown in Fig. 83, in which the enclosing panels of the center section and two of the individual connector switch covers are shown removed and on the floor. The rear panels are removable in the same way, affording complete access to all the equipment. In this particular switchboard, the front compartment of the lower section is the "power shelf" containing the power panel, busy and ringing interrupters, and associated relays, while the rear compartment contains fifty line switches. The middle and upper sections each contain in their front compartments capacity for ten ten-party frequency selectors, of which ten for local service are seen in the illustra-

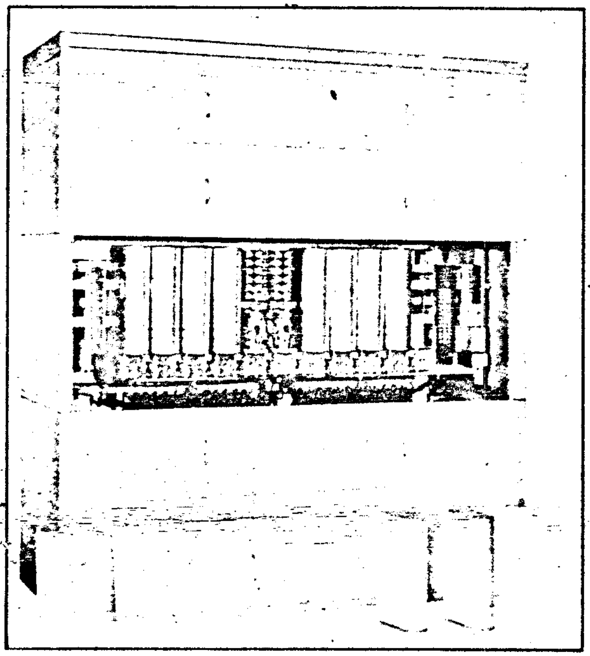


FIG. 83.—Sectional-type switchboard—top and bottom section panels in place.

tion. Multiple banks for the complete switch capacity are installed and wired on each shelf. The rear compartments of these sections contain miscellaneous equipment, such as reverting-call switches, impulse repeaters, numerical switches associated with trunks to other offices, and supervisory and testing equipment.

The battery and charging equipment is enclosed in a separate metal cabinet. A separate distributing frame with protective apparatus for the lines is also required. This may be of either the wall or the floor type according to the size of the office.

AUXILIARY CENTRAL-OFFICE EQUIPMENT

The more important groups of auxiliary equipment, not directly entering into the switching operations proper but, nevertheless, essential or convenient in the operation of the exchange, are the distributing frames, power plant, testing and routine equipment, and information and service-observing equipment.

Distributing Frames.—The general type of main and intermediate distributing frames described in Chap. IX are used in step-by-step systems, but, in addition, some special types

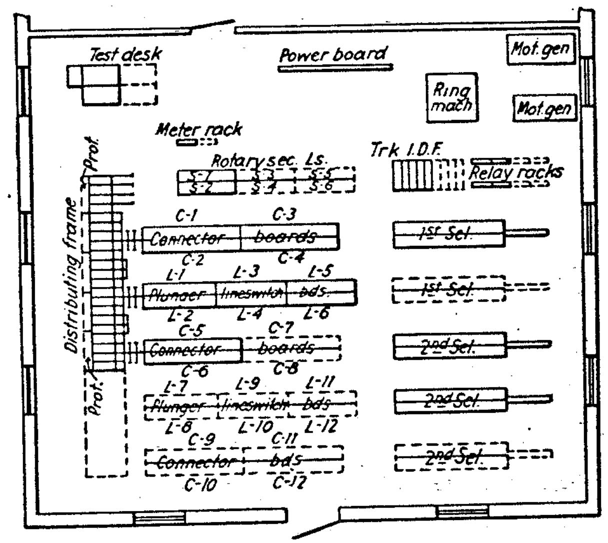


FIG. 84.—Floor plan of central office with combination distributing frame and selector distributing assembly frames.

developed for the particular requirements of the system may be referred to here. The two most important of these are the "combined main and line intermediate distributing frame" and the "selector distributing terminal assembly frame."

Combined Main and Line Intermediate Distributing Frame.—This arrangement provides the necessary flexibility in cross-connecting and at the same time affords a saving in floor space, in cable and cross-connections, and in the number of terminal blocks needed.

Figure 84 is a typical floor plan of a 6,000-line office using the combination type of frame. The combination frame is shown at the left, the protector side facing the wall. Placed on the opposite side of the framework, and adjacent to what would ordinarily be the switchboard terminal side, are the line-switch and connector-board terminal racks. These racks are at the ends of the rows of line-switch and connector boards. These rows, with aisles between, extend at right angles to the distributing frame proper.

The line-switch units are mounted on both sides of their boards and arranged horizontally, as shown in Fig. 40. The connectors also are mounted on both sides of their boards. The terminal blocks on the line-switch and connector racks are mounted vertically and replace the terminal blocks formerly mounted on the separate boards. What would formerly have been the switchboard side of the main framework carries no terminals, except that the party-line grouping terminal blocks, when required, are mounted in the spaces opposite the aisles, and except that the four vertical rows of terminal blocks shown at the upper end of figure on the combination frame are provided for terminating toll and miscellaneous circuits.

At the right of the vertically mounted terminal blocks are the rotary secondary line switches, and at the right of these is the trunk I.D.F. Below the trunk I.D.F. are the first and second selectors, mounted on double-sided boards and with selector distributing terminal assembly frames (to be described later) shown at the right of each.

In the arrangement shown, the subscribers' line circuits of the primary plunger line switches and the normals of the connectors are cabled to blocks on the respective terminal racks. The trunks from the primary and secondary line switches are cabled to the trunk I.D.F. The trunks to the first selectors are cabled from the trunk I.D.F. to the first-selector boards. The multiple bank circuits of the first selectors are wired to the associated terminal assembly frames and from these the trunks are cabled to the second selectors. The multiple bank circuits of the second selectors are likewise wired to associated terminal assembly frames and from there trunks are cabled to the connectors. The subscribers' outside lines, the terminal blocks on the line-switch terminal racks, and the terminal blocks on the connector terminal racks are cross-connected on the combination frame properly to connect the line switches and connector normals to the subscribers' lines. The primary

line switches are cross-connected to secondary line switches, and the secondary line switches to first selectors at the trunk I.D.F.

Selector Distributing Terminal Assembly Frame.—This type of frame has been developed to facilitate the re-arranging of selector trunk groups, to provide for readily making additions to the trunking system, and to permit the use of the method of trunk multipling, which is the most economical for a given installation. Figure 85 shows a selector distributing frame at the left, and a portion of a trunk selector board at the right. This is a high-type board with eight shelves of selectors, each shelf having a capacity for twenty selectors, divided into two subgroups of ten each. The selector terminal frame may be placed between two single-sided trunk boards or at the end of a double-sided board as was shown at the right of Fig. 84.

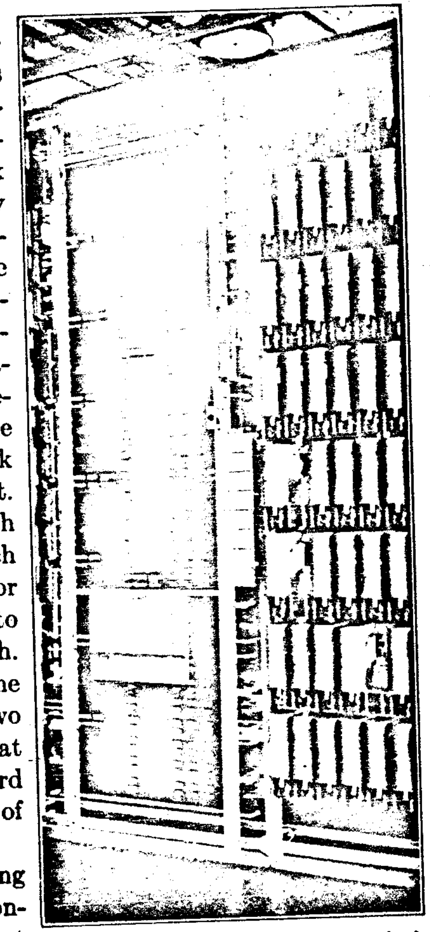


Fig. 85.—Selector distributing terminal assembly frame.

The selector distributing frame consists of 32 horizontal rows of three-pin contact blocks mounted on an iron framework. The pins in these blocks project on both sides and, therefore, connections may be made at either side. Each horizontal row of blocks has 300 terminal pins, on which are terminated the multiple bank circuits for a subgroup of 10 selectors. The 32 rows will, therefore, serve to terminate the multiple bank circuits of 32 subgroups or the total capacity of two single-sided high-type selector boards or one double-sided board.

The multiple bank wires from the switches are connected to the back side of the frame terminals and on the front side vertical cross-connections are placed to arrange for any desired grouping of the subgroup multiple bank circuits. The circuit groups are wired from the horizontal blocks to terminal blocks mounted vertically on the right and left sides of the selector distributing terminal assembly frame. From these, terminal blocks cables are extended to the next selectors or connectors in the switch train. Therefore, by merely changing the cross-connections and the connections to the vertical terminal blocks, changes may be made in the trunk groups without disturbing, in any way, the permanent multiple switch-bank wiring on the horizontal terminal blocks.

Power Plants.—The common elements of telephone power plants, such as storage batteries, charging and ringing machines, and power boards, are dealt with in Chap. VII, which also contains a description of typical power-plant practices of the Strowger step-by-step system. As it is the practice of Automatic Electric Company closely to associate the apparatus of its supervisory alarm system with its power-plant apparatus, specific attention to this alarm system may be given here.

Supervisory Alarm System.—This is an arrangement of signal equipment which, in case of a non-standard condition, gives an alarm indicating the nature of the abnormal condition and its general location. The alarm generally consists of an audible and visual signal. The operation of the various alarm circuits is under the control of relays mounted on the supervisory panel of the power switchboard (right panel of Fig. 215, Chap. VII), and also relays on the connector, selector, and line-equipment boards. Alarm circuits are usually provided for line-switch boards, selector trunk boards, connector boards, power equipment, and the main distributing frame.

Non-standard conditions may be divided into two classes. The first is non-standard as soon as the fault occurs, such as the blowing of a fuse on any one of the fuse panels, which must cause the immediate operation of an alarm; and the second becomes non-standard only after an appreciable time interval, such as the failure of a connector to release. In the latter case, the alarm equipment must not operate until after the normal releasing time of the switch has elapsed. Each of the line-switch, connector, and selector signal groups has associated

with it a group of relays, the function of which is to delay the operation of the alarm equipment on non-standard conditions of the second class. The interval of delay is controlled by two release-time control relays which are operated alternately by the ringing interrupter equipment or by special timing control equipments.

The particular supervisory arrangement provided is determined by the type and layout of the switching equipment, the alarm apparatus being divided into the most convenient signal groups according to physical location. In an office employing the low type of frame equipment, a typical signal scheme would operate as follows: When a non-standard condition develops, an audible alarm signal sounds, and directing lamps are illuminated. One lamp is located in a "ceiling panel" (Fig. 86)

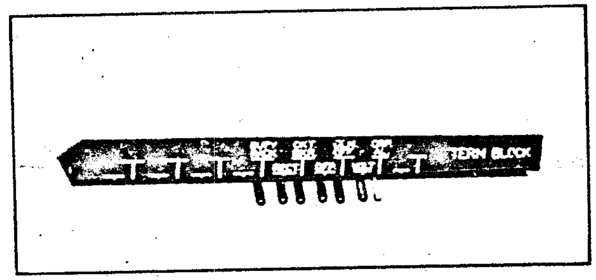


Fig. 86.—Signal-lamp panel—ceiling type.

which is placed near the ceiling in a position easily visible from various parts of the switchroom or visible from a desk at which some switchman is normally on duty. This lamp indicates by its color and marked designation the nature of the alarm and the signal group in which the fault exists. Another lamp is lighted on the shelf of the particular board where the non-standard condition occurs. A switchman following these signal lamps is readily guided to the location of the fault. In an office using high type of frame equipment, the ceiling panel lamps are usually omitted, since they could not be readily seen, and, instead, signal group lamps at the main-aisle ends of the trunk-board line-ups are generally employed. In this case, signal lamps also are provided on each shelf of the boards.

On the line-switch boards, a blue lamp is lighted when a master switch continues to rotate and a green lamp when a line-switch line relay fails to release. A red signal light indicates a blown fuse. On the trunk selector boards, a green lamp indicates that a selector switch has failed to release, and a white lamp shows that a selector switch is held operated but not switched through. As in the case of the line-switch alarm, a red light indicates that a fuse has blown. The alarms for the connector boards are the same as for the selector boards and the non-standard conditions are indicated by lamps of the same characteristic colors. Associated with the delay relay group of the line-switch, selector, and connector boards and mounted on the audible alarm panel is a harmonious bell which operates simultaneously with the visual signals. The blowing of a battery or ringing-generator fuse, or the opening of a circuit breaker, causes the operation of a buzzer on the audible alarm panel, and a generator failure causes an alarm bell to ring. An alarm bell is also provided to indicate high or low voltage at the battery bus-bars. When a main distributing-frame heat coil operates, a buzzer located on the distributing frame gives an audible alarm and a white lamp associated with the particular protector vertical is lighted.

Testing Facilities.—Facilities for rapidly and accurately testing to determine the presence of conditions that interfere with the proper operation of the system or that, if allowed to persist, would be likely to do so in the future form an important part of step-by-step exchange equipment. The type of testing equipment provided depends somewhat on the size of the system, smaller offices requiring relatively simple and larger systems more elaborate equipment. Centralized testing from one office is usually employed in the multi-office exchanges on account of the economy resulting from maintaining only one group of testing employees. However, sufficient testing equipment is usually installed in each of the other offices to provide for the cut-over and additions or major changes in the outside plant, and for use in cases of emergency, such as a cable failure or damage from a disastrous storm. In offices where quite a number of toll lines are terminated or looped through, separate toll test panels are usually provided in addition to the local testing equipment.

Local Test Desk.—When the ultimate equipment of an office or system is planned to exceed about one thousand lines, the more complete testing facilities operated from a "local test desk" are usually provided. The desk has a volt-milliammeter and associated equipment for quickly determining the nature and

degree of electrical faults and a dial speed indicator for accurately measuring the speed of impulsing of the subscribers' dials, and it may be provided also with a Wheatstone bridge for making "location" tests of faults in the outside plant. In addition the desk is afforded means for communicating, usually by call circuits, with other test desks and service facilities in the system. Circuits are provided from the special selectors to the desk for extending calls from inspectors, installers, or other company employees. Outgoing calls to subscribers' stations are made by single-ended cord circuits terminated in selector switches.

In general, three methods may be employed in connecting the subscribers' lines or trunks to be tested to the test desk. The first is by means of the incoming trunks to the test desk from the special selector levels. These trunks are provided for the use of company employees in communicating with the test desk and, when not equipped with repeaters or holding bridges, they may be used to advantage for testing purposes. The second method is by means of test lines to the M.D.F. These lines terminate in multiple jack boxes suitably located at the M.D.F., from which a connection may be extended through a flexible cord and test shoe to the protector springs of the line or trunk to be tested. At the test desk each of these test lines terminates in a bridged listening jack and two cut-off jacks, so arranged that the "line" side of the circuit may be tested independently of the "switchboard" side, thus providing a means of first determining whether the trouble is "inside" or "outside." The listening jack permits the testman to determine whether or not the line or trunk is in use before "splitting" the circuit for test. The third method utilizes the "test switch train," which was briefly described in connection with Fig. 71. The test switch train is made up of two or three special types of Strowger switches, depending on whether the exchange is a single- or multi-office system and, in the latter case, on the number of central offices. The test switch train circuits terminate at the test desk in jacks with associated supervisory lamps, busy lamps, and release keys. They enable the testman to make direct connection with the normals of any desired line at the connector banks over a test trunk free from all bridges and attachments, and therefore suitable for making tests on the outside line, station equipment, and line switch. When the wipers of a test connector are rotated to the normals of a busy line, a busy tone and visual signal are transmitted to the test desk and the testman may hold the test trunk until the line becomes idle or he may connect with the busy line. In cases where a number of lines terminating on the same connector are to be tested, the testman may release the test connector and connect with the other lines by simply dialing the tens and units digits of the number or, when the desired number is on the same level, by dialing the units digit only. This feature is generally employed when routine tests are made on all the subscribers'

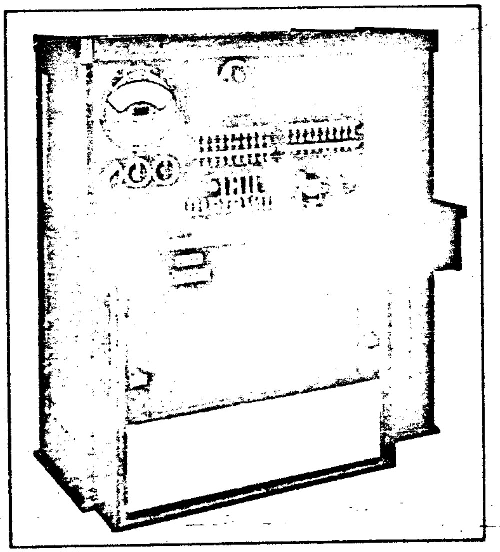


FIG. 87.—Local test desk.

lines. The test connectors are also utilized in the toll-verification switch train as previously referred to in connection with Fig. 71. When so used, the toll-verification switch-bank levels are multipled to the bank levels of the test-distributor switches and the verification switch train connected to the toll board in the same manner as the test switch train is connected to the test desk.

The front of a typical one-position local test desk, with a cable-turning section at the right, is illustrated in Fig. 87. When several positions are required, the necessary number of one-position sections are placed adjacent to each other. In the desk is mounted all the apparatus associated with the various

circuits with the exception of the switches in the test switch train and in the combined howler and insulation breakdown test switch circuit. The face equipment of each section is installed in three panels. The volt-ammeter is located in the left panel, and below it the associated rheostat dials. The center panel has the dial speed indicator mounted at the top and immediately below are ten test distributor trunks with designation strip, busy lamps, jacks, supervisory lamps, and release keys; and below these are ten miscellaneous test lines including those to the M.D.F. This test line equipment consists of designation strip, jacks, and supervisory lamps. The right panel has ten inspectors' trunks from selector levels, consisting of designation strip, hold lamps, answering jacks, and answering lamps. The lower group of trunks in this panel are reserved for test lines to a toll test panel and consist of designation strip and jacks. Below the jack space in the center and right panels are various pilot lamps and keys associated with the position.

The key shelf of the position is equipped with keys, plugs, and supervisory lamps associated with the circuits of the desk. The dial will be seen at the right of the keys. At the left of the lever keys are five standard call-circuit keys. The first nine lever keys from the left are arranged in two rows, those in the front row being associated with the primary test circuit and those in the back row are the master ringing keys and the keys associated with the auxiliary test circuit. The tenth key in the front row is the coin-control key associated with the coin-box test circuit. The next three keys are for use with the Wheatstone bridge. A key space comes next and then the key for talking and dialing on the single-ended cord circuit. The last key in the row is the transmitter cut-out. Of the five plugs, the two at the left are respectively for connecting the primary test circuit and the auxiliary test circuit. The third plug is associated with the sounder test circuit and the fourth with the Wheatstone bridge. The last plug at the right is the answering plug of the single-ended cord circuit. These plugs have associated cord supervisory lamps, not visible in the illustration. Mounted in the lock rail below the key shelf at the left are the jacks for the operator's telephone set, and at the right is the drawer for the Wheatstone bridge.

The principal elements of the testing equipment proper are associated with either the primary or auxiliary testing cord circuits. The primary test cord is ordinarily used for making routine tests and others requiring the use of the volt-milliammeter or the Wheatstone bridge, while the auxiliary testing circuit is employed in making howler and insulation breakdown, dial speed, sounder tests, etc., which consume considerable time. This arrangement permits the testman to conduct dif-

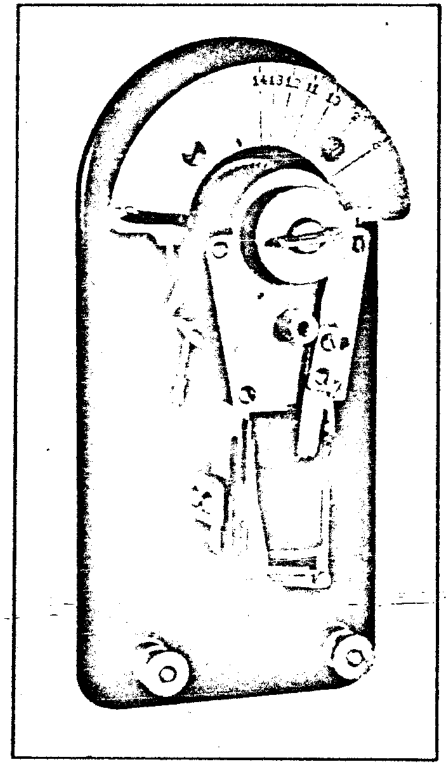


Fig. 88.—Dial speed indicator.

ferent kinds of tests simultaneously. However, by means of a switching key the primary and auxiliary testing circuits can be interchanged with respect to their cords without the necessity of actually changing the plugs.

Besides the tests common to telephone exchanges in general, the step-by-step system requires some peculiar to itself. An important one of these, for which this desk is equipped, is that for the accurate determination of the speed of the substation

dials. The device for making this is the dial speed indicator which was referred to in describing Fig. 87. A larger view of this apparatus, with the cover removed, is given in Fig. 88 and its operating circuit in Fig. 89. The pointer of the dial speed indicator is moved from left to right by a clock spring under control of an escapement. Its speed is constant regardless of the speed of the dial being tested and is such as to move from 0 to 10 on the scale in just 1 second. The starting and stopping are under control of the station dial being tested, the first dial-break starting it and the tenth stopping it at whatever point it may have reached. Obviously, if the dial under test is running too fast, the pointer will stop before it reaches 10; if too slow, it will be stopped some point beyond 10; if just right (10 impulses

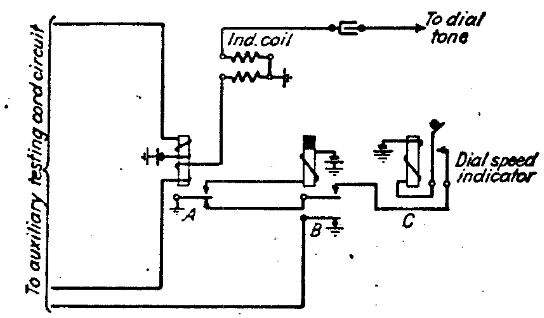


Fig. 89.—Dial speed-testing circuit.

per second), it will stop at 10. The scale is calibrated in impulses per second.

The circuit of this indicator is connected to the auxiliary testing circuit by means of a "dial key" and supervision is provided by means of the cord supervisory lamp. The auxiliary testing cord is connected to the subscriber's line by any one of the three means previously stated, namely, test lines at M.D.F., inspectors' trunks, or test connectors. Before making the test, the testman must be assured that the line is free from bridges or attachments at the central office, this condition being indicated by a lighted cord supervisory lamp. To set the indicator for operation, the testman turns its handle to the left until the pointer is at the 0 mark. The handle then turns clockwise to close the circuit-breaker springs shown at the right of the magnet C in Fig. 89. The device is now ready for the dial impulses.

With the receiver off the hook at the subscriber's station, the line circuit is closed through the dial-impulse springs and relay *A* in the testing circuit is energized. The operation of the slow-acting relay *B* follows and connects the circuit of the stepping magnet *C* through the closed circuit-breaker springs to contacts of relay *A* and extinguishes the testing cord supervisory lamp. Dial tone is transmitted to the subscriber's station to advise that the testman has the indicator connected and ready to receive the dial impulses. The inspector or person assisting the testman then dials zero (0). At the central office, relay *A* will be released momentarily on the first break-impulse from the dial and thereby close the circuit of magnet *C* to release the

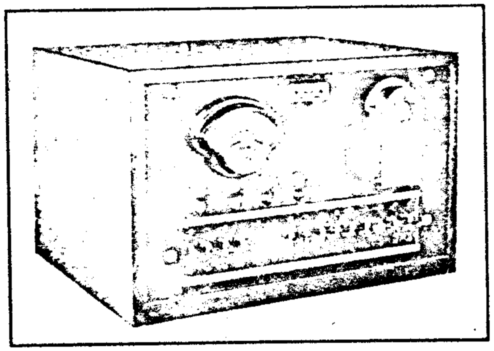


FIG. 90.—Testing turret—front view.

indicator pointer which will begin to move at its own speed. Meanwhile, magnet *C* will be operated ten times and on the tenth impulse will operate a tripping device to stop the pointer. The position of the pointer when stopped indicates directly the number of break-impulses transmitted by the dial per second. The usual standard for which dials are adjusted is ten per second.

In small installations the duties of testman and repair clerk, and sometimes of information operator, are performed by one employee. In such cases, the complaint and information trunks are wired to the local test desk, and the jack and signal equipment are installed in vacant jack spaces of the face panels. However, if these classes of work require more than one employee, it is more economical to assign separate employees to the different classes and provide separate information and repair clerk desks than to install additional test-desk positions.

For smaller offices, with estimated ultimate capacities not exceeding 1,000 lines, a less elaborate test-desk equipment called a "testing turret" (Fig. 90) is used. This is of the cordless type and may be placed on an ordinary desk and used with the dial and talking set of any standard dial telephone.

Repair-clerk Desk.—The duties of the repair clerk are principally of a clerical nature. He maintains the subscribers' line card records, records the data and prepares the reports of the routine tests, receives complaint reports from subscribers, and assists the testman by locating for him cards needed in the testing work. Obviously, the local testing and the repair-clerk services are closely related and therefore, if the testing in a multi-office system is centralized, the repair-clerk service also should be centralized.

In small offices where these clerical duties are not great enough to require a separate employee, they may be carried out by the testman at the local test desk. For larger offices, however, one or more repair clerks may be required and specially equipped desks have been designed for their use. One of these consists of the necessary number of "operator's writing-shelf" units and "card-compartment" units to meet the requirements of the system. Each writing shelf is equipped with an operator's telephone circuit, with a dial, incoming key-ended trunks from selector levels, outgoing trunks to the verification switch train, and such other circuits as are required for the operation of the service. A desk consisting of one writing shelf and one card compartment is illustrated in Fig. 91.

In the larger multi-office exchanges with centralized service, where the line records occupy a number of card compartments and several clerks are required, it would be difficult to arrange all the card compartments so as to be accessible to each of the clerks. In such cases, it is often advantageous to segregate the cards in office or district groups and also to arrange the incoming complaint trunks terminating at the desk in corresponding groups, so that a clerk may be assigned to a particular office or district and have the corresponding line records within reach.

Routine-test Equipment.—In order to anticipate conditions which lead to future faulty operation, the outside plant, subscribers' station apparatus, and certain of the apparatus at the central office associated with the subscribers' lines are periodically subjected to "routine" tests. When a step-by-step installation is first put into service, a program is prepared recommending the intervals at which inspections should be made, adjustments checked, apparatus cleaned, and routine tests conducted. The schedule is subsequently modified, if necessary, depending upon the percentage of faults found each month. This method tends to insure the continuation of commercial service without incurring expenses out of proportion to the benefits derived. As a general principle, the routine-test intervals are scheduled so as to produce a weighted balance

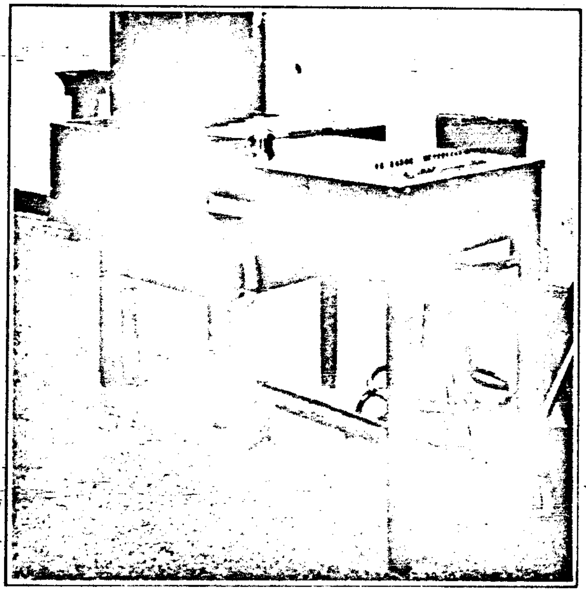


FIG. 91.—Repair-clerk desk.

between the percentage of faults detected and their relative effect on present or future service. To facilitate these tests, a number of special routine testing devices have been developed. Representative among these are the "hand test telephone," the "rotary test set," the "interrupter machine," the "connector test set," and the "toll train and repeater test set."

Hand Test Telephone.—The hand telephone set, probably used in more of the routine tests than any of the other portable test apparatus, is commonly called by testmen the "buttinski," a name derived from the slang expression "butting in." One of them is shown in Fig. 92 with cord and test plug attached.

By means of its plug and a test jack provided on each unit of switching apparatus, this set forms a convenient means of making certain tests on individual units of equipment.

The set has a transmitter at one end and a receiver and dial placed back to back at the other. The handle portion of the frame contains two exposed push buttons marked *C* and *R* and a condenser, retardation coil and resistance inside. The button *C* is depressed, when plugging into a test jack, and opens the transmitter circuit, leaving only the receiver and a condenser in series across the line. This prevents interference with dialing if a subscriber should happen to be establishing a connection when the test plug was inserted. If the testman desires to communicate with the subscriber, the button *C* is released closing the transmitter circuit. The button *R* normally short-circuits a 1,000-ohm resistance and, when this button is depressed, the short-circuit is removed, and the resistance is connected directly in series with the dialing circuit of the set. This enables the testman to test a switch to determine whether or not it will step properly on the break-impulses of the test dial over a 1,000-ohm loop circuit. The hand set is utilized in routines which require talking, listening, and dialing over a standard-resistance test loop.

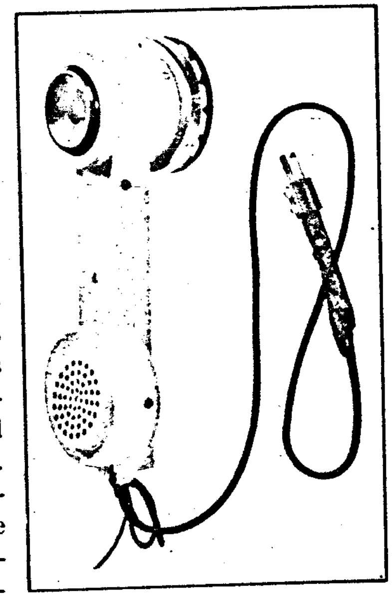


FIG. 92.—Hand test telephone.

Rotary Test Set.—The rotary test set, shown in Fig. 93, is used for testing the automatic rotary (trunk-hunting) movement of switches, such as selectors and P.B.X. connectors. As shown, it is arranged for convenient temporary attachment to the top angle-iron support of switch shelves. The set has mounted on the front a standard dial and on the left side two keys for changing the test resistances and the test conditions, and for releasing the switch after it has been rotated. Of the two cords at the left, one has a plug fitting the regular switch test jacks individual to each switch, and the other a "busying tool" for connecting with a row of bank contacts of a Strowger-type

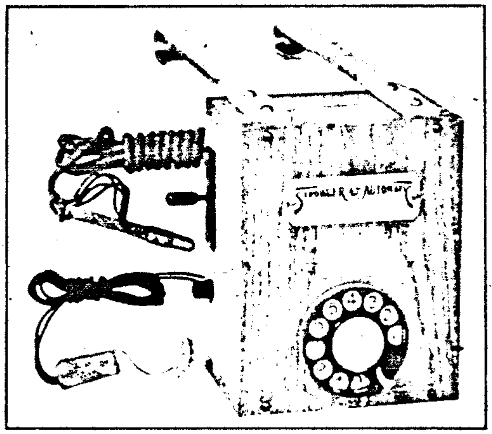


FIG. 93.—Rotary test set.

switch. All the radial contacts of the busying tool are connected together, with the exception of the fifth which is insulated from the others and to which a separate electrical condition may be

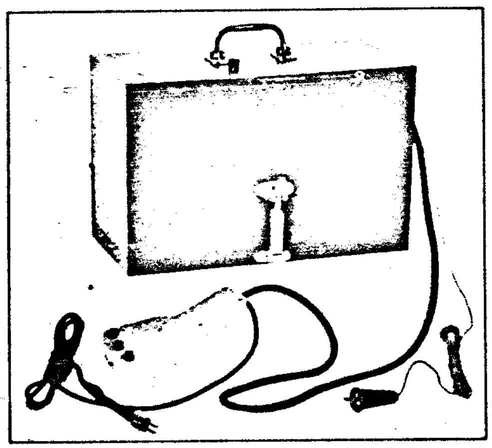


FIG. 94.—Interrupter machine.

applied. Within the case are two standard resistances and a condenser. In testing, the busying tool is first placed on the control bank contact level of one of the switches in the group under

test. Then the test plug is inserted in the jack of the individual switch to be tested and the dial operated to raise the wipers to the corresponding bank level. It is obvious that the switch on which the busying tool is placed cannot be tested until the tool has been moved to some other switch in the group.

This set provides for testing the rotary movement of switches, first, with the control bank contacts grounded through 20 ohms resistance (trunk-hunting connectors through 150 ohms) and, second, with direct ground on all the bank contacts, except the fifth which has a capacitance to ground of ½ microfarad. All switches should make a complete rotation under the first test and should rotate tc and stop on the fifth contact under the second.

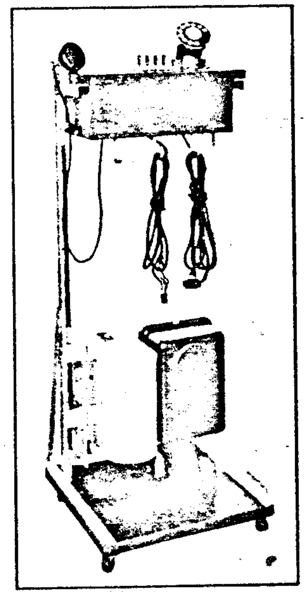


FIG. 95.—Connector test-set stand.

Interrupter Machine.—The test set shown in Fig. 94 is called the "interrupter machine" or "varying machine." It is used for testing the stepping action of selector switches under extreme operating conditions. Also, it is employed frequently in making certain tests on repeaters. The extreme conditions, under which it is considered a selector must operate satisfactorily, are: over a zero-resistance loop with a 15,000-ohm non-inductive resistance shunted across the impulse springs (representing leakage) and over a 1,000-ohm loop with no resistance shunt (no leakage), both at a fixed speed of 14 break-impulses per second.

The case of this set contains a motor driven from the central-office battery with a rheostat for adjusting its speed. Through a speed-reducing worm gear, this motor drives two impulse-spring units. The necessary standard resistances and a switching relay are also carried in the case. A connecting clip in the lower right corner of the cut is for making the battery connection and the small plug at the left is for the test jack of the switch under test. The fan-shaped "hand control unit" below the box contains three push buttons, marked respectively "loop," "shunt," and "rel," these being respectively for applying the

1,000-ohm loop and the 15,000-ohm shunt tests and for releasing the switch after testing.

Test-set Stands.—In addition to the sets readily portable by hand, such as those shown in Figs. 92, 93, and 94, more elaborate "floor sets," wherein testing apparatus is assembled on floor stands supported on casters, have been developed. One of these for testing individual line, trunk-hunting, frequency selecting, and other special types of connectors is shown in Fig. 95.

The tests for which this particular set was designed may be enumerated as follows:

1. Impulsing at 10 impulses per second through 1,000-ohm loop resistance having no leakage.
2. Impulsing at 10 impulses per second through a zero loop resistance having 15,000 ohms leakage.
3. Back-bridge cut-off relay operating in series with 1,500 ohms resistance.
4. Busy relay operating in series with 150 ohms resistance.
5. Ring-back tone.
6. Reverse-battery supervision.
7. Interrupted ring.
8. Ring cut-off.
9. Grounding of control normal.
10. Release.
11. "Last-party-hang-up" feature.
12. Transmission continuity.
13. Wiper cords.

Information Desk.—In the larger step-by-step offices, specially designed desks are provided for handling information and special-service calls. In the smaller systems, where the volume of this class of traffic does not require the full services of one operator, such calls are sometimes answered at one of the toll-board positions. The usual custom now, in multi-office exchanges, is to centralize information service in one of the central offices. The subscribers' line records may be in book form or in rotary card files. A desk arranged for a rotary card file is manufactured in one-position sections which may be grouped as necessary to meet the needs of any particular system. The trunks from the selector levels terminate in keys with associated supervisory signals, and, when several positions are installed, the circuits are multipled through them as required. A group of four positions, using rotary card files, is illustrated in Fig. 96. The positions are staggered, a rotary file being placed between the two operators on each side.

Service-observing Equipment.—It is desirable to make service observations for three reasons: first, to test the quality of service the subscribers are receiving in general; second, to watch for particular irregularities that have been reported; and, third, to collect data, by stop-watch timing, as to the time elements of the service, such as holding time, dialing time, and

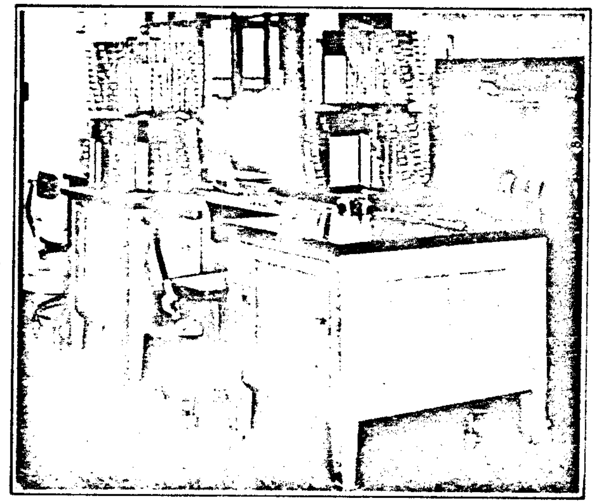


Fig. 96.—Information desk.

answering time, as an aid in determining the circuit and apparatus requirements in various parts of the system.

Service-observing equipment in Strowger exchanges comprise a "service-observing turret" (Fig. 97), a single-pen register, control relays, and cut-in relays. It has been developed for single-office and multi-office centralized service, but the following description refers to the single-office type.

With this, one control relay group is required, and a number of sets of cut-in relays, depending upon the total number of subscribers' lines or trunks to be connected for observation at one time. In a 10,000-line office, fifty sets are usually provided, permitting observations to be made on a group of fifty lines or trunks. The cut-in and control relays are mounted in groups on standard mounting plates similar to those shown in Fig. 53 used for impulse repeaters. The control relay group is connected to the turret, which may be located on a desk or table placed in some reasonably quiet position. The circuits of the cut-in relays are cabled to the line I.D.F. or the connector boards, where they terminate in multiple jack boxes so placed as to give access to all the lines and trunks, by means of flexible extension cords equipped with shoes designed for clamping to the terminals. The lines or trunks under observation are thus connected directly to the cut-in relays, and thence they are extended to the observing turret by the control relays in the order in which calls originate on them. Means are

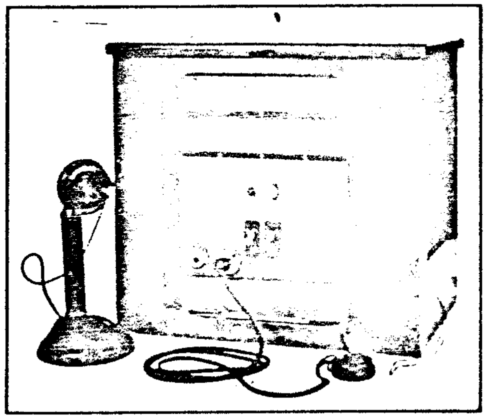


FIG. 97.—Service-observing turret.

provided to prevent interference when observations are being made on a particular call.

In ordinary observing, the operator is required to manipulate no keys and therefore may confine her entire attention to timing and recording the different time elements of the connection and to making any special notes, such as those regarding transmission. When a subscriber connected for service observation removes his receiver from the hook switch, the cut-in supervisory lamp lights; when the called number is dialed, the pen register (not shown) records the number; and when the connection is released, the "disconnect" supervisory lamp lights. The service observer is connected during the entire period and may, therefore, obtain a complete time-interval record of the connection.

CHAPTER IV

THE PANEL DIAL SYSTEM[1]

Outstanding Characteristics.—The panel-type machine-switching system derives its name from the fact that its contact banks take the form of flat panels. It is the type of equipment generally used by the Bell System for providing dial telephone service in large cities and their environs.

In such telephone-exchange areas the trunking plan is always complicated, while the service requirements are varied and frequently subject to change. Where each modification of service or operation affects so much equipment, a flexible system becomes of first importance.

At its first adoption, such a dial system must be introduced into a manual-exchange area where the service and trunking conditions are already very complex and where the large number of subscribers involved makes it impossible to introduce any rapid wholesale changes in the subscriber's method of placing calls. The system must be capable of handling in an economical way the calls requiring interconnection between manual- and dial-system subscribers; and, when manual offices are replaced by dial offices, the conversion should be accomplished with the least possible expense of time and equipment. At any stage of its life, the equipment must permit rapid changes in trunk routings or in the number of trunks in working groups. When new offices are placed in service, the new trunk groups necessary to reach them from the offices already working must be readily established.

Such flexibility under changing conditions is the most outstanding characteristic of the panel system. The two most important means of providing it are the use of a "sender" and the provision of a switching train made up of selectors with a large trunk or line access; but many other details of apparatus and circuit design have been dictated by the same requirement.

The Sender.—With the panel system, when a subscriber initiates a call, his line is extended to an auxiliary unit of equipment

[1] The photographs and other material used in preparing the illustrations of this chapter were furnished by courtesy of the American Telephone and Telegraph Company.

called a "sender." As he dials the office code and line number he desires, it is the sender which receives and records this information. The subsequent control of the selectors, by which this call is routed first to the desired office and then to the desired line in that office, *is exercised by the sender and not directly by the dial.*

This centralization of the reception and the control of the call in the sender serves many useful purposes, the most important of which are:

1. The arrangement of the inter-office trunks on the selector banks is independent of the code digits; economy and convenience are the controlling factors.
2. It is possible to change the routing of calls to a particular central office or group of central offices without affecting the code that the subscriber dials or changing the routing of calls to other offices.
3. The steps of selector operation, being under the control of the sender, are not dependent upon the speed or other limitations of subscriber's dialing.
4. The decimal basis of selection upon which the switch train must be arranged when under the direct control of the dial is no longer necessary and freedom of selector design is gained.
5. With selectors under direct dialing control, it is necessary to provide space on the selectors for every office code which can be dialed whether used or not. This necessity is eliminated since the sender recognizes non-working codes and routes them all in the same way.
6. Tandem operation is greatly facilitated, since any code can be routed through tandem without reference to other codes and, having been so used to determine the routing from the local office, it can still be used as a whole to control the routing in the tandem office.

Large Access Selectors.—Freeing the selectors from the need of following the decimal basis of selection and making them independent of the time elements of dialing permit the use of larger banks and selectors of longer travel. Advantage has been taken of this in the panel system to use selector frames upon which 500 sets of terminals appear before each selector. This has two fundamental effects on the selector train. In the first place, it reduces the number of selectors through which a connection need be routed by increasing the number of routes to which one selector has access and, in the second place, it permits increasing the size of the trunk groups over which the individual selectors may test to find an idle trunk, thereby improving trunk-group efficiency.

Other characteristics of the panel system are the provision of motors to supply the power by which the selectors and controlling switches are moved and the use of flat, double-faced banks with selectors mounted on both sides of them.

ELEMENTS OF PANEL EQUIPMENT

Figure 98 shows in a summary schematic form the elements involved in establishing a telephone connection through panel equipment.

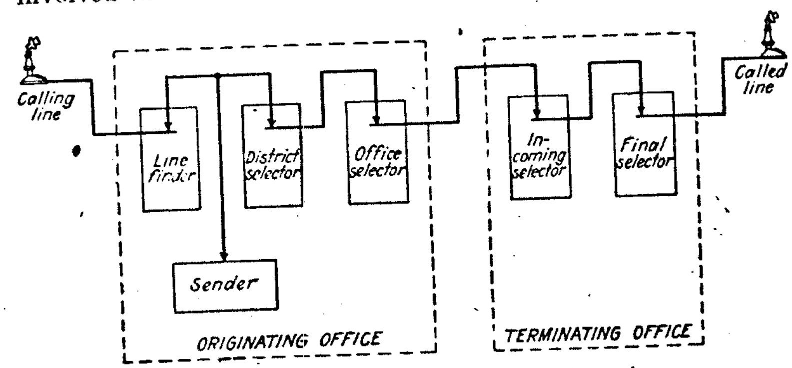


FIG. 98.—Panel dial-system elements—schematic.

The subscriber's line terminates on the banks of a line finder. When a call is originated, an idle line finder searches out the calling line and makes connection to it. To this line finder a sender is then attached into which the subscriber proceeds to dial the number he is calling. The selection of the inter-office trunk is made through the district selector, one of which is permanently associated with each line finder, and through the office selector. On some calls the latter is omitted and the desired trunk is selected directly by the district selector.

In the terminating central office, the selection of the called line is made by the incoming selector and final selector. The incoming selector is permanently associated with the inter-office trunk. Its function is to select the final group in which the desired line appears and to choose an idle final selector in that group. The subscribers' lines appear upon the banks of the final-selector frame and the selection by the final selector of the particular line desired completes the setting up of the connection. All stages of selection from the district selector on are under control of the sender. When the called line is reached, a talking path is established between the calling and the called party and the sender releases.

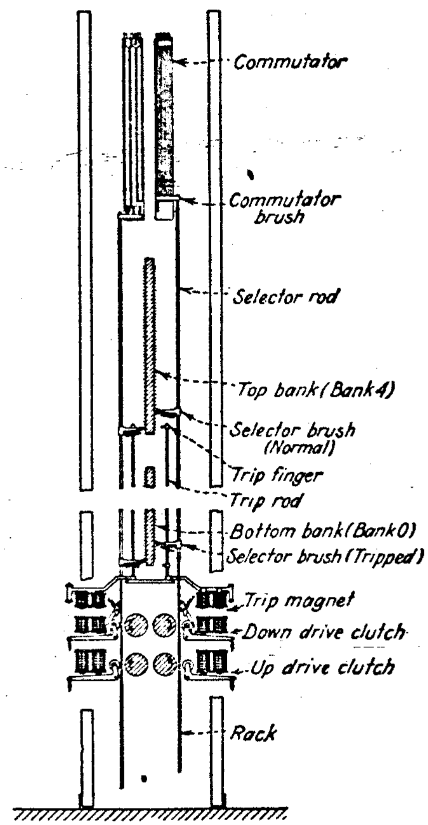


FIG. 99.—Panel selector mechanism.

The Panel Selector.—The essential mechanical features of the panel selector are shown in Fig. 99 which represents, partly in section, an end view of a typical selector frame, such as that of which a complete view is shown in Fig. 112. At the bottom of the frame, on each side, are two power-driven cork-covered rollers, constantly revolving, one in each direction. Above these are the banks, five in number, of 100 sets of terminals each. Long vertical selector rods designed to slide up and down appear

before these banks The bottom of each selector rod terminates in the rack a flat strip of metal which can be pressed against either the up-drive or the down-drive cork roller to drive the selector rod up or down. In front of the rack are two magnetic clutches, one opposite each of the drive rollers. Each clutch is arranged, when operated, to force a small roller against the rack to hold it against the corresponding cork drive roll. One of them operates in this way to produce the upward motion of the selector rod, and the other the downward motion.

The rack is provided with small slots into which may fall the spring pawl that appears just above the down-drive magnet. The armature of the down-drive magnet is arranged to lift this pawl out of the rack slot before pressing the rack against the down-drive roll. The pawl and the rack slots provide the necessary support to hold the rod in a set position after it has moved up the bank. There is one slot for each position that the rack and selector rod are called upon to assume.

Mounted on the selector rod are five selector brushes, one for each of the five banks. The extent of travel of the selector rod is just sufficient to move these brushes from their normal position, below their corresponding banks, to the top of the bank, that is, slightly more than one bank height. These brushes can make contact with the terminals of the bank, but each brush has an operated and a non-operated condition, only one of the five brushes being permitted at one time to be in an operated condition capable of making contact with the bank terminals.

The top of the selector rod terminates in the commutator brush which slides on the metal strips of the stationary commutator. The tip, ring, and sleeve leads are brought into the rod by this commutator and brush and the wires are led down inside the selector rod, which is made hollow for this purpose, to be brought out and multipled to the springs of each brush. This commutator also serves a purpose in controlling the selector operation.

Parallel with the selector rod and between it and the bank is the trip rod. This rod has no vertical motion but it is arranged to rotate through an angle of about 90 degrees. This rotation is produced by the operation of the trip magnet, mounted just above the down-drive clutch magnet. When the trip magnet releases, the rod is restored by a spring. Mounted on this rod by a spring attachment are five small trip fingers. The position of these fingers with respect to the brushes and their corresponding banks is shown in Fig. 100. One of these is located above the normal position of each brush but below the level of the bottom terminal of the corresponding bank. As the drawing shows, all these trip fingers are not in exactly the same relative position with regard to the normal brush positions. The bottom trip finger is

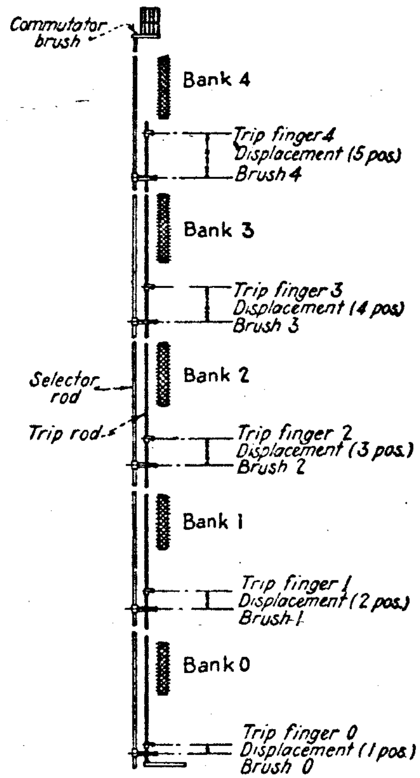


FIG. 100.—Brush and trip finger positions.

the closest to its brush in the normal position, the second one step higher relative to the second brush, the third two steps higher, and so on.

The Selector Brush and Brush Tripping.—A selector brush (Fig. 101) consists of a set of four flexible contacting springs mounted on a clamp by which the brush fastens to the selector rod. These springs project inwardly toward the bank far enough to permit contacting with the bank terminals. The two outside

springs of the brush make connection, respectively, to the tip and ring terminals of the bank. In all frames except the line finder the two inside springs are strapped together and both contact with the sleeve terminal. On line-finder frames an additional terminal is required for control purposes and contact with this fourth terminal is made by one of the inside springs, while the other still contacts with the sleeve terminal.

Below the contacting springs is a support which carries a pivoted trigger. In one position of this trigger a pair of insulated rollers is pressed between the brush springs to hold them sepa-

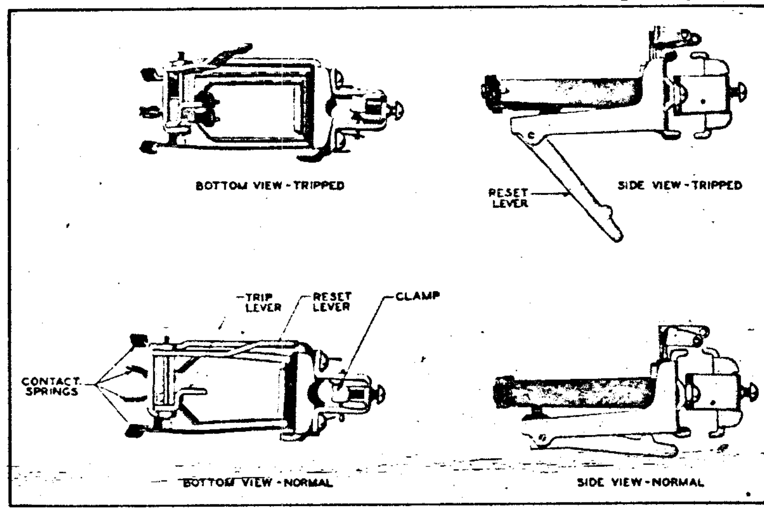


FIG. 101.—Selector brush.

rated and away from the bank terminals. This condition is shown in the lower pair of brushes in Fig. 101. There are two levers to the trigger, one short and one long. The shorter, or "trip," lever is used to operate the brush by engagement with trip fingers. When this level is pulled down, the rollers snap out from between the springs permitting them to come closer together, as shown in the two upper brushes of the figure. In this position, the springs of the brush are capable of contacting with the terminals of the bank. The longer, or "reset," lever of the trigger is provided to restore the brush to the non-operated condition. This it does by engaging with a base plate, or "reset plate," such as that shown in Fig. 102, when the selector is lowered to its normal position.

The selector rod, because of the provision of slots in the rack, can be stopped in any one of five different preliminary positions between normal and the level of the first terminal. These five preliminary brush positions correspond to the five different levels of the trip fingers shown in Fig. 100 and they are so established

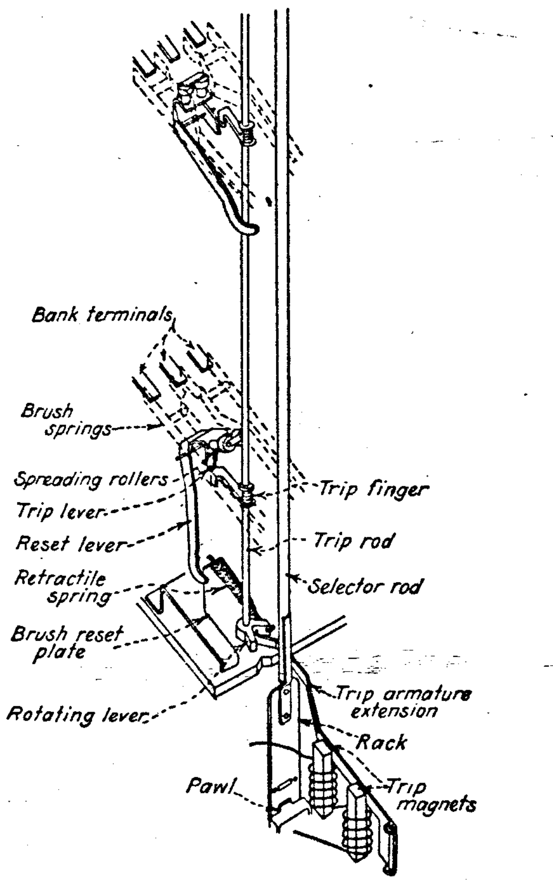


FIG. 102.—Brush-tripping mechanism.

that, if the selector rod is stopped in the lowest position of the five, the trigger of the bottom brush will be just opposite the first trip finger. Stopping the rod in the second position instead of the first will bring the second trip finger just opposite the second brush while the trip finger of the first bank is then below, and those of the upper banks above, the triggers of their correspond-

ing brushes. The third position of the rod brings the third brush opposite its trip finger, and so on.

The tripping of the desired brush is accomplished in the following way. The selector rod is moved up, let us say, to the first step just described and is stopped in this position. The trip magnet is operated as shown in Fig. 102, turning the trip rod and its five trip fingers with it. The bottom trip finger in this position of the selector rod will just hook over the trigger of the brush of the bottom bank. This will not stop the further rotation of the trip rod itself, because there is a spring connection between the rod and the fingers which permits the rod to continue its motion after the finger engages the trigger. The other trip fingers of the rod are all too high to catch upon the corresponding brush triggers, so they move past without engaging anything. With the trip magnet still operated, the selector rod is started up again. As it moves, the bottom brush finds its trigger held down by the trip finger which has caught it and thus the separating rollers are snapped out and this brush is placed in the operated position capable of making contact with the bank terminals. It is this precise stage of the operation which is illustrated in Fig. 102. All the other brushes will remain unoperated.

If, before rotating the trip rod, the selector rod had been moved to the second position, it would have been the trip finger of the second bank which engaged its brush, and so on.

By this arrangement the choice of the brush to be tripped and, consequently, the bank in which connection will be made, depends upon the extent of a preliminary vertical motion of the selector rod. The second vertical motion of the rod brings the operated brushes into contact with the terminals of the bank, and those terminals to which it will be connected are determined by the height to which the rod is raised.

The Clutch and Associated Apparatus.—Typical clutches and some of the associated apparatus for an adjacent pair of selector rods are shown in Fig. 103. The lowest clutch magnet, by operating to raise its armature, forces the associated idle roller against the rack which is, in turn, pressed against the up-drive cork roll (see also Fig. 99). The clutch magnet, just above, in a similar way presses the rack against the down-drive cork roll. Associated with the armature of the down-drive clutch is a second arm so arranged that, as the clutch armature is drawn up, this arm moves with it, pressing upon the pawl which is thus withdrawn from the rack to free the rack and the associated selector rod and permit the downward motion.

The upper, or trip, magnet of each clutch operates an armature which bears upon a lever associated with the trip rod, so that, when this magnet is operated, the trip rod is turned. This is shown diagrammatically in Fig. 102.

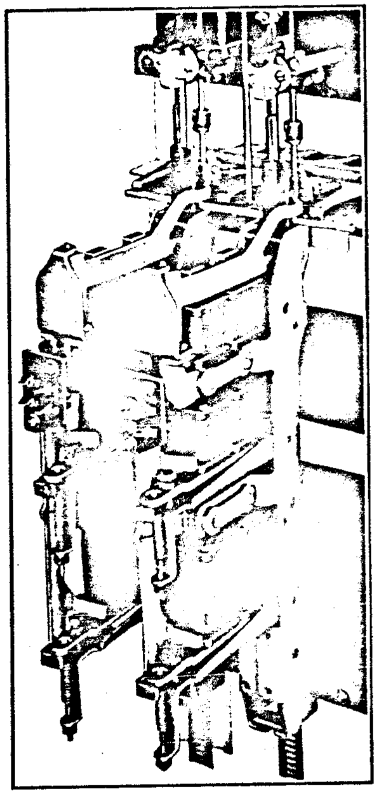


FIG. 103.—Clutch.

The Panel Bank.—The panel selector bank is a double-faced, flat, rectangular block, from both sides of which the contact terminals project. Each outgoing trunk is represented by three terminal lugs per trunk appearance—tip, ring, and sleeve. Each trunk appears thirty times on each side of the bank so that it will be available to all the 60 selectors which mount on a single frame. The bank is 100 sets of terminals high, so that a selector brush can take 100 different contact positions. The details of the bank construction are illustrated in Fig. 104, Fig. 105 being a perspective view of a bank.

Each bank is formed by piling up long flat metal strips *B*, *C*, and *D* of Fig. 104, with intervening strips *A* of insulating material separating each from those on each side of it. Each metal strip has contact lugs projecting from each of its edges as shown. Three metal strips with intervening insulation constitute the terminal lugs and strapping for one trunk. The lugs of these three strips are in different relative positions along the length of the bank, so that those for each selector fall in three different vertical rows before each selector brush (see Fig. 101).

The whole bank is clamped together by insulated bolts running from top to bottom. Soldering lugs are provided at each end of

each strip for making the circuit wiring connections to the banks. In order to allow ample space for bringing in and soldering the wires, the lugs for successive sets of terminals appear on opposite sides of the bank.

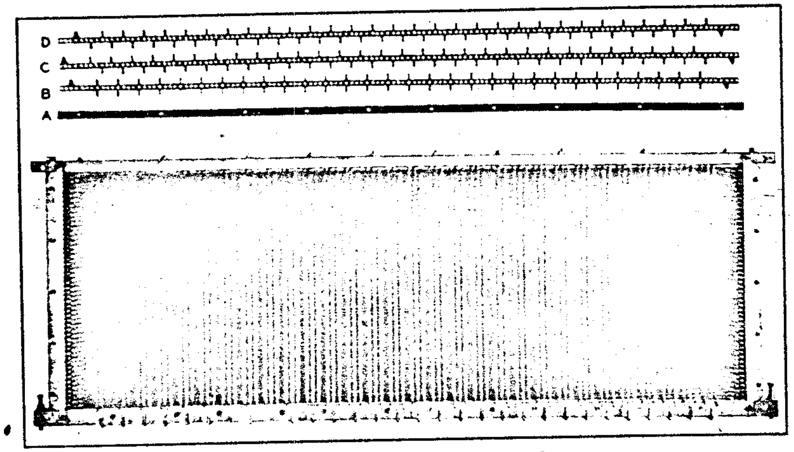


FIG. 104.—Panel selector bank.

This general type of bank construction is used in all panel frames but the number of terminals, terminal appearances, etc., is varied to suit the required conditions. In the line-finder bank, for instance, there are four terminals per line instead of three, and banks are only forty sets of terminals high.

The Commutator.—The commutator of the panel selector is a flat approximately rectangular piece of hard dielectric composi-

FIG. 105.—Panel selector bank.

tion with inset metallic strips on both sides. These strips are of various shapes one being shown in Fig. 116. In Fig. 106 they are shown mounted in place at the top of a selector frame. Connections to these strips are made through soldering lugs at the top or bottom.

The commutator brushes, associated with the selector or elevator rod, slide over these metallic segments as the selector rod moves. The main purpose of the ladder-like segments is to signal to the sender the position of the moving selector rod as a part of the selection process to be later described. They also play a part in returning a signal to the subscriber, when all the trunks in a group are busy, and assist as well in centering the elevator rods on the bank terminals.

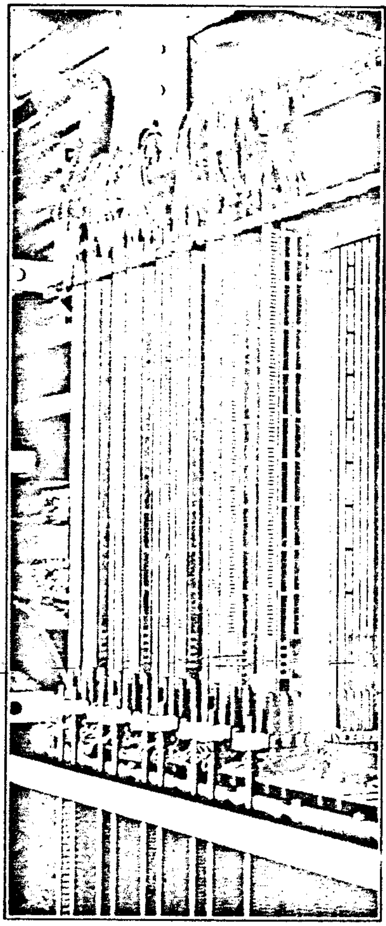


Fig. 106.—Commutators.

The Sequence Switch.—One piece of auxiliary equipment which finds very extensive use in the panel system is the sequence switch. This switch consists of a set of electrical contact cams mounted on a horizontal shaft to the end of which a disk is attached by means of a flexible spider. A magnet is provided which, when operated, draws this flexible disk against a constantly revolving driving disk mounted on a vertical drive shaft. Four brushes bear on each cam and any two or more of these can be electrically connected together through this cam in any position of the switch by proper design and cutting of the contacting faces.

The sequence switch can be stopped in any one of eighteen angular positions and, since the sequence switch can carry twenty-four cams, it is possible to produce eighteen different sets of interconnections between ninety-six different leads.

This switch is used in the sender circuit, selector circuits, etc., where it is arranged to move from position to position as the circuit functioning progresses, accomplishing as it moves most of the essential circuit operations. The duties which it per-

forms could be discharged by relays but the number required would be so great that the cost of the equipment would be considerably increased.

The details of this device will be clear from Fig. 107, which shows an unmounted switch. At the left is the driven disk with

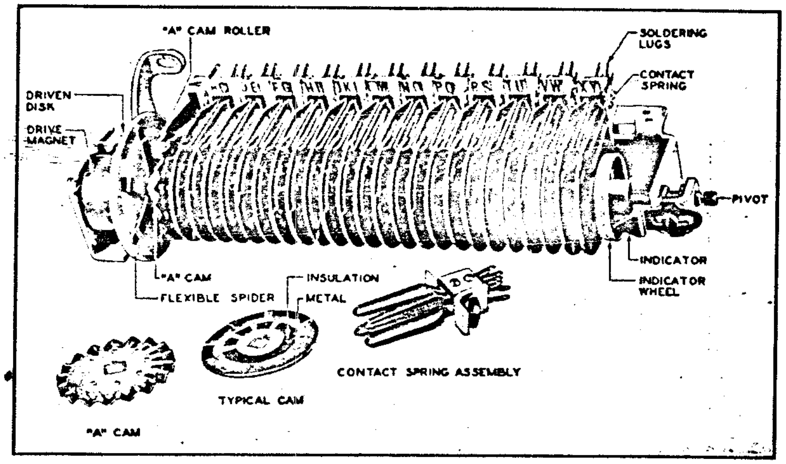


Fig. 107.—Sequence switch—detail.

the magnet which pulls it against the driving disk. A flexible spider provides the attachment between the disk and the shaft, with its associated cams. Nearest the driven disk is a special cam with a crimped edge upon which a small roller bears. This is called the "A" cam and is shown in detail at the bottom of the figure. This cam aids to center the switch in each of its eighteen different positions. This effect is accomplished by a combination of mechanical and electrical action. The tension of the roller tends mechanically to stop the switch with the roller in one of the disk depressions which are arranged to correspond with the eighteen switch positions. In addition, an electrical circuit through the brushes and cuttings of this cam is arranged to hold the driving magnet operated between switch positions, opening the circuit and releasing the magnet when the switch is centered. At the end of the shaft farthest from the driven disk is an indicator by which it is possible to read the position in which the switch is standing.

Motion of the switch is accomplished by closing a circuit to its driving magnet through a cam contact of the switch itself, so that, when the switch has moved ahead far enough to break the circuit, the magnet will be released and the switch will stop in the first position following. The electrical circuits accomplishing this are independent of the centering circuit of the "A" cam.

At the bottom of Fig. 107 is shown a typical cam of the sequence switch. It consists of a disk of insulating material, upon each side of which are riveted metallic plates punched in the proper shape to make the desired connections. The rivets serve as an electrical coupling between the two plates, so that each cam

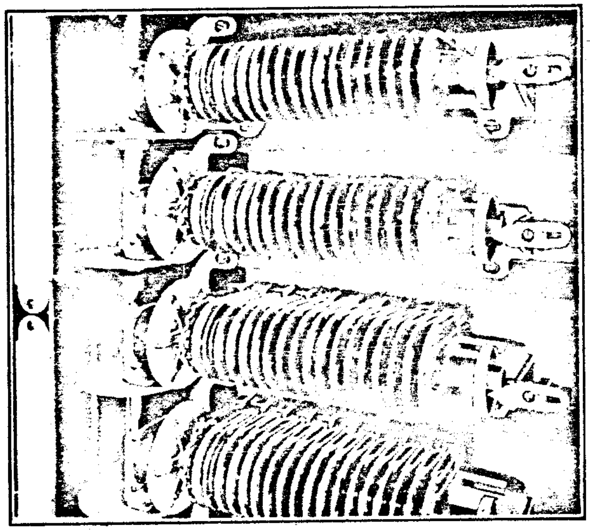


FIG. 108.—Sequence switch—assembly.

comprises one circuit connecting unit. A detached brush assembly for making contact with these cams is also shown. In Fig. 108 appears a group of these sequence switches mounted in position on a frame. The vertical constantly turning drive shaft and its associated driving disks appear at the left.

Relays.—In the panel system as in all other telephone switching systems the relay plays an important part. In order to serve the wide range of requirements which the design of the system demands, many varieties of structure and many winding and spring arrangements are used.

By far the greatest number of relays in the panel system are of the "flat" type already discussed in connection with Fig. 163

of the preceding volume.[1] The distinguishing feature of relays of this type, it will be remembered, is that the whole framework including the core is formed by punching operations. In some cases, the core, which would otherwise be left rectangular, is swaged into an oval shape, permitting more wiring turns to be introduced in the winding space.

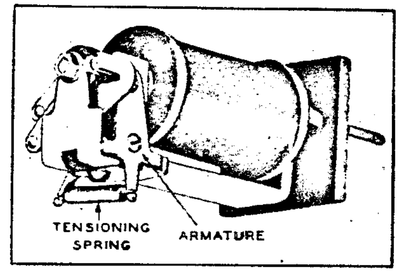


FIG. 109.—Counting relay.

Round-core relays, which lend themselves more readily to the design of relay structures of low magnetic reluctance, are used for some purposes in the panel system, especially where high sensitivity or exceptional time requirements are necessary, but their use is comparatively small. The stepping and counting relays of the sender, whose functions are later described, are examples of this. The stepping relay must be both fast operating and sensitive, while the

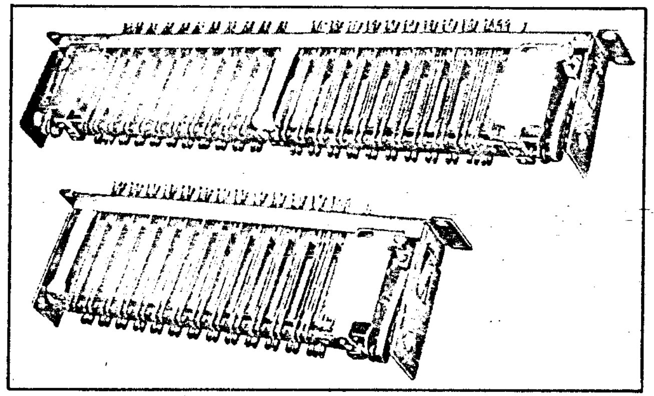


FIG. 110.—Multi-contact relays.

counting relays must meet particularly the requirement of speedy operation. Figure 109 shows one of the counting relays.

Figure 110 shows two types of multi-contact relays. In the lower relay of the two shown, the operating magnet appears at the right-hand end. The metal sheath covering it forms a part of the magnetic structure. When this magnet is energized, a

[1] Manual Switching and Substation Equipment, p. 184.

bar extending across the relay is drawn toward the right, moving with it the contact springs mounted above and below. In the relay shown, this results in the closing of fifty make contacts and two transfer contacts. Upon the release of the magnet, this bar restores to its normal position.

The upper structure in the figure comprises two relays independent of each other except for their common mounting. The operation of each of these relays is the same as that of the one described, except that the magnet of the left-hand relay is at the left of the operating bar instead of at the right.

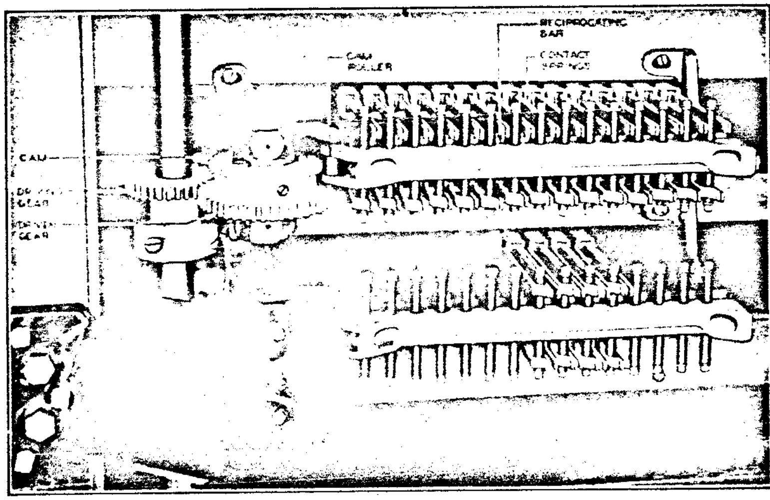


FIG. 111.—Interrupter.

The Interrupter.—The power-driven interrupter is a mechanism used in various capacities in the panel system. This type of interrupter consists of a reciprocating bar driven back and forth by a cam geared to a drive shaft. This bar, as it reciprocates, periodically closes and opens sets of contacting springs. Figure 111 shows an interrupter of this type mounted in place. At the left of this figure is shown the vertical drive rod with its attached driving gear. Meshing with this driving gear is the driven gear with its associated cam. Bearing against this cam, under the tension of the stiff retactile spring, is a roller, which is attached to the horizontal bar extending across the front of the interrupter. Projecting from the top and bottom

of this bar are small cylinders of insulating material which bear against the contacting springs. As the cam rotates, this bar is moved back and forth in accordance with the elevations and depressions of the cam, so that the time at which the contacts are opened and closed is determined by the design of the

FIG. 112.—District selector frame.

cam and the gearing ratio. Since these interrupters are used for many different purposes, there is a number of different designs of gearing and of cams as well as of spring arrangements. For very slow interrupters, an idling gear element is added.

The cam design is frequently arranged to permit three different bar positions, that is, right, left, and neutral. This permits the alternate closing of pairs of contacts with an intervening time interval during which neither pair is closed. This is a form very useful in timing circuits, since the two different signals serve to indicate the beginning and the end of a timing interval.

The Selector Frame.—A complete district-selector frame is shown in Fig. 112. Since the frame is double-sided, the rear of it would present a similar appearance. Thirty selectors are equipped on each side. At the right of the selectors is mounted a bay of sequence switches, while the circuit relays are located under the covers on the right of these. One selector circuit would

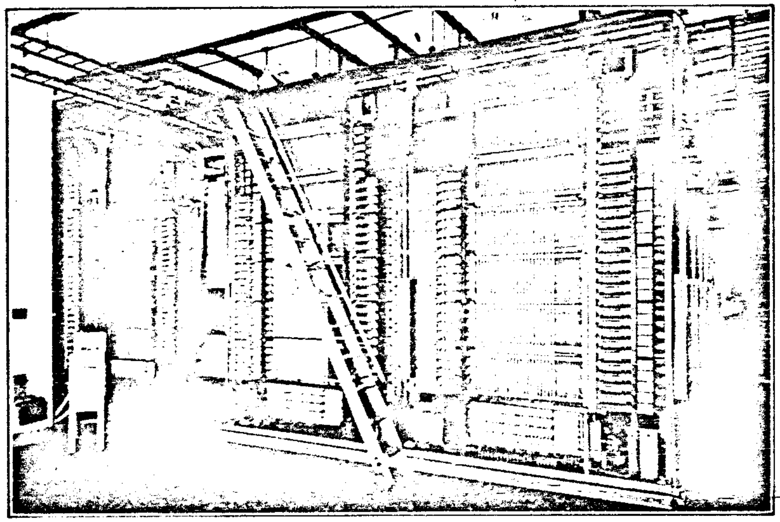


FIG. 113.—Panel central-office terminal room.

include one complete selector rod and its associated apparatus, one sequence switch, and the relays under one of the covers. Except for minor differences such as the number of relays per circuit or cams per sequence switch, the district, office, and incoming selector frames are similar in appearance. The final frame differs in that it has an additional drive roll and clutch to provide a slow speed of up-drive. For circuit reasons this has been found desirable in making line selection. Figure 113 shows a section of a central-office terminal room with aisles of selector frames.

One motor provides the drive for one side of each of two adjacent frames. These are duplex motors running normally

on the alternating-current power supply but, in case this should fail, they automatically transfer to the 48-volt central-office battery. Reduction gear boxes translate the drive to a suitable speed for the cork rolls and sequence-switch drive shafts. The top of the motor and gear box can just be seen in Fig. 112 at the lower left corner of the frame.

GENERAL OPERATION

In describing the way in which the panel system functions, a general outline of the operation will first be given. This will be

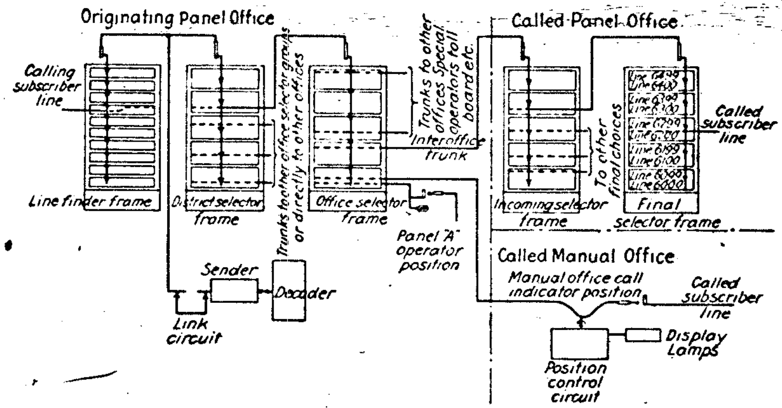


FIG. 114.—Panel dial system—schematic.

followed by a more detailed description of the operation of the separate elements.

Figure 114 represents a connection in a schematic form, and reference to this sketch will assist in understanding the description which follows.

Each subscriber line appears on a set of terminals of a line-finder frame. Such a frame is of sufficient capacity to serve the outgoing calls from 400 subscribers' lines. Associated with each line is also a line relay and a cut-off relay. The operation of the line relay, when a subscriber initiates a call, serves to start an idle line-finder circuit searching for this line. A link circuit is associated with the line-finder circuit, and this link circuit will choose an idle sender and connect it to the line finder.

When the line finder has found the calling line, connection will be established from the line through the line-finder circuit and the link circuit to the sender. The sender will return dial tone to the subscriber informing him that he can proceed with his dialing.

The subscriber then dials the desired number, and this number the sender receives and records. The digits which the subscriber dials form two groups: first, the office-code digits which represent the called office and, second, the digits representing the number of the called line in that office. The sender determines in accordance with the office code dialed what the routing of the call should be. This it does by the use of an auxiliary circuit called a "decoder." As soon as the office code has been dialed, the sender attaches itself to an idle decoder circuit. To this circuit it transmits the code which represents the called office, and the decoder, in turn, informs the sender with regard to the type of office, trunk routing, etc.

Let us first assume that the called office is another panel dial office to which direct trunks are provided. Information which the sender has gained from the decoder permits it to set the switches of the outgoing train in the proper positions to reach the desired group of trunks.

The outgoing switch train usually consists of a district selector and an office selector. One district selector is permanently associated with each of the line finders, so that in assigning a line finder to this call a district selector has been assigned at the same time. Under the control of the sender this district selector is now moved and its selection operation consists of three stages: first, the proper brush is tripped in order to choose that one of the five banks through which routing is desired; second, the selector is moved up to the bottom terminals of the proper group of trunks; and, third, the selector tests these trunks one by one until an idle trunk is found.

Each of these trunks terminates in a selector on an office-selector frame. This office selector now moves and, under the control of the sender as the district selector was before, the proper brush is first tripped and then the selector is moved to the bottom terminals of the desired trunk group. This selector also tests to find an idle trunk.

These trunks on the banks of the office-selector frame are the inter-office trunks and each one terminates in the called office on a selector of the incoming selector frame. This incoming selector frame is similar in general appearance and operation to the district and office-selector frames.

The selection of the proper line in the called office is made through two successive frames, the incoming selector frame and the final selector frame. Since each final selector frame, upon the banks of which the subscriber's lines appear, has a capacity of 500 lines, a 10,000-line office will thus be divided into 20 final choices. The incoming selector frame access is, therefore,

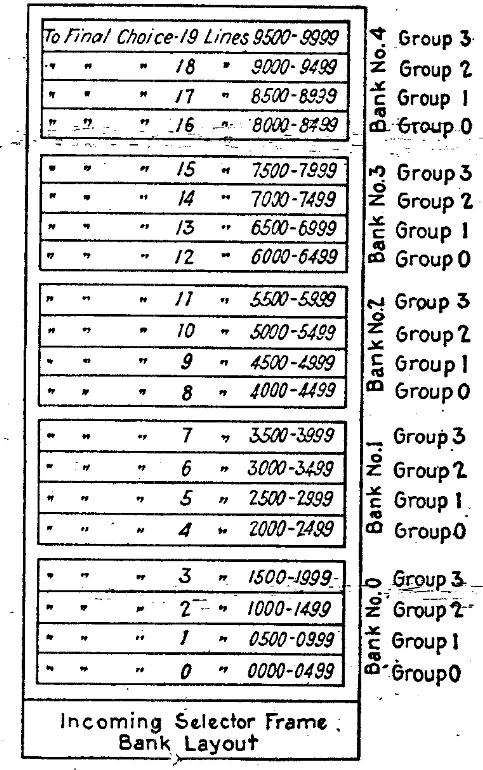


FIG. 115.—Incoming frame trunk layout.

divided into 20 trunk groups in accordance with these 20 final choices, 4 groups being assigned to each of the 5 incoming selector banks. This will be made clear by reference to Fig. 115. The first final choice, comprising terminals numbered from 0000 to 0499, will be reached through the bottom group on the bottom bank on the incoming frame, and successive choices appear above this in order, ending with the choice which comprises terminals 9500 to 9999, which appear as the top group of the top bank.

In accordance with the number dialed, the sender will, therefore, control the tripping of the proper incoming selector brush and the raising of the selector rod to the proper group of terminals to reach the final choice in which the called number appears.

The final selector frame (Fig. 114), which is divided into five banks of 100 sets of terminals each, requires three selection steps to reach the proper line: first, the proper brush must be tripped; second, the proper group of 10 lines must be reached; and, third, the desired line of the 10 must be selected. All of these steps are made under the control of the sender and, when they have been completed, this sender, its duties accomplished, disconnects from the line finder. The link circuit also releases. The ringing is controlled by the incoming selector and the call is cut through when the subscriber answers. The talking path now extends from the originating subscriber's line, through the line finder, the district selector, the office selector, the incoming selector, and the final selector to the called subscriber's line.

In the case of party lines, each station on such a line is given an independent number and the choice of the desired station is determined by the type of ringing current sent out.

The provision of the two steps of outgoing-trunk selection constituted by the district and the office selectors is necessary to give access to all of the required outgoing trunks. If the number of trunks were small enough, the district selector alone might be sufficient to reach them and the office selectors might be omitted, but this seldom occurs in the larger cities. Provision is, however, made for reaching outgoing trunks directly from the district selector, for use in the case of individual trunk groups when it appears economical. When this trunk arrangement is used in the case of a particular called office, the sender is informed of the fact by the decoder and, after completing district brush and group selections, it completely omits the steps of office-selector control. This is one of the features which assists in lending flexibility to this system.

In case the call dialed is intended for a subscriber in a manual office, the office code dialed is recognized by the decoder as that of a manual central office and the sender is so informed. The sender controls the district and office selections just as it did in the previous case, but, having reached the inter-office trunk group, its procedure after that is quite different.

Each trunk of this inter-office group terminates in a cord on a "B" position in the manual office. The sender closes through an electrical circuit over the trunk, which constitutes a signal for associating a pulse-receiver circuit with this cord. As soon as the path to this receiving circuit has been established, the sender transmits a series of code pulses which are recorded in the pulse-receiving circuit, and from this record a set of indicator lamps is lighted to display to the "B" operator the number of the called line. She then plugs into the line jack indicated by the displayed number. The sender disconnects after sending out the pulses and the talking path is established.

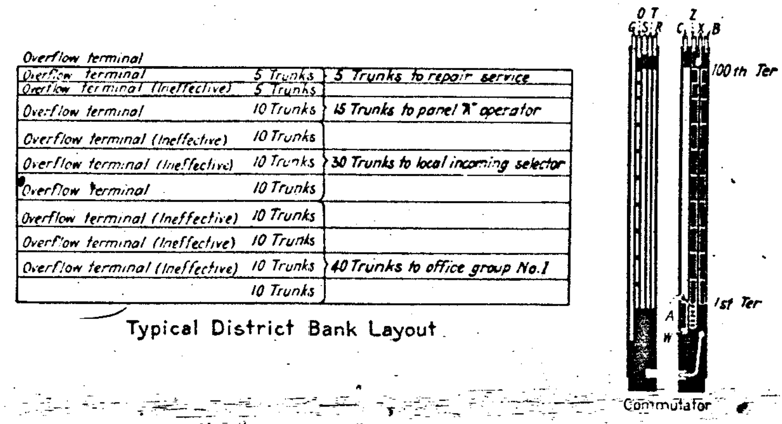


FIG. 116.—Typical district bank layout.

Each panel office is provided with an "A" board, the main functions of which are to complete short-haul toll calls, handle irregular connections, etc. To reach this operator's position subscribers are requested to dial 0. The sender upon receiving this code routes the call through district and office selectors as before, after which the lamp at the "A" operator's answering jack is lighted and the sender is freed. The subsequent handling of the call is under the control of the answering "A" operator.

Other service codes, such as those for long distance, repair service, and information, are recognized by the sender and these calls may be completed either by trunks from the office-selector frames or directly from the district frame, as desired.

Selector-bank Layout.—As stated before (Fig. 114), each district- or office-selector frame is provided with five banks of 100 sets of terminals each. Not all of these terminals are connected to trunks, however, 10 sets of terminals in each bank being reserved as overflow terminals to facilitate returning a busy signal on calls which find all the trunks of the desired group in use.

The layout of a typical bank is shown in Fig. 116. Beginning at the bottom of the bank, the first 10 terminals are available for connection to trunks and the eleventh is an overflow terminal. This arrangement continues throughout the bank, except that the two top groups are of five trunks each. The bank provides 90 terminals for use with trunks and 10 overflow terminals. In case a trunk group extends over more than one of these bank divisions, the intervening overflow terminals are made ineffective and only the overflow terminal at the top of the group will signal back a busy condition. This is done by making ineffective overflow terminals test busy, while the effective ones always test idle to the hunting selector.

The drawing shows a typical district-bank layout, in which the bottom 40 trunks are assigned for connections to the office selectors, the next 30 trunks for local calls connecting directly to incoming selectors without using office selectors, the 15 following trunks go to the special service operator, and the top 5 to repair service. At the right is shown a commutator in its position relative to the bank as determined by the corresponding positions of the selector brush and the commutator brush of a selector rod.

DETAILED OPERATION

Line-finder and Link Operation.—Returning now to the more detailed operating features of the line finder, Fig. 117 is a schematic showing the stages of line-finder operation. Figure 118 is a photograph of a line-finder frame.

Each line-finder frame carries 10 banks of 40 subscriber lines each. The 40-point banks are used rather than the 100-point banks in order to provide a short hunting time. Each line appears as four terminal points before each finder: tip, ring, sleeve, and a fourth conductor used for control and for message registration.

The line-finder selector rods are each equipped with 10 selector brushes, one before each bank. If a whole frame is assigned to a single 400-line group, there will be space for 60 selectors to serve them. In case either more or less than 60 line-finder selectors are required to serve the 400-line groups, provision is

made for splitting the multiple at a point within the bank. This is done by building up the bank with terminal strips which, instead of extending continuously from one end of the bank to the other, are cut to provide an electrical separation at the desired point. One end of the bank can in this way be associated with one group of lines, while the other end serves a different group.

Two types of split frames may be used in cases where, owing to a lower calling rate, less than 60 line-finder selectors are required for the 400-line group. In one type, the frame is split two-thirds

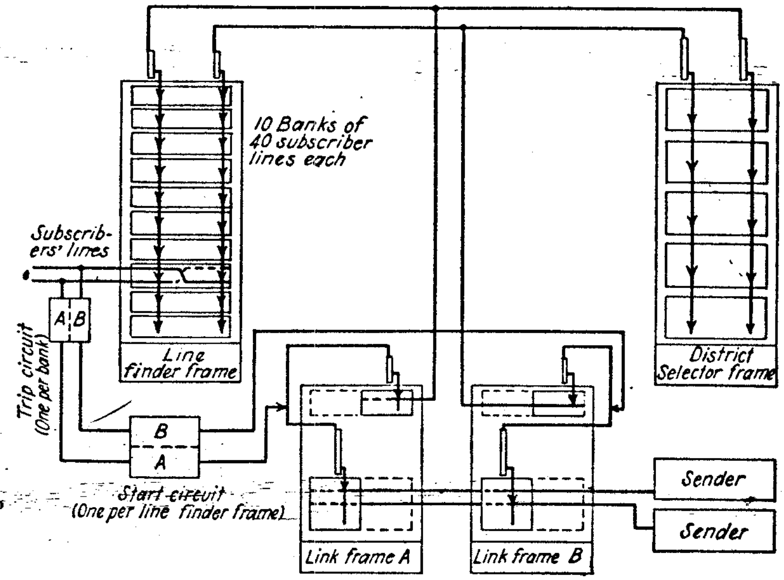


FIG. 117.—Line finder—schematic.

of the way across, allowing a maximum of 40 selectors to the line-finder group. The other third of the frame will be used in conjunction with the third of an adjacent frame to provide another complete line-finder group, also of 40 selectors. In case the calling rate is still lower, the banks are divided in the middle and space for 28 line finders is made available before each of the two line-finder groups which such a frame would serve. In a similar way, it is possible by utilizing sections of adjacent frames to build up groups served by more than 60 selectors for high calling-rate conditions.

In order further to reduce the time of hunting for a line, all line-finder banks have a reversal in the line multiple in the middle of the group, so that half of the selectors have access to the straight multiple and half to the reversed multiple. Under normal operation, each line is so connected that it will use a line finder in the section of the frame at which that line appears nearest to the bottom of the bank. This subgrouping of the line finders, which is necessitated by this feature, extends to the trip, start, and link circuits also, as Fig. 117 shows. The designations

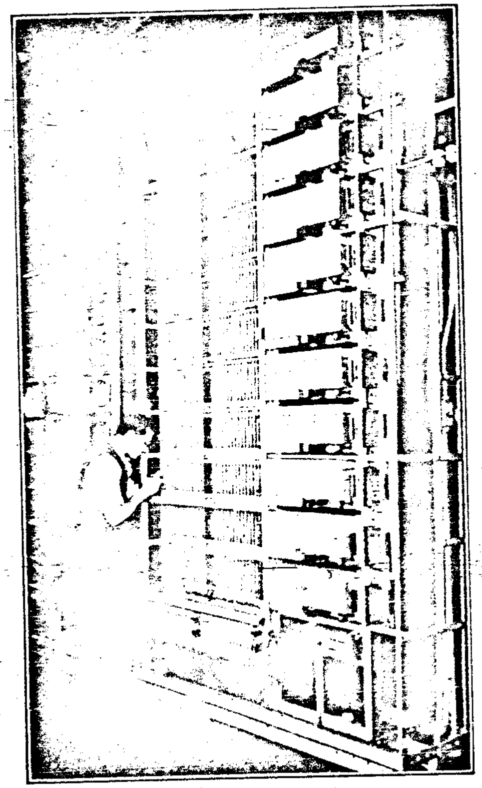


Fig. 118.—Line-finder frame.

"A" and "B" are used in each case to distinguish these subgroup divisions. In case all the line finders in the first choice subgroup are busy, provision is made for starting a line finder in the other subgroup. This grouping arrangement materially reduces the line-finder hunting time, because very seldom does a selector have to hunt over more than half the bank in order to find the calling line.

The link circuit is a two-ended unit, both ends of which terminate in short selector rods having access to panel banks. Its function is to connect a line finder with an idle sender. These link circuits are mounted on frames as shown in Fig. 119, each frame having capacity for thirty link circuits.

Like the selector frames, these link frames are double-sided, with fifteen link circuits mounted on each side. The selectors

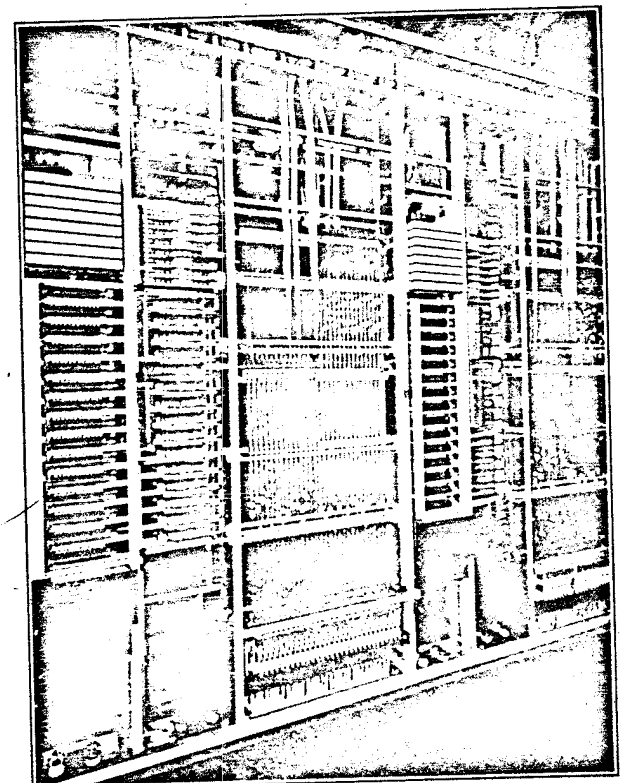


Fig. 119.—Subscriber link frame.

on the right half of the frame use the top bank and the commutators above it. These serve to find and connect the link with an idle line finder. This selector and bank are called the "district finder" and the "district-finder bank," since the line finder and its associated district-selector circuit, as stated before, really constitute a single circuit unit.

At the left side of the bank are the sender-selector rods, one of which is associated with each district finder. These sender selectors use the two lower banks and the commutators just above them. Through these banks the link has access to a maximum of 100 senders.

The sequence switch and the relays associated with each link circuit appear in the bay to the right.

Each group of links is divided into two subgroups to correspond with the subgroups of line finders before the direct and the reversed multiple. Link group *A* has access to the line finders before the direct and group *B* those before the reversed multiple, as Fig. 117 indicates. Each link circuit is arranged to search for an idle line finder in its district-finder bank as soon as it has become free from a previous call. The idle links, each with an idle line finder that it has seized, are allotted in turn to handle the originating calls.

One trip circuit for each line-finder bank and a start circuit used in common by the whole line-finder group are provided. The main purpose of the trip circuit is to control the tripping of the line-finder brush. The start circuit controls the order in which calls from lines in the different banks are handled. The trip and start circuits are each divided into an *A* and a *B* section. These sections work independently, each with its corresponding subgroup of links and line finders, except that, when all the links or all the line finders of a subgroup are busy, provision is made for allotting a link and a line finder in the other group, tripping the line-finder brush, etc.

Let us assume that a call has been originated by the lower one of the two subscribers' lines indicated in Fig. 117. The line relay operates and this fact is signaled through the trip and start circuits to the previously allotted link.

In the normal case, the two link subgroups *A* and *B* will each be waiting with a link allotted and in the present case the one started will be the one on link frame *A* because this has access to those line finders which will find the calling line in the lower half of the bank. In case either all the links or all the line finders of subgroup *A* are busy, the allotted *B* link will be started. The only penalty is a slightly longer line-finder hunt to find the calling line.

The link circuit, when the signal indicating an originated call has been received, starts in motion the line finder which it has previously selected. At the same time, the sender-selector end of the link begins searching for a sender.

The next step of line-finder operation is to trip the proper brush in order to insure testing over the lines in the bank in which the calling line is located. The method of tripping the line-finder brushes is different from that of other selector frames and is accomplished by a horizontal rod at the bottom of each bank which extends across the frame before all the line finders of a subgroup. When this rod is turned, fingers associated with the rod are placed in a position to trip the brush of any line finder which starts moving up. It is the function of the trip circuit to place the proper trip rod in this rotated condition and thus to operate the proper brush. No interference with other selectors occurs because the start circuit is designed to permit only one line finder to be started up at a time, insuring that the trip rod will restore before another selector is started. With its brush tripped, a line finder then tests, one after another, the lines of the bank until it finds the one which has been marked by the operation of its line relay as having originated a call, and on this line it stops.

Assuming that both the line and the sender have been found, the subscriber's line is now extended through the line-finder bank to the line-finder selector rod, and from there to the district-finder bank of the link frame. Through the brush of the link-circuit district-finder selector it is carried into the link, and from there to the bank on the sender selector, whence it goes directly to the sender circuit. This establishes the path for the subscriber's dialing.

Sender and Decoder Operation.—It is the function of the sender to receive and record the number dialed by the subscriber and to use this information in controlling the subsequent handling of the call. In this, it is assisted in the larger cities by the decoder.

In the smaller of the panel cities, where the number of codes is not too great nor the changes too frequent to permit changing connections in individual senders when routing changes are required, it is possible to make the sender entirely self-contained; but if such a plan were extended to the larger cities, not only would the mass of code cross-connections per sender be extremely expensive in initial cost but the labor of making the required changes would be excessive.

This difficulty has been met by the use of the decoder. This decoder is an equipment unit consisting of relays and cross-connecting panels. It is seized by a sender when the office code has been dialed; it receives from the sender signals which inform it what the dialed code is; and it returns to the sender all the information necessary for completing the routing of the call. Thus the decoder serves somewhat the same purpose as a routing chart in manual operation.

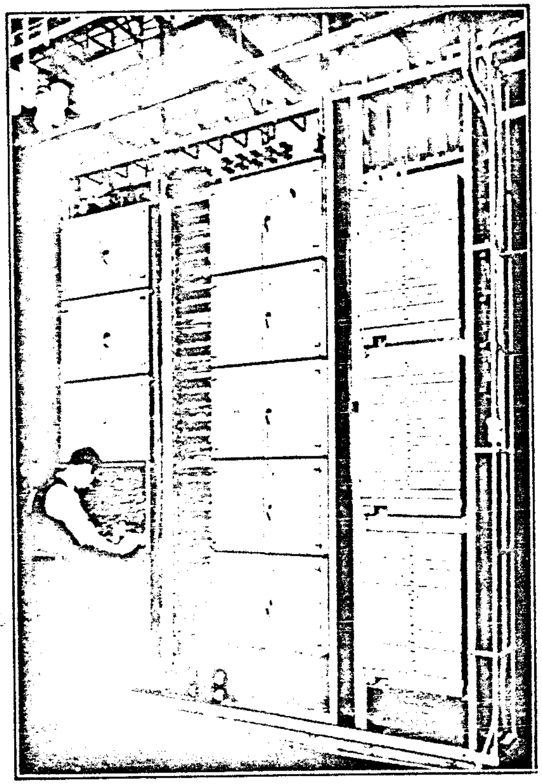


FIG. 120.—Sender frame.

Owing to its very short holding time, from three to five of these decoders will be ample to serve very large central offices. The result is both to reduce the cost of the cross-connections and to facilitate the making of changes.

Figure 120 shows a sender frame mounting ten senders. The open doors display the relays associated with one sender. In the middle are the sequence switches, three of which belong to each sender. The bay at the right of the picture provides relay equipment by which connection between the senders and decoders is accomplished.

A decoder frame is shown in Fig. 121. Relays of the usual type are mounted at the left of the frame. At the lower right, above the fuse panel, appear multi-contact relays and above these are the cross-connecting panels.

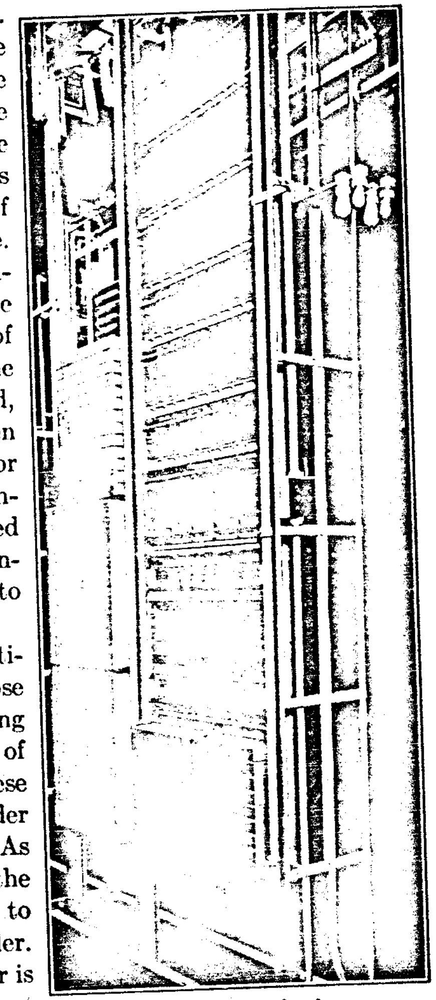


FIG. 121.—Decoder frame.

In the larger cities it is the first three digits dialed by the subscriber which designate the central office desired. The next four digits in all cases will represent the number of the desired line in that office. Each set of dial pulses, constituting a single digit of the number, is recorded on a set of relays as it is received by the sender. In the case considered, there will, accordingly, be seven sets of recording relays, one for each digit of the required number. An eighth set is provided to record party letters whenever these are dialed on calls to party lines in manual offices.

The first three digits, constituting the office code, are those which determine the routing and the general method of handling the call. It is these three digits which the sender transmits to the decoder. As soon as they are received, the sender is, therefore, ready to connect itself to an idle decoder. For this purpose each sender is provided with a multi-contact relay. This multi-contact relay has access to a link circuit, called a "decoder connector," which is used in common by the ten senders of a single sender frame. Each of these link circuits is also provided with a set of multi-contact relays. There will be as many in this set as there are decoders to which this link may be connected.

Figure 122 shows the connecting arrangement between a pair of sender frames and a set of three decoders. Let us assume that sender *A* requires a decoder. If the link circuit is not being used by any other sender on the frame, the multi-contact relay of sender *A* will connect it with this link. Next, one of the relays of the link circuit will operate to connect the link with an idle decoder. Each link has an order of preference in accordance with which it uses the decoders, but any one of the three decoders will serve the purpose equally well. In case the link circuit was in

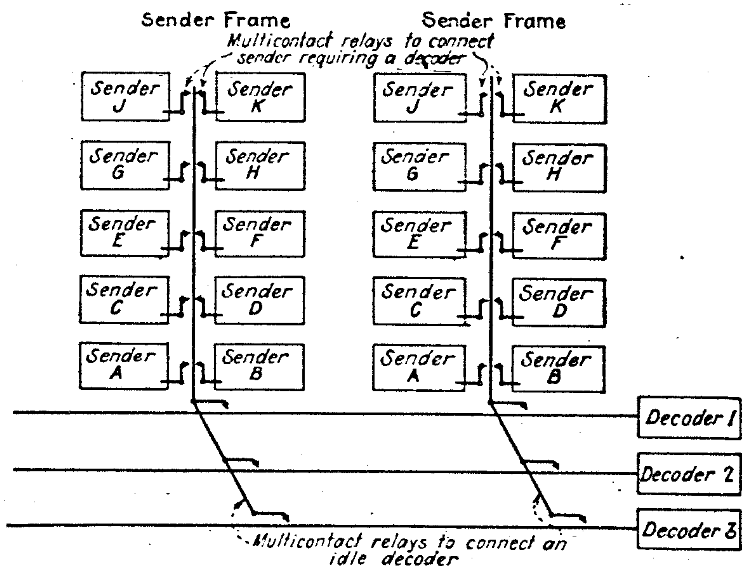


FIG. 122.—Sender-decoder interconnection—schematic.

use at the time sender *A* desired to use it, the connection would merely be delayed until the previous sender had finished with it. Since the holding time of the decoder and its connecting link is only a fraction of a second, this delay is hardly appreciable.

After the connection between the sender and the decoder has been made in this way, the sender transfers the digits representing the desired code into the decoder.

Figure 123 represents in schematic form the steps of decoder operation. Its first function after receiving the three digits of the code from the sender will be to combine them in order to isolate the specific code desired and so be enabled to deal with it as a unit. This is done in two steps: First, the 10 digits represent-

ing the third number of the code are combined with the 10 digits representing the second number of the code to make 100 combinations. Second, these 100 combinations are combined with the digits representing the first number of the code. Now the use of 1 as the first digit of the code is always avoided because it cannot be distinguished from a false preliminary pulse such as frequently occurs from a jarring of the switch hook when the receiver is lifted. The digit 0, dialed as the first digit, is used to route the call to an "A" operator without requiring the dialing of any

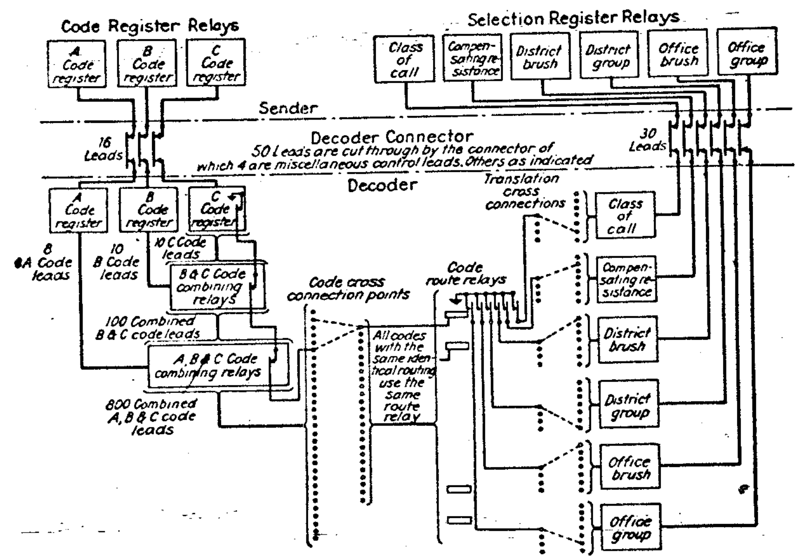


FIG. 123.—Decoder—schematic.

further digits, so there is no occasion to combine it with the second or third digits of the code. This leaves only 8 first code digits to be combined with the 100 combinations already obtained from the 2 other digits, making a total of 800 possible codes. With this combining arrangement a specific code, when transferred to the decoder, will result in the operation of a corresponding set of code-combining relays, the effect of which is to place ground upon a particular one of the 800 code cross-connecting points to show that this is the code which has been dialed.

On the other side of this cross-connecting frame appear the leads to a group of "code-route" relays. By cross-connection, any one of the code points may be connected to any one of the route-relay points. Usually only one code point will be connected to a route relay, but there are certain cases in which more than one code may be connected to a single route relay, as for instance where codes of a group are all routed through a single tandem point or where a number of unused codes may be routed to an intercepting operator. When the ground has been placed on the code point as a result of the transfer of the code digits into the decoder, the route relay corresponding to this code point will operate.

Each of the code-route relays has six contacts, each one of which controls a major feature of the routing information. These contacts are terminated on a second set of cross-connecting points and it is this set of cross-connections which determines the information that will be returned to the sender. In taking, for instance, the connecting lead which determines the class of call, cross-connecting to one point would indicate a direct connection to a dial office, cross-connecting to a second point would indicate a call to a manual office, to a third point would indicate a call routed through tandem, etc. A second connecting lead represents the compensating resistance which should be put in the fundamental selecting lead in order to give the proper resistance to the selecting path. This cross-connection will, therefore, depend upon the trunk resistance between the originating and terminating offices. A third lead, by its cross-connection, will determine which brush on the district frame should be tripped. A fourth will determine which group in the district bank the call should be routed through. The fifth and sixth leads will convey similar information for the office selector.

Between these cross-connecting points and the sender are thirty conductors divided into six sets of five conductors each. Each set of five conductors will convey the information with regard to one of these major features of the call. As a result of the combination in which these thirty leads are grounded by the decoder, a corresponding combination of selection register relays will be operated, and from these operated relays the sender controls all subsequent routing of the call.

As soon as these selection register relays have been set, the connection between the sender and the decoder is broken and the decoder may be used for a new call.

Having gained this information, the sender can now proceed with its selections.

Dial Pulse Recording.—Figure 124 is a simplified circuit showing the means used to record the dialed number. It assumes that the circuit between the subscriber's dial and the sender has already been established. All the equipment shown in the drawing, with the exception of the dial itself, is located in the sender circuit.

During dialing, the line circuit is completed through the *L* relay which is connected in series with the dial contacts to follow the dial pulses. This relay also acts as an induction coil to place

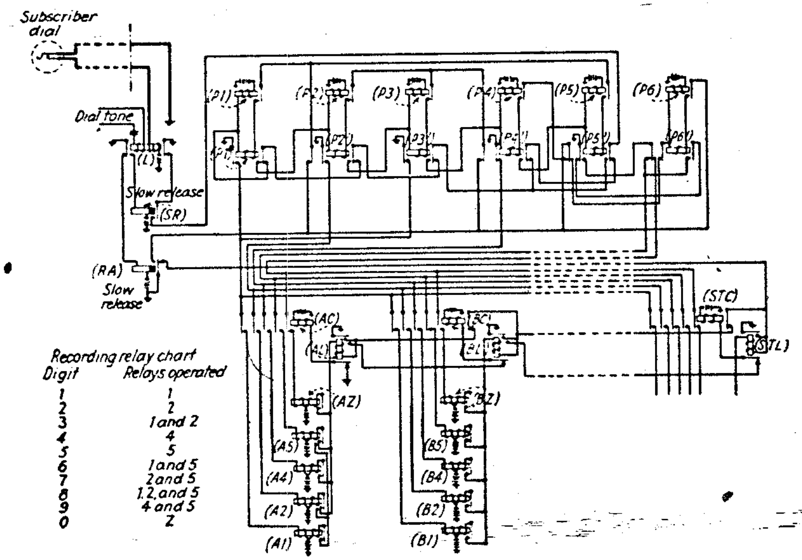


Fig. 124.—Dial pulse-recording circuit.

dial tone on the line. The *L* relay is operated as soon as the pulsing path is closed, since the dial in the normal position completes the circuit through its contacts. The subscriber receives the dial tone as soon as the dialing path is closed and he can then begin to dial the desired code and number.

Each digit is represented by a set of short breaks in the line current. At each break the *L* relay releases, so that the number of breaks which represents the digit dialed results in a corresponding number of releases and reoperations of the *L* relay.

The *SR* relay is of the slow-release type. It is energized at the first operation of *L* and remains operated during virtually the whole sender holding time, since the pulses during which *L* releases are of too short duration for the release of *SR*. Relay *RA*, also slow release, operates on the first pulse of each digit dialed, holds up on the succeeding pulses, and releases after the last pulse of the group which represents the digit.

The group of counting relays between *P*1 and *P*6 functions on each digit. After they have been set from one dialed digit, they transfer their setting to a recording group of relays, such as the *A*1 to *AZ* group or the group *B*1 to *BZ*, and then restore to await the dialing of the next digit. The recording group of relays *A*1 to *AZ* takes a setting from the first digit that the subscriber dials and holds this record until the sender releases. The *B*1 to *BZ* relays make a similar record of the second digit dialed and similar groups, not shown, do the same for the other digits.

While the circuit is awaiting the dialing of the first digit, relays *L*, *SR*, and *AC* are operated. Let us now assume that the subscriber dials as the first letter of his code a *D* which, on the dial, corresponds with the digit 3. At the first break in the circuit, the *L* relay releases, operating the *RA* relay from its left back contact. Tracing the ground from the right back contact of relay *L*, we find relay *P*1 will also be operated. At the end of the first pulse, relay *L* reoperates and relay *P*1′, being no longer shunted by the ground that operated *P*1, will now operate over the series path through the winding of *P*1, the winding of *P*1′, the make contact of *P*1, the back contact of *P*2′, and the front contact of *RA*, which still remains up because of its slow-release characteristic. On the second pulse, relay *L* will again release and the circuit through its right-hand back contact, which is now completed through the make contact of *P*1′, will operate the *P*2 relay. The reoperation of *L* at the end of the second pulse permits the *P*2′ relay to operate. The operation of *P*2′ breaks the locking path for *P*1 and *P*1′ and they release. It also extends the lead from the *L* relay to relay *P*3, so that upon the third break in the line current the release of *L* will operate *P*3 and the reoperation of *L* will permit the operation of *P*3′.

This being the last pulse of the digit, relay *L* will now remain operated for a time. Relay *RA* will release shortly after but, before it releases, the setting will have been transferred to the *A* group of recording relays. At the end of the three pulses, relays *P*2, *P*2′, *P*3, and *P*3′ were operated. Ground at the left-hand make contact of *P*2′ will complete a circuit through contact of relay *AC* to operate relay *A*2. Similarly, ground from the left-hand make contact of *P*3′ will operate *A*1. Upon the release of *RA*, a locking path will be established from its back contact through the winding of relay *AL* to hold *A*1 and *A*2. *AL* will operate in series with this locking path to establish a locking ground of its own as well as to release relay *AC* and to operate relay *BC*. The release of relay *RA* has meanwhile removed the locking path for the remaining counting relays of the *P* group so that these will release and be ready to record the next digit.

Let us assume that the next digit dialed is a *U*, which results in the sending of eight pulses. The *P* group of counting relays will be operated as before in the following steps: On the first pulse, the *P*1 pair will be operated, on the second the *P*2 pair will operate and the *P*1 pair will release; on the third the *P*3 pair will operate; on the fourth, the *P*4 pair will operate and the *P*2 and *P*3 pairs will release; on the fifth, the *P*5 pair will operate and the *P*4 pair release. At the same time, the *P*6 pair will operate. On the sixth pulse, the *P*1 pair will operate, on the seventh the *P*2 pair will operate and the *P*1 and *P*5 pairs will release and finally, on the eighth pulse, the *P*3 pair will be operated. We find that the relays now operated are the pairs *P*2, *P*3, and *P*6. This will result in the operation of recording relays *B*1, *B*2, and *B*5, the last one of which is operated through a make contact of the *P*6′ relay from ground at the back contact of *P*5′.

The subsequent digits dialed by the subscriber act in a similar way to set other groups of recording relays until finally, when dialing is complete, all of the digits which the subscriber has dialed will be recorded in relay combinations. In three-digit offices, it would be the setting of the first three sets of recording relays which is transferred into the decoder in order to determine the routing of the call.

One further detail which may be noted upon this circuit is the means by which preliminary pulses are handled. Suppose that a single pulse had been received before the first digit was dialed. The *P*1 and *P*1′ relays would have been operated by this pulse and from *P*1′ the *A*1 recording relay would have operated. In the *A* group of register relays, however, there is no locking path for the *A*1 relay operated alone. It must be operated in combination with either *A*2 or *A*5 to insure its holding. The release of *RA* at the end of this single pulse would release *P*1 and *P*1′ and relay *A*1 would also drop. Relay *AL* which cannot operate without the battery from one of the recording relays would not obtain

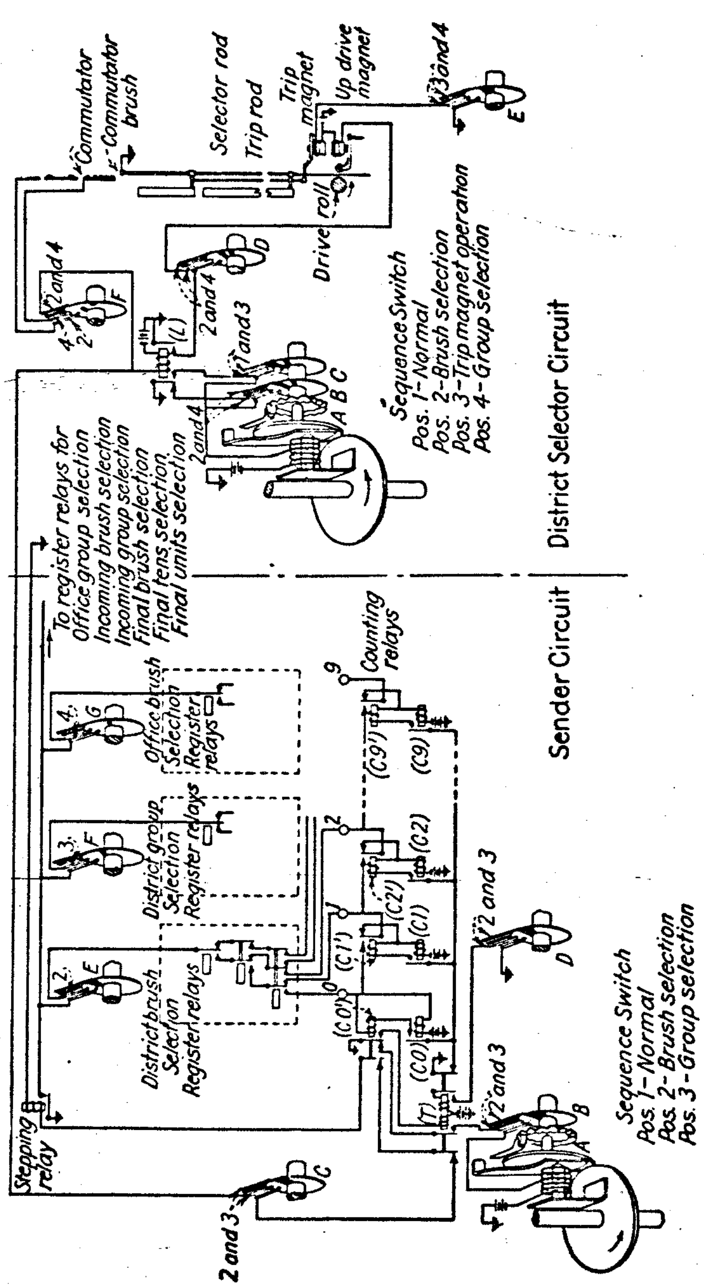


FIG. 125.—Selection control circuit.

it from relay $A1$ alone and would not operate. The circuit, therefore, would stand in identically the same condition that it did before the single pulse was received and no record of this pulse would have been made.

Selection Control.—The means by which the sender controls the selection process is usually called the "revertive" method of pulsing. The principle of this plan is to start a selector in motion by action of the local selector circuit and, as the selector moves, to return signals to the sender to indicate the successive steps of this motion. The sender counts these signals and when the correct number to represent the desired selector position has been received, the sender signals the selector circuit and the selector stops.

In the simplified selector circuit shown in Fig. 125, it is the commutator of the district selector circuit which sends back the pulses; the "stepping relay" follows them, the "counting relays" count them, and, when the correct number of pulses has been received, the last counting relay opens the pulsing circuit. This opening of the circuit stops the selector by releasing the L relay.

The dotted rectangles which contain the district brush-selection register relays, district group-selection register relays, etc., correspond to those of Fig. 123. As explained, these relays are set from the decoder. The relays which control the value of the compensating resistance to be inserted in the selecting path do not come into play in district selections, because both the district selector and the sender are in the same office and no material variation in trunk resistance exists. A fixed resistance can, therefore, be used and for simplicity it is not shown in the simplified circuit. Only those selection operations which may be made to selectors in other offices use this compensating resistance information, since only in this case are variations necessary.

As shown in the drawing, the effect of the setting of district brush-selection register relays is to determine to which pair of counting relays the stepping relay lead is connected. It is in this way that the number of steps counted before stopping the selector is determined.

The circuit drawing illustrates the process of selection in the first step of the switching train, that is, in the district selector. Position 1 is the normal position of both the sender and the district sequence switches. Selection is started as soon as the decoder has set the selection register relays by moving the sender sequence switch into position 2. The path for this is not shown in this simplified circuit. As soon as the sender sequence switch reaches position 2, it closes the selecting path through the cam marked *C*, which, though shown separately for clearness, is one of the cams of this switch. The *L* relay of the district-selector circuit is operated over this closed selecting path and, through its left-hand make contact, it provides a ground which is transmitted through the district sequence-switch cam *C* to operate the sequence-switch magnet. This magnet draws the flexibly mounted disk of the sequence switch against the driving disk and the switch turns. As soon as the switch has moved out of position 1, the operating path for its magnet is broken and the switch stops in the next succeeding position, that is, position 2. Through cam *D*, a path is closed in position 2 from the right-hand make contact of the *L* relay to energize the up-drive magnet. This magnet acts to press the rack of the selector against the up-drive cork roll and the selector starts its upward motion.

As it moves upward, the commutator brush at the top of the selector rod makes successive contacts with the commutator segments. Each time it passes over one of these segments, ground is placed on the selecting circuit through cam *G*, shunting down the stepping relay of the sender. The stepping relay will reoperate as the brush moves between the segments, so that each segment passed over will be represented by one release and reoperation of the stepping relay.

The first operation of the sender stepping relay occurred when the selecting path was closed. From its make contact, the stepping relay at that time closed a path from ground through the *E* cam of the sender sequence switch to the contacts of the district brush-selection register relays. Let us assume that the first and third of these relays were operated by the decoder. This path would then be continued through the make contact of the first relay, the back contact of the second relay, and the make contact of the third relay to the No. 2 pair of counting relays. The ground from the stepping relay would operate relay *C*2. No further action occurs until the commutator brush reaches the bottom segment of the commutator. At this point, ground on the commutator shunts down the stepping relay, removing the ground from the path to the counting relays.

The removal of this ground permits relay *C*2′ to operate in series with *C*2, transferring the operating path from the stepping relay to the No. 1 pair of the counting relays. As the commutator moves over the first segment, breaking contact with it, the stepping relay is permitted to reoperate and ground from its contact now operates relay *C*1. When the commutator brush makes on the second commutator segment, the stepping relay releases and relay *C*1′ operates, transferring the counting path to the zero pair of counting relays. As the commutator brush breaks with segment 2, the stepping relay again operates, energizing relay *CO*. When the commutator brush reaches the third segment, the stepping relay is again released and relay *CO*′ operates. The operation of *CO* opens the selecting path to the district selector and also operates relay *T* which locks up through cam *D* of the sender sequence switch. Relay *T* at its right-hand break contact removes the ground from all the counting relays and permits them to release. Through its left-hand break contact it continues to hold open the district selecting path. As soon as the *CO* relay has released, the ground at its break contact is extended through the make contact of relay *T* and cam *B* of the sequence switch to operate the sequence switch magnet. The operation of this magnet draws the flexible disk against the driving disk and the sequence switch moves from position 2 into position 3. In moving between these two positions, the locking path of relay *T* is opened and *T* releases before the path can be reestablished in position 3.

Meanwhile, in the district-selector circuit, the *L* relay may still find a path to hold it operated through the commutator until the commutator brush has moved past the third segment. When this occurs, the *L* relay releases, breaking at its right-hand contact the circuit to the up-drive magnet, stopping the motion of the selector at this point. Through its left-hand back contact it provides a path through cam *B* of the sequence switch to operate the sequence-switch magnet, moving the switch into position 3.

The selector has now been set in the position for brush trip, and in position 3 a path is established through cam *E* of the district sequence switch to operate the trip magnet and so revolve the trip rod. In the position in which the selector rod is standing, the trip finger is opposite the third brush of the bank, so that, when the trip rod is revolved, the trip finger catches on the trigger of this brush and is thus in position to trip the brush when the brush moves.

When the sender sequence switch has been moved into position 3, as described above, the selecting path between the district and the sender is re-established at cam *C* of the sender sequence switch. The *L* relay of the district again operates and through its left-hand make contact it moves the sequence switch from position 3 into position 4. In this position, a path is again established from the right-hand contact of *L* to operate the up-drive magnet, and the selector rod again starts to move upward. This commutator segment representing the steps of group selection has now been connected through cam *F* to the fundamental path. The motion of the brush over the segments of this commutator is signaled back, as in the previous case, to produce releases of the stepping relay. Corresponding pulses are given by the make contact of the stepping relay but, in this case, they are carried to the district group selection register relays through cam *F* of the sender sequence switch. These selection register relays have a setting from the decoder which also results in connecting this path to one of the pairs of counting relays, and, as before, these relays are counted down in order until the *CO′* relay is finally operated. This, as before, breaks the selection path, operates the *T* relay, releases the counting relays, and moves the sequence switch on into position for further selection stages. In the district circuit, the *L* relay is released, as before, as soon as the commutator brush has moved off the desired commutator segment. The up-drive is stopped and the sequence switch is moved forward in order to perform the other selector functions. The selector rod is now standing with the third brush tripped and in contact with terminals of the bank at the point in the bank which the sender has determined by the group selection.

The selector circuit can now proceed to test the trunks of the group which starts at this point of the bank, in order to find an idle one which it may seize to extend the connection forward. This is accomplished in the usual way by moving the selector upward from terminal to terminal, testing at the same time the third, or sleeve, conductor to determine from its electrical condition whether the trunk is idle or busy. On the first terminal which it finds idle it stops, and the circuit is cut through.

If the call is routed through an office selector, the path is now completed for office-selection control. The process by which this is accomplished is similar to that of district selection. The selection recording relays set by the decoder determine, by means of the counting relay connections, the setting that the office selector takes. The office selector then trunk hunts to find an idle inter-office trunk to the called central office.

If the inter-office trunks are reached directly from a district selector, the setting of the office-selection register relays indicates this fact to the sender and all the steps of office-selection control are omitted.

In case all of the trunks to which a selector has access are busy, the selector, after testing them all, stops on the overflow terminal. When standing on this terminal, one of the commutator segments will be grounded by the commutator brush and the grounding of this segment operates a relay in the selector circuit which reverses the tip and ring leads back to the sender, thereby reversing the polarity of the current. In series with the stepping relay in the sender is a polarized relay called the "overflow relay" omitted in the simplified circuit. This is so connected that it is not operated by the direction of current flow used in normal selections, but this reversal of the current from the overflow condition operates it. The result of its operation is to cause the sender to discontinue further selections and release, after setting the district circuit in a condition to send a busy signal to the calling subscriber.

After an idle inter-office trunk has been chosen, the sender is in position to make incoming selections. The choice of the incoming selector brush to be tripped is the first step in this process. From Fig. 115, it is apparent that this is determined by the thousands digit dialed by the subscriber. If this digit is 0 or 1, the bottom brush, that is, brush 0, must be tripped. If it is 2 or 3, the next brush (brush 1) must be selected, etc. The counting relay connections for this are determined by the register relays set from subscribers dialing without the intervention of the decoder. The compensating resistance in the selecting loop is, however, determined by relays set by the decoder. Otherwise, the method of selection is like that described for the district selector.

The incoming group selection is determined by the thousands and hundreds digits of the called number taken in combination.

From Fig. 115, it will be apparent that, in any bank, the bottom group (group 0) is chosen whenever the thousands digit is an even number and the hundreds digit is four or less, the next group (group 1) whenever the thousands digit is even and the hundreds digit five or more, group 2 whenever the thousands digit is odd and the hundreds digit four or less, and the last group (group 3) whenever the thousands digit is odd and the hundreds digit five or more.

When incoming group selection has been completed, an idle final selector circuit is found by the usual trunk-hunting process. The next step is final brush selection. This is determined from the hundreds digit. If this digit is 0 or 5, the bottom bank (bank 0) is selected. If it is 1 or 6, the next bank (bank 1) is chosen, and so on.

The position of the subscribers' line in the final bank is determined by the tens and units digits. The final bank arrangement differs from that of the banks of other selectors in that all the terminals are used; no overflow terminals are required. The tens digit is first used like a group selection to reach the proper group of ten lines. The units digit is then used to determine the exact line, in this section of ten. Thus the final frame has three selection steps instead of the two required in other frames.

When the final line has been reached, the final selector tests this line to determine, in the first place, whether it is busy or not. If it is idle, connection is immediately made. If it is busy, the selector must further determine whether it is an individual line or the line of a private branch-exchange group. This is indicated by marginal resistance conditions on the third, or sleeve, conductor. If it is a busy individual line, the final selector does not seize it but returns a busy signal to the calling subscriber. If it is the line of a private branch-exchange group, the final selector moves on to test over the succeeding terminals, stopping when an idle line is found or when it has tested all of the lines of the group and found them busy. The selector recognizes the last line of the group because this line is wired to give the same marginal condition as an individual subscriber's line. Reaching this line and finding it also busy, the selector will stop and return a busy signal as it does in the case of individual lines.

The speed of up-drive at which units selections and the line testing are accomplished is slower than that of other selections to permit sufficient time for the necessary circuit operations. In order to make this possible, an additional drive roll turning at slow speed and a corresponding clutch per selector circuit are provided on final frames.

With the arrangement for private branch-exchange lines described, it will be apparent that the only limitation in the number of lines which may be assigned to a subscriber is the number of sets of terminals available between the one which corresponds to the listed number and the top of the bank. In very large groups it is customary to assign listed numbers ending with the digits 00, so that all the terminals of the bank may be made available as private branch-exchange lines if

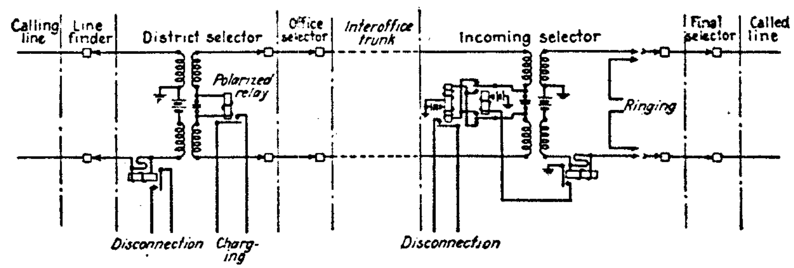


Fig. 126.—Talking and supervisory circuit.

desired, since such numbers appear as the bottom lines in their banks. It is thus possible to provide groups of 100 lines and at the same time permit each call to test, if necessary, all the lines of this group.

The sender completes its functions after final unit selections have been made, by sending a signal to the district-selector circuit to effect the connecting through of the talking path from the subscriber to the inter-office trunk. The release of the sender and its associated link circuit then occurs and they become available for use on another call.

The battery supply for the calling subscriber's transmitter and supervision is connected at the district selector through a repeating coil. For the called party, this function is performed in the incoming selector circuit. Figure 126 represents the talking and supervisory circuits for a panel connection.

The location of the ringing, supervisory, and current supply functions in the incoming selector, which is directly associated with the inter-office trunk, makes unnecessary special final selectors for types of service which require different transmission or supervisory conditions, such as toll and testing.

Message Registration.—On subscribers' lines where the charging is on a message-rate basis, a message register is provided. The operating path of this register is carried through one of the terminals of the line finder into the district circuit. The actual operation of the register on a completed call occurs at the end of conversation but the circuit condition to effect it is prepared upon the answer of the called party, by the operation of a "charge" relay in the district-selector circuit.

From Fig. 126 it will be clear that the operation of the called party's supervisory relay reverses the current over the inter-office trunk. The polarized relay at the originating end is operated by this reversal. This polarized relay operates the charge relay, but there is introduced at this point a delay interval so designed that the polarized relay must continue operated for a period of about three seconds to be effective. A closure of the contacts of the polarized relay of less than this interval would not result in a charge to the subscriber. This delay interval is timed by a power-driven interrupter of the type described above.

This delay interval has shown itself to be of considerable value. In the first place, it protects against false charges due to surges and other transient conditions. It has, besides, aided the flexibility of the system because it is possible to use short flashing signals for busy-back, re-order, and other similar purposes, so that the operators may use the same final selectors or trunks as calling dial subscribers do and at the same time may receive visual indication of these conditions on their supervisory lamps.

After the charge relay in the district-selector circuit has been set, no further action is taken until the end of conversation. When the calling subscriber restores his switch hook, this charge relay provides a circuit for imposing an operating current on the message-register lead to operate the register associated with the line.

In case of a busy line or a failure of the called party to answer, no reversal of the trunk supervisory current of sufficient duration to operate the charge relay will occur. No registration will be made. The same is true of service calls and the like, for which no charge is made.

Coin-box Operation.—The district and sender circuits used with coin-box lines must be made capable of additional functions. On account of these added functions, the line-finder groups on which they appear and their associated district circuits are used by coin lines exclusively. The average number of coin lines per central office is so small, however, that it is not usually economical to use a group of senders for coin lines alone. For this reason, the coin senders are designed to be capable of serving the non-coin lines as well. The link circuits associated with coin lines signal to the sender, when the link seizes it, that a coin-box call is to be handled, so that upon the receipt of such a signal the sender brings the coin features into play.

In order to initiate a call from a coin box, a coin must be deposited and the receiver removed before a line finder and sender will be associated with the line. When these conditions are satisfied, the operation is the same as that for the regular subscriber's call, up to the completion of subscriber's dialing.

Now the coin box is so designed that the deposit of a coin closes a circuit path through the coin magnet to ground. This can be removed only by collection or return of the coin. Any kind of a ground connection would serve to connect the line finder and sender, so, to make sure that a legitimate deposit has been made, the resistance of the ground circuit must be tested to determine that it is such as a coin deposit gives. When the last digit has been dialed, the sender, therefore, makes a test of the line to insure that the proper conditions have been met. If this proves to be the case, the sender completes its functions as usual. The lack of a correct resistance ground condition indicates to the sender that there is some irregularity and in this case the sender proceeds only to the completion of final tens selection. Before making final units selection, the sender brings in a signal to an operator. This operator, upon answering, is connected to the line and she tries to establish the reason for this irregularity. If it can be cleared up by a coin deposit, the connection will be completed when this is done.

The answer of the called subscriber sets a charge relay in the district circuit just as it does in the case of a message-rate subscriber. The delay interval is effective in this case as in the other. When the calling subscriber restores his switch hook at the end of a call, the coin-box district-selector circuit is connected with an auxiliary coin control circuit. There are usually four of these circuits available to the thirty district circuits on one side of a district-selector frame. After seizing the circuit, the district circuit informs it whether or not a charge is to be made. The coin control circuit is given direct access to the line conductors and its first act is to test the line to make sure that there is a coin in the box. If the coin is to be collected, it next places battery of the proper polarity over both sides of the subscriber's line in parallel. The circuit is completed at the coin box through the coin-box magnet to ground, and the magnet is operated in the proper direction to accomplish the collection. After this is done, it makes a last test of the line to insure that the collection has been accomplished.

In case the call was not completed, the process is the same except that the current sent out over the line is of the opposite polarity and operates the magnet in the direction to return the coin.

In case of any irregularity, such as no coin being in the box upon the first test or the coin remaining in the box after collection or return, a signal is given to an operator and the difficulty is reported for investigation. After its functions have been performed, the coin control circuit frees itself from the district selector and can be used by another one. The restoration of the line-finder circuit follows shortly afterward.

Another general plan of coin-box operation used in some cities differs from the one described in permitting the subscriber to seize a sender and to dial even if a coin has not been deposited. The sender coin test will be made, however, substantially as described and the call will not be completed until a deposit is made. With this arrangement it is customary to permit calls which dial the "A" operator to reach her without a coin deposit and this facility is the main reason for its use.

"A" Operator.—The duties of the "A" operator are varied. She completes short-haul toll connections, answers subscribers' requests for assistance in completing their calls, supervises those which have been incorrectly or incompletely dialed, and verifies busy reports. The regular intercepting work is also done at this line of board and may be combined with other duties of the "A" operator.

In its general form the panel "A" board is similar to a manual "A" board. The answering jacks in the panel board, however, are not directly associated with subscribers' lines, but, instead, the greater number of them will represent those trunks from the district or office selector, which the subscriber reaches when he dials "Operator." A similar group of answering jacks will be reached by the subscriber if he, in error, dials an unused combination of digits as an office code. The trunks to the intercepting operator come from final terminals which are unused or which, on account of some irregular condition, require an operator's intervention.

The most widely used form of panel "A" board is the dialing type. Double-ended cords are provided and a position dial may be associated with the calling end of any cord. These cords may also be used to complete connection in the same way as in manual "A" boards. Either straightforward or call-circuit operation may be used and calls may be trunked either directly or through tandem.

Figure 127 is a view of a representative panel "A" board. The dial is mounted on the right of each position, otherwise the shelf equipment is similar to a manual "A" position. In the face equipment the answering jacks appear nearest the bottom. Since the trunks associated with these jacks have a high calling rate, a comparatively small number will provide a load for an operator. Above the answering jacks are the outgoing trunk jacks and the jacks for reaching the dialing district selectors, described below.

At the top of the multiple space appears the checking multiple. This consists of a set of terminals, one connected to the sleeve lead of each subscriber's line. In ticketing a toll call, the operator must ask the calling subscriber for his own number since his call comes in over a trunk. In order to check the number that is given, an arrangement is provided for sending a signal back from the trunk on which his call appears to the sleeve conductor of his line. If the number given is correct, the operator will hear a tone when she touches the checking terminal corresponding to that number with the tip of her plug.

The signal of an originating call is the lighting of the lamp associated with one of the answering jacks. These jacks are multipled before several operators, and one who is idle plugs in with her answering cord.

In case a call is to be completed by dialing, she plugs her calling cord into a jack which is associated with an operator's district selector. These selectors generally have access to the same out trunks and connect with the same senders as the subscribers' district selectors do. The operator associates her dial with the cord by means of a key and dials the number desired into the sender to which the dialing district has been connected. The sender then completes the call in the usual

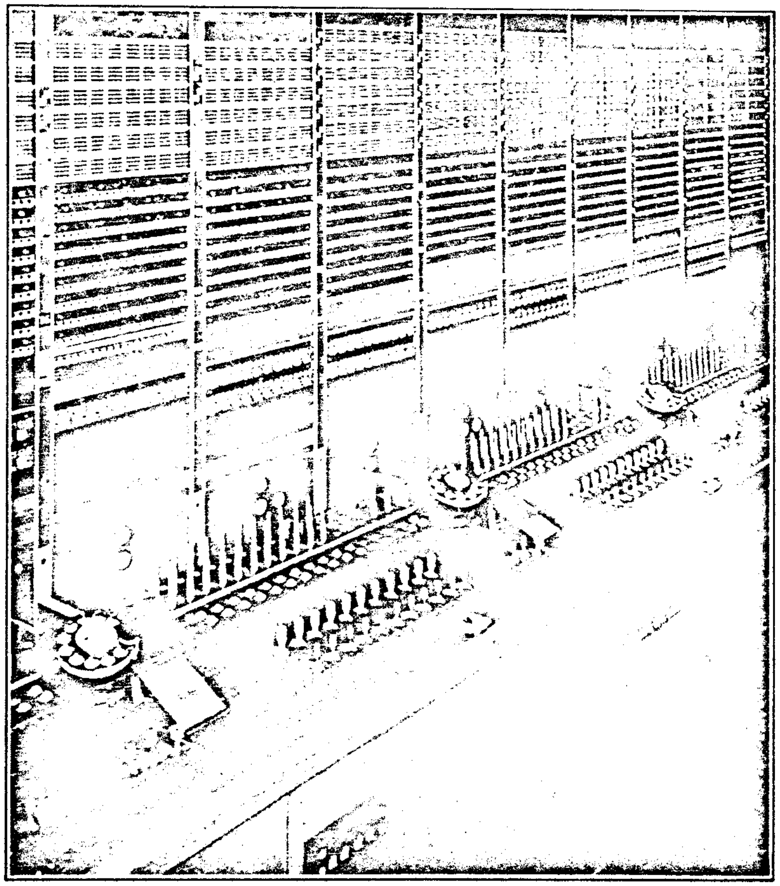


FIG. 127.—Panel "A" positions.

way. This dialing method of call completion is used mainly in the handling of assistance calls to lines in the dialing area; the toll calls are usually completed by the straightforward or call-circuit method, frequently through tandem.

Another form of panel "A" board which is coming into use uses a simple ten-button key set in place of the dial, following

a method of operation similar to that of key pulsing, described below.

INTERCONNECTION WITH MANUAL BOARDS

Call Indicator.—Calls originating in a panel office for subscribers in a manual office are completed by the panel call-indicator method. The call-indicator trunks appear at the originating panel office on the district- or office-selector frame and at the called manual office each terminates in a cord on a call-

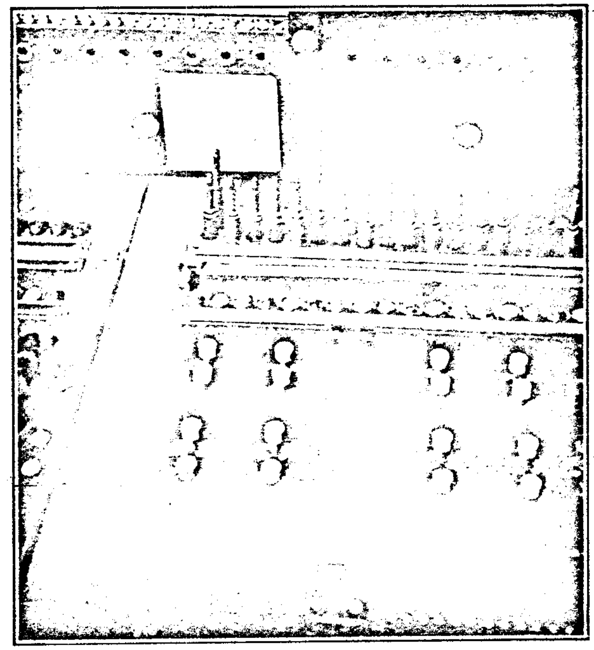


FIG. 128.—Call-indicator "B" position.

indicator "B" position which is similar to a manual "B" position. A portion of a position of this type is shown in Fig. 128. The indicator for displaying the called number to the "B" operator here replaces two strips of ringing keys. This form of indicator is designed for easy installation in an existing manual "B" position. On positions on which the cord ringing keys are not used, the form of indicator sketched in Fig. 129 may be provided instead.

The two main functions of the call-indicator position circuit are, first, the finding of the trunk upon which a call is held and its connection to the position and, second, the recording and display of the called number as received from the pulses transmitted by the sender. Figure 129 shows the main operating features of the call indicator in schematic form.

The position connecting equipment includes a set of three trunk-finding rotary selectors each having access to sixteen trunks, that is, one-third of the forty-eight which appear at each position. An additional selector, called the "control

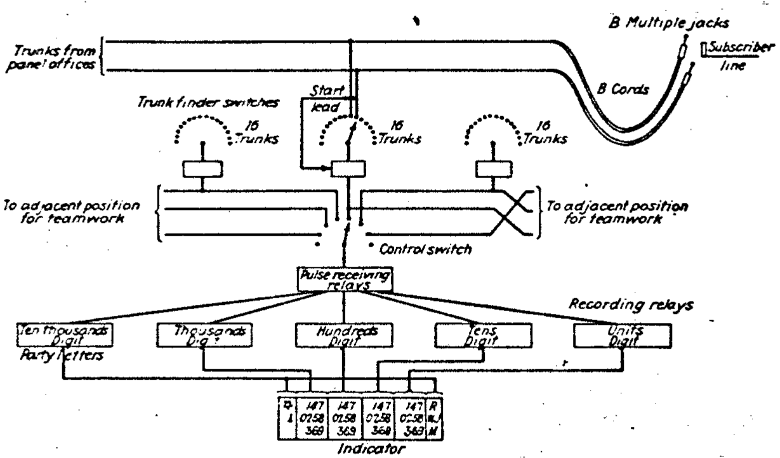


FIG. 129.—Call indicator—schematic.

switch," is arranged to connect a position call-indicator circuit to any one of the three trunk-finder selectors or, for team-work purposes, to similar selectors on adjacent positions. All these selectors are of the rotary single-motion type.

The position call-indicator circuit includes a set of pulse-receiving relays and, associated with them, the pulse-recording relays, one set of which is provided for each of the digits to be received. These recording relays control the lighting of a set of lamps on the indicator on the key shelf of the position, such as that shown in Fig. 128.

In order to facilitate the provision of call indicators on existing manual "B" positions, the call-indicator apparatus for each position is mounted and wired in a single unit, thus simplifying its shipping and installation.

Manual offices, unlike dial offices, sometimes serve lines designated by numbers over 10,000 or by four-digit numbers followed by party letters, though both of these are never combined in the same line designation. A maximum of five digits or letters must consequently be provided for.

Let us assume that a subscriber dials a central-office code which represents a manual office reached by call indicator. By means of the "class-of-call" setting, the decoder will inform the sender that this is the case. District and office selections are made in the usual way to reach the inter-office trunk. The sender, when the called number is completely dialed, places a circuit closure on the chosen trunk, thus operating a relay at the manual-office end. Recognizing that this is the signal of a waiting call, the trunk circuit grounds a start lead to its associated trunk finder, and this trunk finder moves to test over the trunk circuits, searching for the one which is calling. The control switch is started at the same time as the trunk finder, and it, too, tests, searching for the trunk-finder switch that is being used. When these switches have been successful in their search, the tip and ring conductors of the trunk will be extended through the trunk-finder switch and the control switch to reach the pulse-receiving relays. A circuit is thus prepared to receive pulses from the sender. The sender is informed of this by a change in the circuit conditions and proceeds to send out a series of pulses to indicate the number of the desired line.

The type of pulses used to transmit the number consists of combinations of polarity and resistance changes. For convenience we shall designate a condition of battery on the ring of the trunk and ground on the tip as a negative polarity, while a positive polarity is the reverse of this. Four pulse intervals constitute a set for the sending of one digit. The arrangement and possible variations of these pulse intervals are as follows:

The choice of pulse conditions for the first and third intervals is:

1. Positive polarity through a low resistance.
2. Positive polarity through a high resistance.
3. An open-circuit condition.

The choice of pulse conditions for the second and fourth intervals is:

1. Negative polarity through a low resistance.
2. Negative polarity through a high resistance.

This alternate succession of positive and negative polarities provides clean-cut pulsing cycles which simplify the pulse recording and also permit rapid pulsing.

Connected in series with the trunk conductors in the pulse-receiving circuit of the "B" position are three relays: a polarized relay operating on negative pulses, a polarized relay operating on positive pulses, and a marginal relay. From the contacts of these relays, the recording relays are set.

The selection of the proper pulse conditions to send the number desired is determined by the sender from the record on the register relays set by the calling subscriber's dialing. The first digit transmitted by the sender is the one which determines the party letter or the ten-thousands digit if either of these is used. This is followed by the pulses representing the thousands digit, the hundreds digit, the tens digit, and the units digit. In this order each of these sets of pulses is received at the "B" end of the trunk by the pulse-receiving relays and, one after another, the sets of recording relays corresponding with these digits are operated. As soon as all the pulses have been sent, the calling line is switched through the district circuit and the sender disconnects.

From the contacts of the recording relays is controlled the lighting of the proper indicator lamps to display the called number to the operator. This indicator, which is mounted in the position key shelf, as shown in Fig. 128, consists of a bank of lamps over which is placed a translucent screen on which appears the set of numbers and letters indicated in Fig. 129. Each of these numbers appears directly above one of the lamps and, when a lamp is lighted, the corresponding number is displayed to the operator. These lamps are divided into groups. In the first group is the digit 1, used for numbers over 10,000, and a star, which indicates that the number has neither a party letter nor a digit in the ten-thousands place. The next four groups display successively the thousands, hundreds, tens, and units digits. The last group displays the party letter if there is one. In order to completely designate a number, it is, therefore, necessary to light a particular set of five of these lamps. Such a display indicates to the operator that a call has been received for this number. The cord upon which this call is held is indicated by a flashing supervisory lamp, so she takes up this cord and completes the call by plugging it into the line multiple as in manual operation. The called party is rung and as soon as he answers conversation may take place.

The disconnection of the position indicator equipment from the trunk is accomplished by the depression of a release key by the operator as soon as she has read the displayed number. The indicator equipment will then be free to handle subsequent calls.

In offices which have no numbers above 10,000 and no party letters, the sender can send out the circuit closure for connecting the position circuit as soon as the units digit is dialed. In the more common case of offices with some five-pull numbers, the sender delays the signal for a period of four seconds after four digits have been dialed to allow time for the dialing of a fifth digit. At the end of this interval the circuit closure will be sent. Of course, the dialing of the fifth digit cancels further delay, and in this case the circuit closure is sent immediately afterward.

Another problem of pulsing is that, when a subscriber dials a number over 10,000, the first numerical digit is recorded in the sender on the register relays commonly used to record the thousands digit; the second numerical digit, which really represents the thousands, will be recorded on the hundreds register, etc. In order to send out the digits in the proper order, the sender must recognize this fact and change the order of sending. Now, whenever numbers over 10,000 are used, these numbers never exceed 10,999. The sender, therefore, recognizes a number of this type by the fact that five numerical digits have been dialed, the first two of which are 10. When this occurs in combination with the code of a central office which has such numbers, the sender makes the necessary change in the order of pulsing. Lines with numbers from 1,000 to 1,099 followed by a party letter cannot be used at the same time, because the sender could not distinguish these from lines numbered from 10,000 to 10,999.

On the accompanying schematic drawing (Fig. 129) it will be noted that the control switch of the position has access not only to the trunk-finder switches of its own position, but also to the two adjacent trunk-finder switches of the position to the left and the one adjacent switch of the position to the right. With this arrangement, it is possible for the operator on one position to receive and handle calls which come in on trunks on an adjacent position when the latter is either busy or out of service. For this purpose, trunk-finder switches are so arranged that, if they find their home position busy on a call or otherwise unavailable, they will start the control switch belonging to the next position in the line if it is idle, bringing in the call to this operator. In this case, the cord lamp flashes at a different rate to avoid confusion with a cord whose call is being handled at the home position. The further operation is the same as that described.

The call-indicator position arrangement described above is called "automatic-display call indicator" to distinguish it from a key-display arrangement previously used. The connecting arrangement between the trunk and the position circuit is particularly designed to simplify the installation of call indicators in existing manual "B" positions by requiring but small change in the trunk circuits and position equipment. The same connecting equipment can be used to handle straightforward trunks by substituting the operator's telephone set for the pulse-receiving circuit. This permits the call-indicator equipment to be installed and used on a straightforward basis earlier than it is required for calls from panel offices. As the originating manual offices which it serves are replaced by panel offices, simple conversion changes can be made to change to call-indicator operation. Such facilities for rapid conversion are a great convenience and frequently avoid the necessity for providing additional equipment for temporary operation. The simplicity in operation which this plan of automatic connection between the trunk and position provides is also a decided advantage.

Panel "B" Board.—Calls originating in manual offices for subscribers in panel offices are usually completed through the panel "B" board. The form of "B" position now used in panel installations is based on a straightforward method of operation with call distribution to the "B" operators.

At the manual office the trunk to the panel "B" board is reached through an outgoing-trunk jack on the "A" board in the usual way. At the panel-office end the trunk is directly associated with an incoming selector. A schematic drawing of this equipment is shown in Fig. 130.

The "B" position, a photograph of which is shown in Fig. 131, consists of a simple desk in which is mounted a ten-button key set with the keys marked in order from 0 to 9. Link circuits are provided for finding a calling trunk and connecting

it both with a position and with a "B" sender. These links, as the schematic diagram indicates, use panel-type selectors for the trunk finder and for the "B" sender selector, while the operator is connected through a rotary selector which permits access to a team of twenty operators.

The incoming selector, except in minor circuit details, is similar to that used on calls from panel offices and is, in fact, designed to be readily convertible to these, when the replacement of manual offices by panel makes it desirable to do so.

When a call for the panel office is received, the "A" operator plugs into an idle trunk to that office as she does in manual

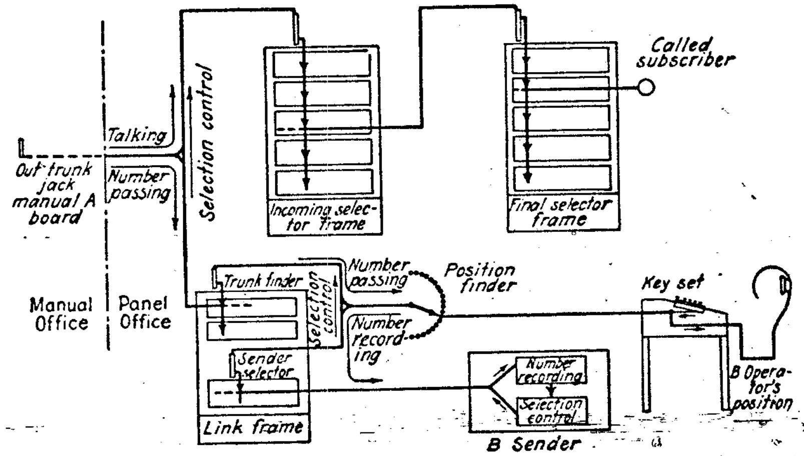


Fig. 130.—Panel "B" operation—schematic.

straightforward operation. The incoming selector circuit receives an indication of this and over a starting lead it sets an idle link in motion. The trunk finder associated with this link circuit tests over the trunks to which it has access, until it finds the one by which the call is being held. At the same time, the position finder of the link tests over the group of positions to which it has access and chooses an idle one. The connection is then extended from the trunk through the trunk-finder switch and the position finder to the "B" operator's position. An order tone is sent back to the "A" operator to indicate that the "B" operator is waiting, and the called number is then passed verbally by the "A" to the "B" operator.

As soon as this path between the two operators is established, the sender selector of the link starts testing over the "B" senders to choose an idle one. The connection of the link to an idle sender is indicated by a lamp on the operator's position. Recognizing that a recording path to the sender has been established, the "B" operator now sets up on her ten-button key set the number which she has received, one digit at a time. By a system of marginal pulses, these key settings are transferred to the sender circuit and recorded there. The operator's position is

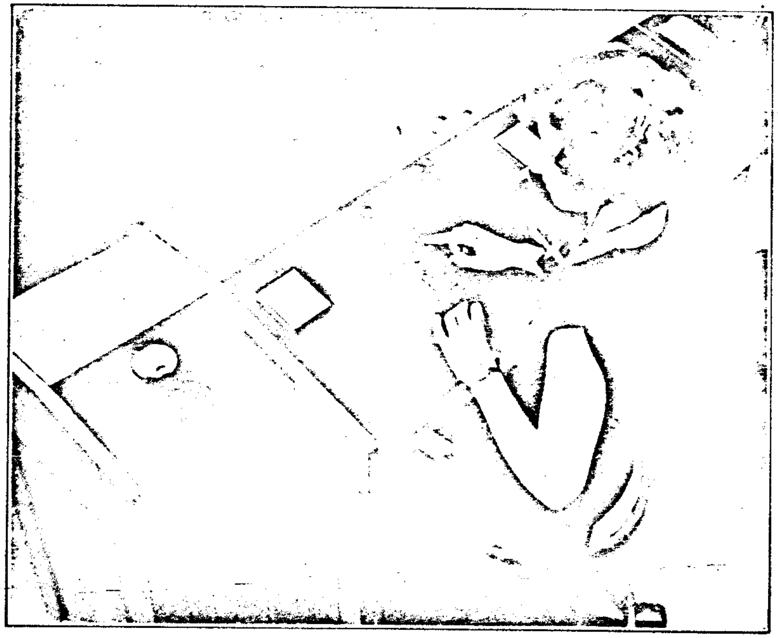


FIG. 131.—Panel "B" position.

released and made free to other calls as soon as the last digit is recorded.

The "B" sender now proceeds to use the recorded number to control the incoming and final selections. This operation is similar to the corresponding selections made by subscribers' senders from the recorded dial pulses. As soon as these selections are complete, the sender and link are both dismissed and the talking path is established in the usual way.

At the end of the conversation, the "A" operator receives the disconnect supervision as in manual operation and, when she pulls down her cord, the incoming and final selectors release without further action on the part of a "B" operator.

The very short "B" operator's work time permits the handling of high loads with this type of equipment. It is also well adapted to service in hours of light load because unoccupied positions test busy to the link circuits and all calls are then received by the positions remaining in service.

Key Indicator.—Another method for handling calls from manual to panel offices, called the "key-indicator method," has been used in some cases. The principle of this arrangement is to provide senders in the manual office and key sets on the "A" operators' positions. Calls to the panel office are then completed by associating a sender with the operator's key set and also with a trunk to the called office. The operator then sets up the number and it is recorded in the sender, which uses it to control the incoming and final selections. A set of indicator lamps displays to the operator the number of the trunk to which this sender has connected, and into this trunk she plugs her cord. Upon the completion of selections, the talking circuit is established through the operator's cord to the trunk jack and from there directly to the incoming and final circuits in the called office. The sender releases as soon as the selections are completed.

The key-indicator equipment is designed to be readily installed in existing manual offices. By avoiding the use of a "B" operator it effects a saving in operating charges as compared with panel "B" boards. The initial cost of the key-indicator equipment is, however, the greater of the two, so that the relative economy of the two plans can only be determined by careful study of individual cases.

Key Pulsing.—An arrangement called "key pulsing" for handling calls to panel offices finds particular use on toll positions. With this plan, the toll operator is provided with a key set which may be associated with any of the cords of her position. The panel trunks, which appear in outgoing-trunk jacks before the operators, are arranged to associate themselves through a link circuit with a key-pulsing sender located in the toll office.

When a call to a panel office is to be made, the toll operator chooses and plugs into an idle trunk to the called office as in straightforward operation. By means of a position key, she then connects her key set and its associated circuit with the cord which she has used. The plugging in of the cord is the signal to start a link circuit, which will pick the trunk on which the call is being originated and connect it to an idle sender. When the sender is waiting, a lamp indication is given to the operator and she then plays up on her key set in their proper order the digits of the called number. After the number is recorded, the key set and its associated circuit are released from the cord.

The key settings are transmitted to the sender by means of combined marginal and polarized pulses. The sender records them on relays and uses this record of the number to control selections through incoming and final selector frames in the panel office. When these are completed, the link and sender release and the trunk circuit is cut through for talking.

In comparison with key-indicator equipment, the key-pulsing plan is cheaper in first equipment cost, especially where a large number of positions is involved. It is much less readily installed in existing offices than key indicator and for this reason has found no field in manual "A" boards sufficient to justify its use. It is well adapted to use in panel "A" boards where it will be used in many cases instead of the dialing plan described.

MAINTENANCE AND TESTING

In order to insure accurate and continuous operation of all the elements of the panel system, automatic routine test sets are provided. Taking as an instance the testing of senders, there is provided an automatic sender test circuit arranged to connect itself to the senders much as a link circuit does on an originating call. This test circuit then transmits to the sender a set of pulses simulating subscribers' dial pulses. Operating in the same way that it does on a call from the subscriber, the sender prepares itself for selection control. The test circuit then simulates, one after another, all the steps of the selection process, recording the settings which it thereby obtains from the sender. These it checks against a record of what the proper setting should be and if any discrepancy is found, an alarm is sounded and a lamp lighted to show the point at which the trouble occurred. Keys are provided upon which the test number which is to be used is set up. These, in conjunction with other control keys, permit the testing of any of the normal sender functions on any class of call.

As long as no trouble is found, this test circuit functions automatically without attendance. The dial pulse conditions

and the selection conditions in these tests are made to present particularly severe margins so that a sender passing such a test will have proved itself capable of functioning under conditions more difficult than those usually met in service.

Similar automatic test sets are provided for each selector of the switching train, for "B" senders, etc. Troubles found in this way are more easily located and corrected than those which occur on regular calls, and incipient troubles are likely to be found before they interfere with service. While it does not, of course, eliminate the need of locating trouble conditions which appear under regular operation, it greatly reduces this labor.

TANDEM OPERATION

In large cities of the type that panel equipment is designed to serve, tandem operation is especially useful. With a large number of central offices in the area, the number of daily calls from one particular central office to another is, in many cases very small. Direct trunking between all of them would result in a large number of small, and consequently inefficient, trunk groups.

To escape this situation, it is the practice, as pointed out in earlier chapters, to provide in the large cities trunk-switching centers called "tandem offices" located at central points. When a call is received for a central office to which the volume of traffic is small, this call will be extended first to the tandem office and there it will be switched to a trunk to the office called. The choice of the office routings to be handled in this way is in each case a problem in service and economy: the cost and inconvenience of using the tandem routing must be balanced against the trunk saving which it produces as compared with direct routing.

The saving is effected both in the trunks to the tandem office and the completing trunks from the tandem office, since the first handles calls from one office to a number of called offices and the completing trunks handle traffic to one terminating office from a number of originating offices. The location of the tandem office in the area is such as to give the maximum of economy where both of these types of trunks are considered.

Much of the toll service to near-by toll points, handled by panel "A" operators or by manual "A" operators, is directed through a tandem board. For this reason, the general tandem plan must be arranged to handle both the calls dialed by the subscribers and those handled by "A" operators.

Manual Tandem with Call Indicator.—Manual tandem equipment was the earliest type to be used. Trunks from manual or panel "A" positions terminate on cords before the tandem operators, much as they do in a manual "B" position. In the multiple before the tandem operator are jacks connecting with trunks to terminating offices. These terminating trunks appear either on manual "B" position cords or on panel "B" incoming selectors, just as direct trunks do. Manual tandem positions may be arranged for call-circuit operation but usually the straightforward method of operation is followed.

Call-indicator tandem positions may be included in the manual tandem line-up to handle tandem calls dialed by subscribers. These positions are similar to those of the manual tandem, except that they are provided with call-indicator equipment to display the desired number to the tandem operator. The tandem call-indicator display lamps in addition to displaying the number of the called line must indicate the code of the called office in order to permit the tandem operator to choose the proper group of completing trunks.

On a call of this type, the sender in the calling office transmits the called number to the tandem position by means of panel call-indicator pulses, sending first the three digits of the office code and then the line number. The called office code and number are displayed to the tandem operator, who completes the call to the desired office through a manual or panel "B" operator.

Office-selector Tandem.—The simplest form of tandem equipment used for handling calls dialed by the subscribers is the office-selector tandem. This consists of a selector frame similar to the office selector of a local office but located at a switching point distant from the originating office. The distant-office selector is reached by trunks from the district-selector multiple and it is controlled by the sender just as a local-office selector would be controlled. This plan amounts to the enabling of a number of central offices to combine some of their office-selector frames at a switching center and thus takes advantage of the saving in terminating trunks which results from this combined traffic.

Sender Tandem.—A new type of equipment has been specifically designed to meet the tandem conditions of large panel areas.

This is called the "sender tandem." It is adapted to receive and complete both manual straightforward calls from "A" operators and mechanical calls which have been dialed into senders in the originating office. In the latter case, it serves a purpose similar to the office-selector tandem. However, sender tandem selections are made through two successive tandem selector frames instead of one, and a much greater number of outgoing trunks can, therefore, be reached. Tandem connections can also be established over longer distances than it is possible to do by office tandem, since the originating office transmits the number to the

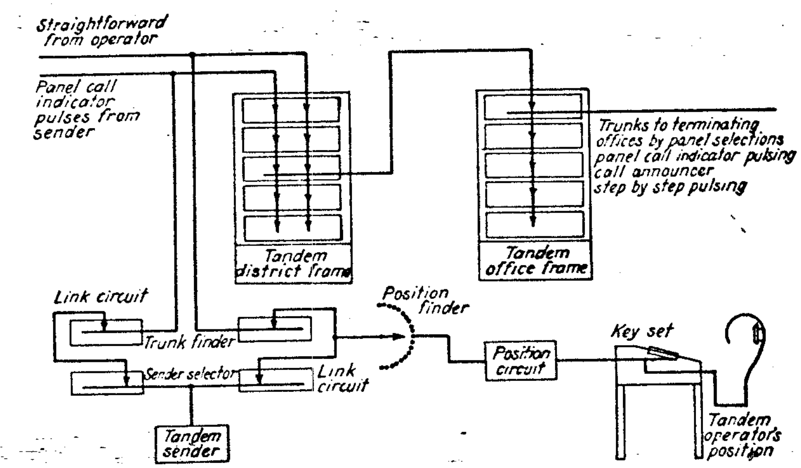


Fig. 132.—Sender tandem—schematic.

tandem office and selections are completed from a sender at that point.

The sender tandem arrangement is represented schematically in Fig. 132. Each trunk incoming to the tandem center terminates on a tandem district selector. Link circuits are provided to pick up these incoming trunks. Such links are of two types. The first type is a two-way link for handling the trunks over which come the calls that have been recorded in senders at the originating office. Its function is to connect the trunk with an idle sender. Panel "A" operators also use this type of link when they handle a call by the use of a sender at the originating panel office. The second type is a three-way link circuit for trunks from manual "A" operators or from panel "A" operators on calls completed manually by the straightforward method. It connects the trunk with an idle sender and an idle tandem operator as well. This second type of link is designed to be convertible to the first type, since the decrease in the number of manual offices frees equipment of this type while the mechanical tandem calls will continue to increase. Senders are provided which can be used with both types of calls. Tandem positions equipped with key sets for recording the number received from the originating operator are also provided. A photograph of one is shown in Fig. 133.

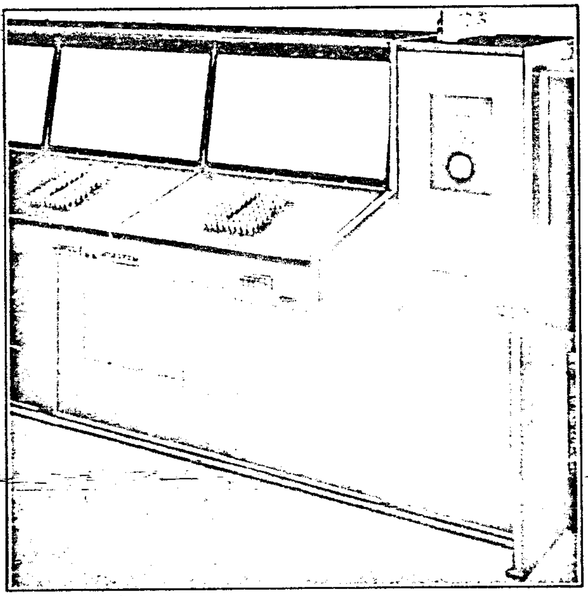


FIG. 133.—Sender tandem operator position.

Consider, first, a call originated by a subscriber's or operator's dialing a call into a sender at the originating office. This is, in the usual way, extended through the district and office selectors of the originating office to reach an idle tandem trunk. When this trunk is selected, the tandem district-selector circuit with which it is associated starts one of the group of two-ended link circuits. The trunk-finder end of this link moves to pick up the calling trunk in the trunk-finder bank, and the sender-selector end of the link chooses an idle tandem sender.

As soon as this connecting path between the originating subscriber's sender and the tandem sender has been established over

the trunk and through the link, the first sender transmits the details of the call to the tandem sender by means of call-indicator pulses. This information includes both the code of the central office desired and the number of the desired line in that office. The tandem sender records this information and then, through a decoder, it obtains the necessary routing information. The tandem sender proceeds to control the selection process through the tandem district frame and also through a tandem office frame if one is required. In this way, it reaches the trunks to the terminating office.

If the called office is of the panel type, incoming and final selections are controlled by the tandem sender to reach the called line. If a manual office is called, the call can be completed by the usual call-indicator method. As soon as these duties are completed, the tandem link and sender circuits release and the through path is established. The release of the subscriber's sender in the originating office occurs as soon as it has transmitted the information to the tandem sender.

On a tandem call completed by the manual straightforward method, the tandem trunks appear on trunk jacks before the operator. When such a call is to be handled, she chooses an idle trunk and plugs in. At the tandem end, each of these trunks is associated with a tandem district selector and each one also appears on the trunk-finder bank of a group of the three-way link circuits. One of these link circuits is started and moves its trunk finder to pick up the calling trunk. At the same time, the link circuit starts a rotary position finder like that used in panel "B" operation to choose an idle tandem operator's position. Upon the connection of the tandem position to the trunk, an order tone is sent back to the originating operator who then passes the details of the call. The tandem operator sets up this information on a key set, recording both the office code and the called number. Meanwhile, the sender-selector end of the link circuit connects to an idle tandem sender. The key setting is transferred into the tandem sender by means of panel call-indicator pulses sent out by the position circuit. As soon as the sender has taken its setting, the tandem position is released. The sender proceeds to complete selections and then releases as it does in the case of the call from a dial subscriber, just described.

The plan of transferring the number recorded on the key set into the tandem sender by means of panel call-indicator pulses permits the same type of sender to be used for both classes of call.

One feature provided in these tandem senders, which subscriber senders do not have, is the call announcer. This is a plan for transmitting the called number to a manual office without the use of the call indicator. It consists in a phonographic device which speaks the called number to a "B" operator at the called office who handles it like a straightforward call. Such an arrangement is capable of operation over phantom trunks, which the call indicator is not, and it can be used to reach offices too distant for satisfactory panel call-indicator pulses.

The call-announcer machine uses a film record of the voice which is reproduced by passing a beam of light through the moving film on to a photoelectric cell. This translates the light variations into variations in the current through the cell. These current variations are then amplified to a sufficient volume to be readily heard when transmitted over the inter-office trunk. Fourteen electrically independent drums are carried by the call-announcer machine. Each drum speaks only a single digit or letter, the fourteen drums constituting the ten numerical digits and the four party letters. To send out the desired number, the sender connects in the proper order to those drums which speak the digits of the line desired. One such call-announcer machine can serve all the senders in the office, any sender making connection to the drums as the sending of the called number requires.

In addition, these tandem senders are arranged to complete calls to step-by-step offices. On this type of call, the inter-office trunks terminate on step-by-step selectors in the called office. The tandem sender, with the assistance of the decoder, recognizes by the office code that the called office is of the step-by-step type and, after reaching the inter-office trunk in the usual way, it completes the selection of the called line by sending out the Strowger form of decimal pulses to set the step-by-step selectors.

CHAPTER V

ROTARY AUTOMATIC TELEPHONE SYSTEM[1]

History and General Characteristics.—The early development of the step-by-step system was little influenced by the then existing wire networks of manual practice. Automatic systems were almost invariably installed either independently of any existing manual networks or else with an idea of altering an existing wire plant to fit the needs of the automatic equipment. Later on when the time came to consider in a really large way the gradual and general conversion of the well-established and well-organized manual networks of the Bell System, the step-by-step system was thought to be lacking in two ways essential to large multi-office systems: first, ability to handle economically large groups of trunks and, second, flexibility in trunking. We have seen in Chap. III that the makers of the step-by-step system later responded to the small-trunk-group criticism by the use of non-numerical switches at the outgoing ends of trunk groups, and to the lack-of-flexibility criticism by the use of the "director."

It was in an effort to meet these two essential requirements that the Western Electric Company in the late nineties, while engaged upon the work that led to the development of the panel and the rotary systems, came to adopt for both their two outstanding characteristics, namely, *power drive* and *the sender* or *register*. As in the case of the panel system, it is around these two features that the present rotary system is built and it is from them that it derives its essential operating characteristics. The panel and rotary systems differ fundamentally, principally as regards their types of selectors. The selector used in the panel system, as we have seen, employs a straight-line movement of the selecting member over a flat *panel* of bank terminals. The selector of the rotary system employs a *rotary* movement of the selecting member over cylindrically arranged bank terminals. It is from this characteristic that the rotary system derives its name.

Eventually the Bell System retained the panel system with its larger-capacity switch and its more difficult manufacturing

[1] The photographs and other material used in preparing the illustrations of this chapter were furnished by courtesy of the International Telephone and Telegraph Corporation.

problem for use in America, while the rotary system with its smaller-capacity switch and its easier manufacturing problem was transferred to Europe, later to become the standard system of the International Telephone and Telegraph Corporation. Manufacture of the rotary system in Europe was begun in 1911 but was stopped at the outbreak of the World War when the German troops took over the Bell Telephone Manufacturing Company's[1] property in Antwerp. Conditions permitting manufacture were not restored until 1920 and it is since that date that this system has made its great advance in use in foreign countries. In 1930 there were in use or in course of installation over a million lines of rotary equipment. So far as known, it is not used at all in the United States or Canada, but some of the notable foreign cities served by it are Paris, Copenhagen, Hague, Geneva, Zurich, Bale, Antwerp, Brussels, Ghent, Marseilles, Budapest, Bucharest, Madrid, Barcelona, Seville, Rio de Janeiro, Wellington, New Zealand, Oslo, Bergen, Mexico City, and Lima, Peru.

In working out the design of the rotary system, the growing cost of switches as switch capacities increased was balanced against the lowering costs of trunks as the sizes of trunk groups increased, with the result that a 300-line switch was adopted with 10 levels of 30 sets of contacts each. This gave each trunk group level 30 sets of trunk-line contacts in the selector switches, with the possibility of extending the trunk-hunting limit to 60 by using two levels as is done in some cases in Paris. As we have seen, the corresponding level or trunk-hunting capacity of the usual step-by-step switch is 10 and of the panel switch 90.

A distinctive feature of the rotary system is "continuous hunting." By continuous hunting is meant a selector switch capable of hunting or testing indefinitely until an idle trunk is found. It is usual to adjust the speed to permit the selector to hunt over a group of 30 trunks in 1 second or a group of 60 trunks in 3 seconds, thereafter retesting all trunks in one level at intervals of 2 seconds. Lost calls due to all trunks being busy are thus converted into delayed calls and the actual or real efficiency of the trunking system increased.

By virtue of the "register," which corresponds in a very general way to the "sender" of the panel system or the "director" (when used) of the Strowger system, the subscribers' line plant

[1] Now a subsidiary of the International Telephone and Telegraph Corporation.

becomes separated from the trunk or switching plant during switching. The register on the one side receives the called number from the calling subscriber without regard to its destination or numerical composition, while on the other side it forwards the call to its destination free from all numerical limitations or limiting conditions of the calling line and its associated equipment. The engineer is, therefore, enabled to design his trunk plant and to route the traffic in the most economical manner. Calls may be sent direct or tandemed through any number of offices, all without reference to the directory numbering system.

A register does not imply any particular construction in the rotary system. A simple register consists entirely of a train of relays. A more elaborate register includes also quick-moving automatic apparatus. The translation may be fixed or cross-connecting facilities may be provided to vary the trunking plan.

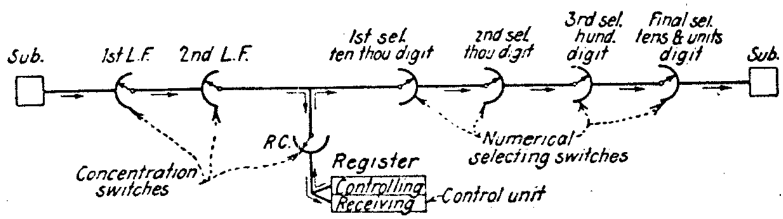


FIG. 134.—Call diagram of a 100,000-line system.

In large networks, such as Paris and Copenhagen, automatic translator switches are used by means of which complete flexibility as regards trunking, numbering, and office prefixes are obtained. It is possible here to describe in a general way only a typical register.

Outline of System.—Aside from the use of the register unit as a control point, the concentration and selecting switches assume a straightforward layout and operate progressively until all functions are completed. The register unit is superimposed on the train of apparatus at a point after the concentration switches and before the first numerical selection switch.

In Fig. 134, a call diagram is shown with the switches in their proper positions for a 100,000-line system. Following the direction of arrows, it will be seen that the subscriber's line terminates on a first line finder. When a call is originated, the first line finder moves to find the calling subscriber and extend the circuit through to the second line finder. At this point, a second line finder functions to extend the circuit through to the register chooser. A register circuit is then attached to the subscriber's line and the sending of the dial impulses may start.

The purpose of the first and second line finders is to act as concentration switches as in other systems and condense the traffic so the actual selecting equipment can be kept to a minimum. A similar purpose is performed by the register chooser in that it further concentrates the traffic into the registers. This additional switch is desirable as the registers are held only for the time required to set up the call and are relatively few in number compared to the number of circuits they serve.

While the number is being sent into the receiving side of the register, numerical selections directed from the controlling side are taking place over an independent path to set up the different numerical selectors. First, the first selector works in conjunction with the register and, when its operations are completed, the circuit is extended to the second selector and, in turn, the third and the final selectors until the entire connection is established. Selections in each switch are made as soon as the corresponding digit is transmitted from the subscriber to the register and in this way the connection is being built up almost simultaneously with the dialing. During a period of light traffic, the complete connection will be established practically as soon as dialing is completed. In the case of heavy traffic, this interval may be increased to the extent of a few seconds if considerable trunk-hunting time is required.

As the register is used only as a control unit, its use is terminated as soon as the final selector is positioned. When the last digit is received and the last numerical selection is made, the register is dismissed for use by other subscribers. Ordinarily, the total holding time for a register used for a 100,000-line system will be in the order of 15 seconds. This means that a small number of registers will be capable of serving a very large number of subscribers.

From a selection standpoint, a 100,000-line system corresponds to a five-digit scheme, since 100,000 combinations of numbers can be produced with five digits. With reference again to Fig. 134, the four selecting switches, classified as first, second, third, and final selectors, must collectively be able to build up a connection to any one of 100,000 numbers. As previously mentioned, the first and second line finders and register chooser play no

part in the actual selections, as they serve only for concentration purposes.

The proper ten-thousands digit is selected on the first selector, the thousands on the second, the hundreds on the third, and the tens and units on the final selector, each switch performing a single numerical selection with the exception of the final, which performs two. Trunk hunting is done automatically on all switches, the first, second, and third selectors to find idle trunks within the particular numerical group they selected and the final selector to find vacant trunks within a P.B.X. group when necessary.

Description of Mechanism.—In general, the use of power drive has permitted the design of very sturdy switches, the power transmitted through the individual switch clutches being ample to drive the switches over large groups of contacts at high speeds and under heavy contact pressures. Again, the central-office control plan places the time allowance for trunk hunting under control of each switch as it works with the register, rather than limiting it to the interval between the successive series of dial impulses.

Power Drive.—All switches are set in motion by temporary attachments to a rotating power-supply shaft, forming a part of a distribution arrangement which is kept in continuous rotation by an electric motor. In Fig. 135, a typical drive-shaft layout is shown. The power from a ⅛-horsepower motor is usually sufficient to drive an entire line-up of switch frames on what is the equivalent of 1,000 lines of equipment. Each bay or switch frame has a main vertical shaft arranged with a toothed gear appropriately placed opposite each switch. The driving mechanism of the switch itself is equipped with a flexible toothed gear which may be brought into temporary contact with the shaft driving gear by means of an electromagnetic clutch.

The mechanics involved in obtaining contact between the switch driving unit and the vertical drive shaft is shown in Fig. 136. The brush carriage of the switch, carrying brushes which rotate over and make contact with the terminals in the arc-shaped bank, is mounted on a short drive shaft 1, the complete assembly revolving in two self-aligning bearings 2, supported by the switch framework. Attached to the lower end of the shaft is a thin flexible toothed German silver disk gear 3, which is 0.015 inch thick and adapted to mesh with a corresponding driving gear 4. This is 0.020 inch thick and clamped in a rigid position between an upper plate 5 and lower plate 6, on the continuously rotating shaft 7. The principle employed for

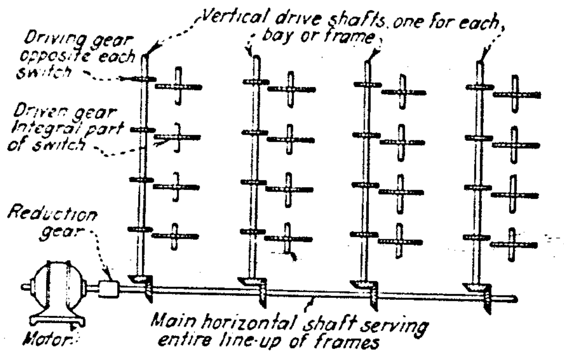


FIG. 135.—Power-drive layout.

controlling the drive is to utilize the flexible characteristics of the driven gear and deflect it out of mesh when a drive contact is not desired. In order to cause the driven gear 3 to enter in positive mesh with the driving gear 4, the former is so positioned on a horizontal plane in relation to the driving gear that it has a

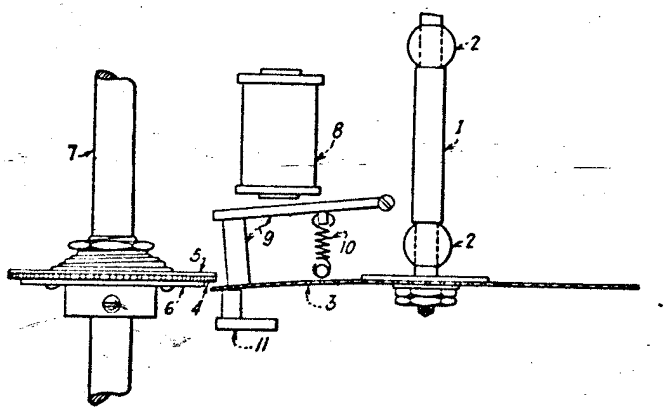


FIG. 136.—Gear-drive mechanism.

natural tendency to spring from its deflected point through the teeth of the driving gear to a normal position opposite the upper plate 5. By extending the upper plate to a point flush with the outer edge of the driving-gear teeth, it acts as a stop for the driven gear when it is released and causes it to come in mesh

with the driving gear under light tension. This is the position of the gears when the switch is rotating and they are held in true mesh under the tension thus created.

The positions of the driven gear, that is, its in-mesh position when it is released and its out-of-mesh position when it is deflected, are controlled by a simple clutch unit comprising a magnet coil 8, armature 9, helical spring 10, and back stop 11. An out-of-mesh position is normally maintained by having the released armature, through the tension created by the helical spring, press against the face of the flexible gear with sufficient force to hold it against the back stop. When the clutch magnet is energized, the armature is attracted opposing the tension of the helical spring, removing the pressure on the driven gear so that it immediately moves into mesh under its own tension.

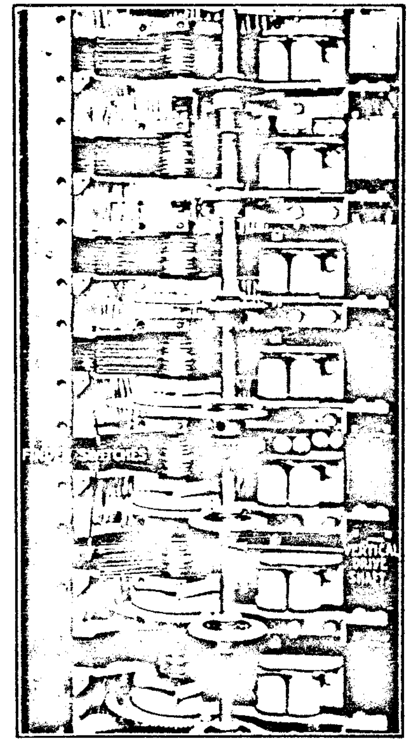


FIG. 137.—Bay of first line finders.

When it is desired to stop the rotation of the brush carriage, the circuit to the clutch magnet is opened, releasing the armature. This forces the drive gear out of mesh against the back stop and stops the brush carriage with its associated brushes on the desired terminal in the switch bank. As the pressure of the armature against the driven gear is approximately four pounds, the stopping action is practically instantaneous. An effective brake is established as soon as the armature strikes the gear and, when it is deflected to the back stop, the two fixed surfaces practically act as a lock.

In view of the perfect gear mesh and the positive stop arrangement offered by this type of drive, a normal hunting speed of forty-five terminals per second is used on the concentration switches and twenty-eight terminals per second on the selecting switches.

Finder Switch.—The finder switch is a general-purpose terminal-hunting unit, usually used as a concentration switch in various capacities throughout the rotary system. Its principal use is found in the regular central-office equipment as a first and second line finder and a register chooser. For the purposes of description, the switch as a first line finder (Fig. 137) will be described, since its use in this connection lends itself to easy explanation.

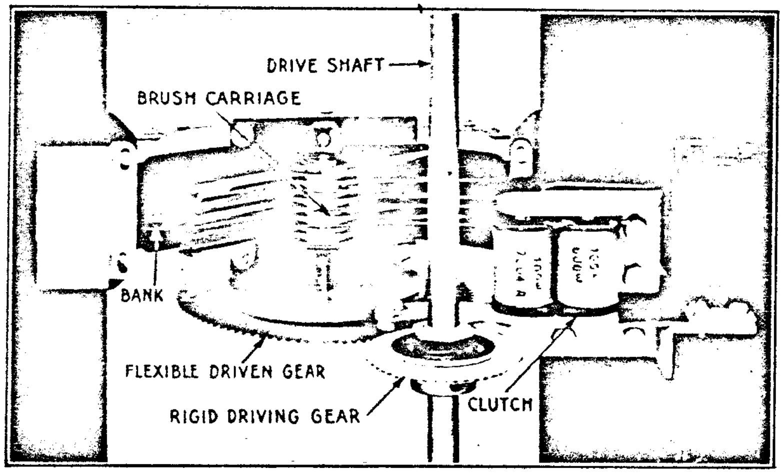


FIG. 138.—First line-finder switch.

As shown in Fig. 138, it comprises a semicircular arc or bank, a brush carriage with flexible gear (driven gear), a clutch, and a driving gear mounted on the continuously rotating shaft directly in front of the position of the finder on the frame. Various terminal and capacity arrangements of the arc and brush carriage are available to meet the different circuit requirements. From an operating standpoint, the functioning of the switch is exactly the same in all cases.

A detail of the bank of the first line finder is shown in Fig. 139. It has a capacity of 102 subscribers' line circuits of four wires each, 100 being used for regular service and 2 for test purposes. The terminals are mounted in eight horizontal rows of 51 terminals each in an arc of 180 degrees.

The circuit arrangement of the terminals in the bank, as shown in Fig. 140, and of the brushes on the brush carriage is such that one-half of the lines, for example, those on the odd horizontal rows 1-3-5-7 are wiped over by one set of brushes

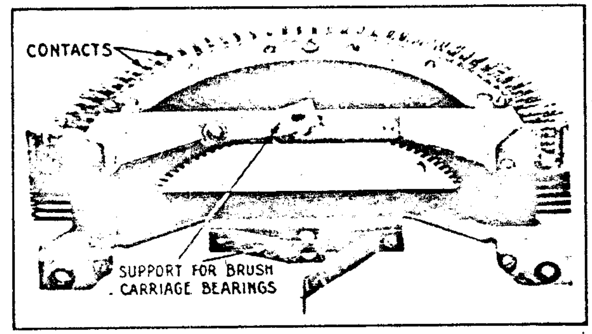


FIG. 139.—First line-finder bank.

during one-half of the revolution, while the other half of the lines, on the even horizontal rows 2-4-6-8 are wiped over by another set of brushes during the other half of the revolution.

This seemingly peculiar assignment of the four conductors of a particular line on either the odd or even horizontal rows

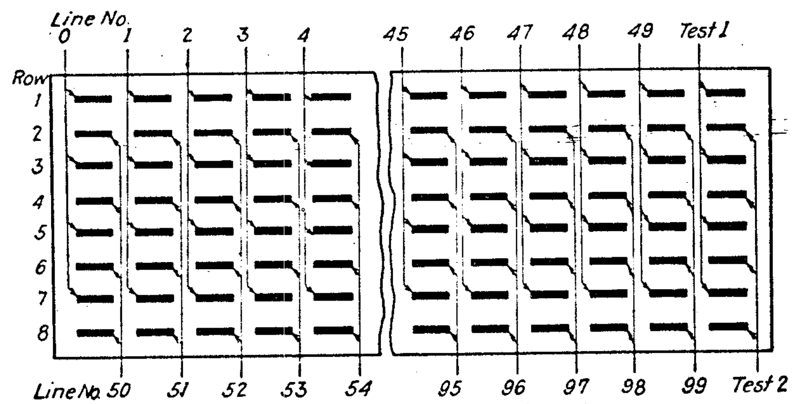


FIG. 140.—Circuit layout of line-finder terminals.

of terminals of a given vertical row, rather than in consecutive order taking in two odd and two even horizontal rows, is made to obtain greater contact separation and more brush clearance. With this arrangement, double-contact brushes can be used to enter in contact with the top and bottom of each terminal offering a very positive contact which otherwise could not be possible unless a wide vertical separation existed between terminals.

In other types of finder switches used in different capacities, either one or two circuits may be terminated in a single vertical row. Also, the number of horizontal rows may be varied to meet particular circuit requirements. Usually the two circuits per vertical row plan is used in cases where the number of circuits is high and the conductors per circuit are few, such as in the subscriber's line circuit. When the bank is on a one circuit per row basis, the brushes forming the brush assembly are

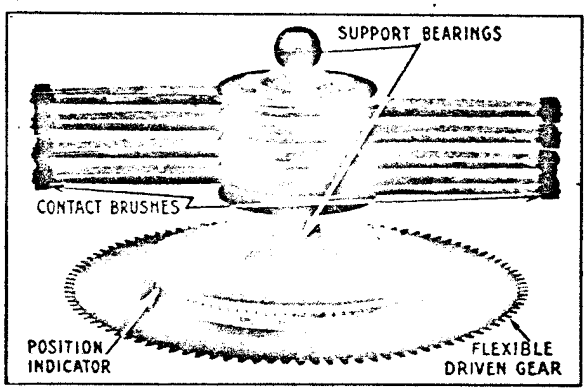


Fig. 141.—Brush carriage.

changed accordingly so that both brush members contact with the same horizontal row.

The brush carriage used on the first line finder is shown in Fig. 141. It will be noted that the two brush sets used for forming the contact with the terminals in the bank are 180 degrees apart and that the set protruding to the right of the figure as compared with those to the left are, brush for brush, assembled on a lower horizontal plane. This arrangement conforms with the terminal layout of the bank on a circuit basis and will permit the brush set to the left to contact with the odd horizontal rows, and the brush set to the right to contact with the even horizontal rows.

As only one set of brushes may be in contact with the bank terminals at one time, the two sets of brushes are connected together to a single set of feeder or lead-in brushes. Each

feeder brush consists of two metal springs which extend from the framework of the bank to the carriage shaft, where they ride in a groove and contact with the corresponding brushes of the two brush sets.

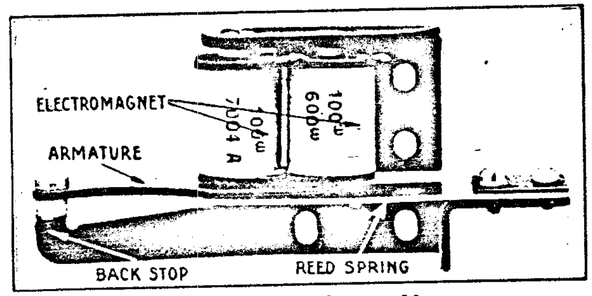


Fig. 142.—Clutch assembly.

In order to facilitate the tracing of calls through the switch, a terminal indicator is provided as a part of the brush carriage. The marking on this indicator corresponds to the numbering plan of the terminals in the switch bank. When the switch is at rest, the designation on the indicator wheel directly opposite

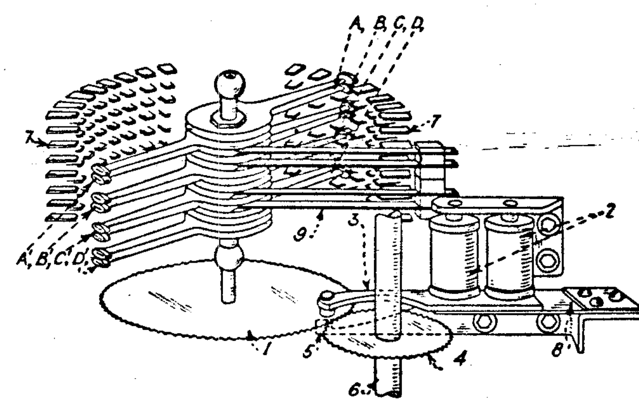


Fig. 143.—Operating diagram of finder switch.

a fixed pointer indicates the set of terminals on which the brushes are resting.

In Fig. 142 the clutch assembly is shown consisting of an electromagnet, an armature, and a back stop. In this case, it will be noted the clutch unit differs from the arrangement shown in Fig. 136, used to illustrate the gear-drive mechanism, in that a reed spring, included as an integral part of the armature, is used to deflect the driven gear rather than a helical spring. Use of the helical spring is made in the selector switches and will be explained later under the selector switch.

An operating diagram of the finder switch using the above-mentioned component parts is shown in Fig. 143. Here the brush carriage supports two sets of brushes, one (*A-B-C-D*) which contacts with the odd horizontal rows, and the other (*A′-B′-C′-D′*) which contacts with the even horizontal rows. On the lower end of the carriage shaft is mounted the flexible driven gear 1. The clutch electromagnet 2 of the finder switch mounted on the adjacent switch framework functions to control the driven gear by means of its armature 3. When in its normal or unoperated position, the armature deflects the driven gear downward out of mesh with the driving gear 4 where it rests on the fixed back stop 5. This represents either the idle position of the switch when it is not in use or the stopped position of the switch when it is in use and the desired terminal in the bank has been found.

When the clutch magnet 2 is energized, the armature 3 is moved to its operated position. The driven gear 1 thus released enters into mesh under its own tension with the driving gear 4 attached to the continuously rotating drive shaft 6. Rotating power is now transmitted through the driving and driven gears to the brush carriage which carries the brushes over the bank terminals 7. Under this condition, the brush carriage will rotate continuously and, owing to the brush sets' being 180 degrees apart and mounted on different horizontal planes, one set of brushes (*A-B-C-D*) will contact with the circuits terminated on the odd horizontal rows during one-half of the cycle and the other set of brushes (*A′-B′-C′-D′*) will contact with the circuits on the even horizontal rows during the other half of the cycle.

When the desired terminal is found, the circuit to the clutch magnet 2 is opened, the armature 3 is released, and the driven gear is deflected out of mesh with the driving gear. The finder is thus stopped on the desired terminal and is held so by means of the braking action of the reed spring 8 exerted through the armature to the face of the driven gear.

Continuous electrical contact is maintained between the brushes of the rotating brush carriage and the switch proper by

means of a set of four fixed feeder brushes 9 terminated at the extreme right-hand end of the bank.

As the finder switch in its use for concentration purposes plays no part in the numerical selections made in the progress of a call, there is no necessity for having the switch restore to a common starting point at the completion of each call. For this reason, the finder is of the non-restoring type and is designed to remain on the terminal last used until it is started again on the origination of a subsequent call. No advantage is

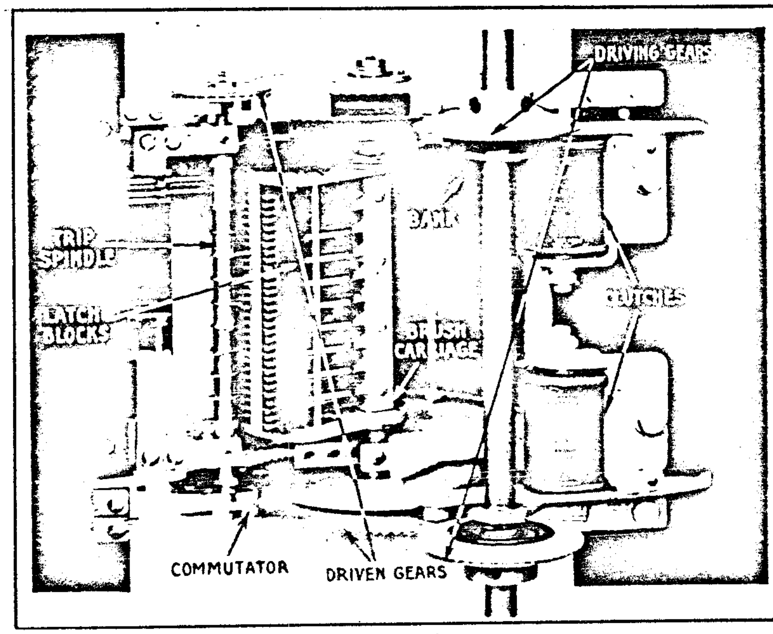


Fig. 144.—Selector.

lost from starting the finder from a random point in the bank, as it is just as likely that the terminal desired on a subsequent call will be as close to the terminal last used as it would be to a common starting point.

Selector.—There are two general types of selectors used in the rotary system: the group selector, which is used in the capacity of a first, second, and third selector, and the terminal selector, which is used as a final selector. The principal operating difference between the two types is that the group selector acts as a medium for selecting particular numerical trunk groups within its bank as determined by the setting of the control apparatus in the register, whereas the final selector goes a step farther under the control of the register to perform a definite terminal selection within the trunk group selected.

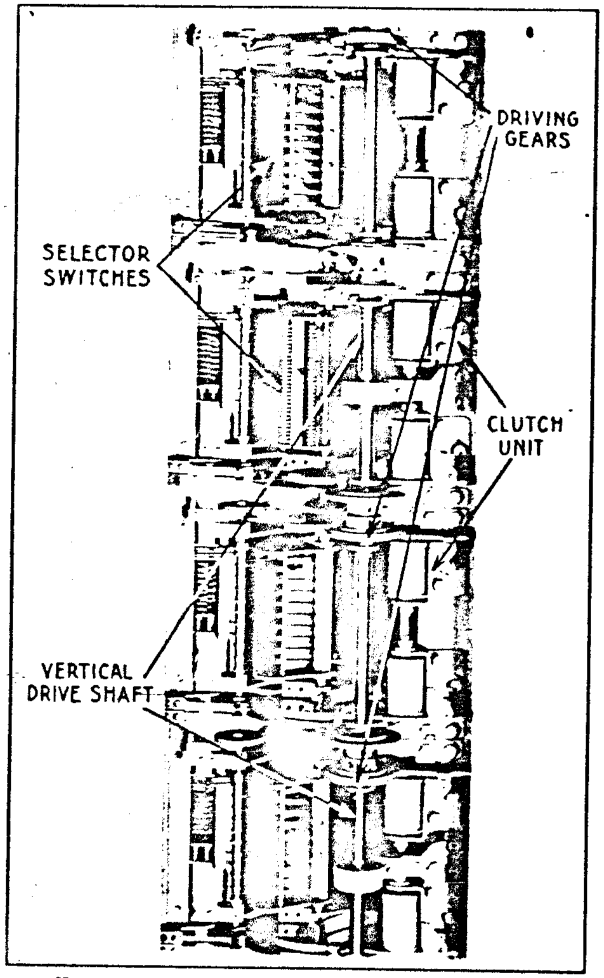


FIG. 145.—Selector-frame mounting arrangement.

After the proper trunk group has been selected, in the case of the group selector it proceeds, independent of the register, to perform an automatic trunk-hunting operation to select an idle trunk. In the progress of a call through the various

group selectors, this automatic action immediately follows each numerical selection, the time necessary in each case being allowed by the register.

In the final selector, the group selection is followed by a numerical selection also under control of the register until the desired terminal is found. When the desired terminal is a part of a P.B.X. group, a third operation similar to the automatic trunk hunting may be necessary to find an idle line. If this last step is necessary, it is performed independent of the register, the same as with the group selector.

A complete selector is shown in Fig. 144 and the frame mounting arrangement in Fig. 145. Structurally, the only difference between the group and final selectors is that the final selector is provided with an additional commutator placed at the bottom of the brush carriage and that a lower gear ratio is used for its drive. These changes are necessary to permit the register to control the terminal selection after the group selection has been made.

For the purpose of this description, the group selector will be described and, wherever a difference obtains over the working of the final selector, suitable explanation will be made. The group selector consists essentially of a semicircular bank, a brush carriage, a trip spindle and commutator, two clutches, and two sets of gears. In the final selector, a second commutator is also provided on the brush carriage.

The selector bank, as shown in Fig. 146, is made up of a series of 30 vertical terminal blocks of 30 terminals each, mounted in a metal frame. These blocks are arranged in groups of 10 in three sections or sectors which, as a complete unit, form an arc or bank of 180 degrees. From a circuit standpoint, the 30 terminal blocks permit of a bank capacity of 300 three-wire circuits arranged in 10 rows, or levels, of 30 trunks each. Through the use of this sectional form of construction, when fewer trunks are required, the unnecessary terminal blocks can be omitted.

The final selector bank, while of the same construction, is ordinarily equipped with only 20 terminal blocks representing the first and second sectors for a 200-line capacity, since numerically the capacity of each final selector must be such a fractional part of a thousand numbers that it can be evenly proportioned over the 10 levels of the preceding selector.

An exception to the above is where the P.B.X. traffic through the final selector is heavy and it is desired not to use too many numbered terminals for additional trunk circuits. In this case, the additional 10 terminal blocks or a smaller number as required can be added to the third sector of the bank and the selector be permitted to trunk-hunt beyond the regular numbered trunks assigned to a particular P.B.X. to the non-numbered trunks also assigned and located on the same level in the third sector.

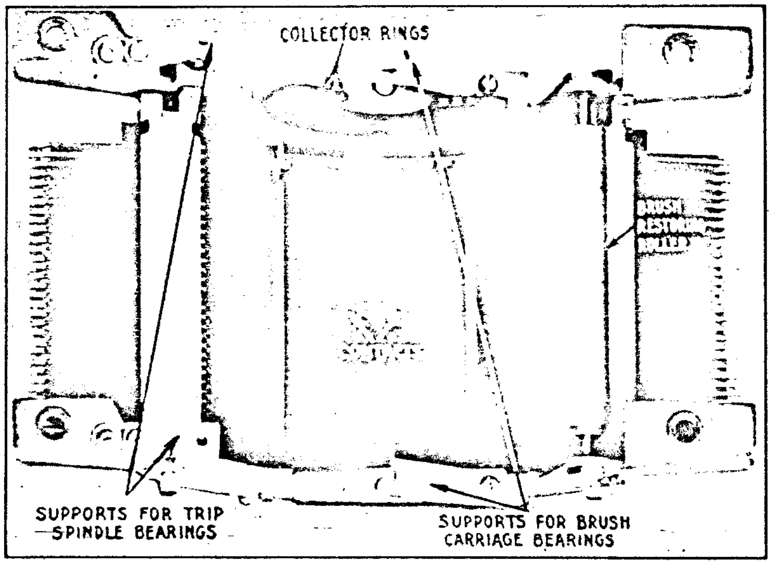


Fig. 146.—Selector bank.

The use of a 200-line final may not be clear at this time, since the operation of a system on a straight decimal basis direct from the dial would not permit the assignment of more than 100 lines on a level of the switch preceding the final selector. This is an outcome of the central-office "register" plan of control which permits the selections to be converted to a non-decimal basis when necessary and is utilized in this case to obtain increased trunk efficiency on the trunks leading into the finals and also in the number of final switches actually required, since the total number of switches required for one 200-line group will be less than the number of switches required for two 100-line groups.

As shown in Fig. 147, the brush carriage comprises a vertical pile-up of 30 brushes, two sets of gears, and a position indicator. The 30 brushes, from a circuit standpoint, are arranged in 10 groups of 3 brushes each, corresponding to the 10 levels of 3 conductors each in the bank. The function of each set of brushes corresponds to that of the tip, ring, and sleeve conductor of a manual switchboard plug. Associated with the brush sets are

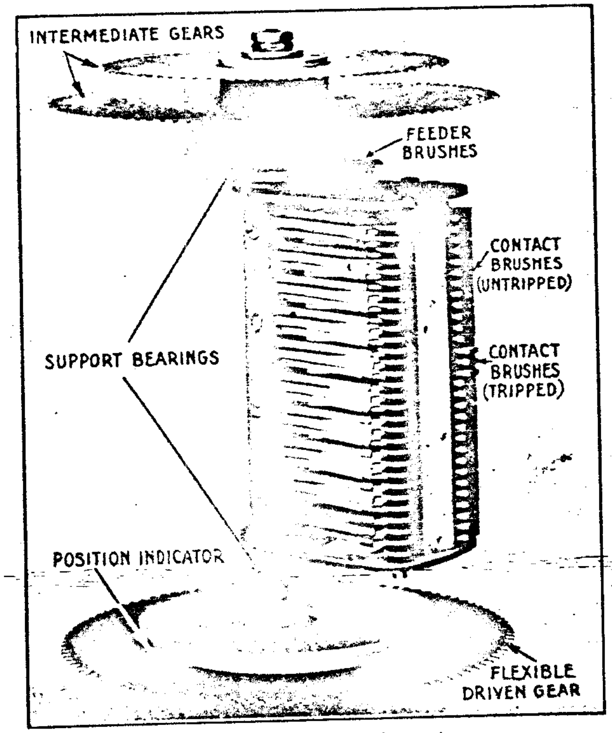


Fig. 147.—Selector brush carriage.

10 latch blocks which are mechanically set and tensioned to hold the brushes in an unlatched position where they are out of contact with the bank terminals. When the brush carriage starts to rotate, a tripping finger on the trip spindle forming a part of the switch trips the proper latch block, the tripping finger having been previously placed by the register in such a location that it will release only the latch block of the brush set which will provide contact with the desired level.

This operation releases a single set of brushes which now protrude beyond the nine other brush sets and enter into contact with the bank terminals. Continuous and reliable contact during the rotary movement of the brush carriage, as the different terminals in the selected level are passed, is maintained by a reed spring in the rear of each brush.

From the foregoing, it may be seen that only one set of brushes are in contact with the bank at one time, and in view of this fact the corresponding terminals of each brush set are multipled together and connected to three feeder brushes located at the top of the brush unit just below the upper set of gears. At this point, the feeder brushes press on and contact with fixed collector rings attached to the under side of the top of the switch frame. In this way continuous contact is made between the moving and fixed parts of the switch, regardless of the position of the brush carriage or the number of cycles of rotation made.

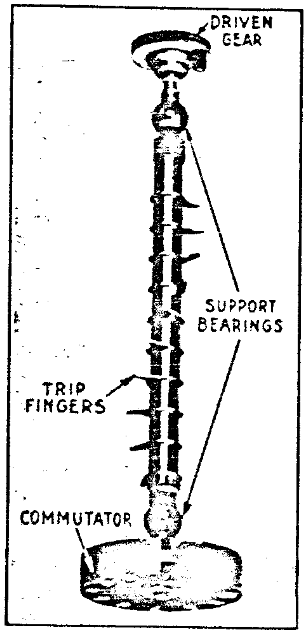


FIG. 148.—Selector trip spindle.

The driven gear and number indicator act in the same manner as the corresponding units on the line-finder switch. In the final selector, an additional commutator is also provided, and for simplicity of design the number indicator and commutator are constructed as a single unit.

On the upper end of the brush carriage immediately above the top bearing is a set of two reduction or intermediate gears, which serve the purpose of transmitting the rotary power from the main vertical drive shaft to the trip spindle. These two gears are clamped together as a unit and rotate independent of the brush carriage. The purpose of two gears rather than one is to permit the trip spindle to rotate at a lower rate of speed than the brush carriage.

The trip spindle, as shown in Fig. 148, consists of a driven gear, a spindle shaft arranged with ten tripping fingers, and a commutator. As it is the function of the trip spindle to assume

the proper rotary position so that it will trip the latch block controlling the brushes associated with the desired level, it is provided with ten tripping fingers each located on the same horizontal plane as its corresponding latch block. In order that only one latch block, and in turn one set of brushes, can be tripped at one time, the fingers are positioned spirally around the periphery of the trip spindle.

The relative positions of the trip spindle and the brush carriage on the main switch frame are such that only one trip finger at a time can protrude far enough to lie in the path of the latch blocks. Thus, by rotating the trip spindle, prior to the rotation of the brush carriage, to a position where the desired trip finger occupies the extreme left position, the proper latch block can be released, and all other trip fingers will be automatically out of reach of their corresponding latch blocks, owing to their staggered spiral position on the spindle.

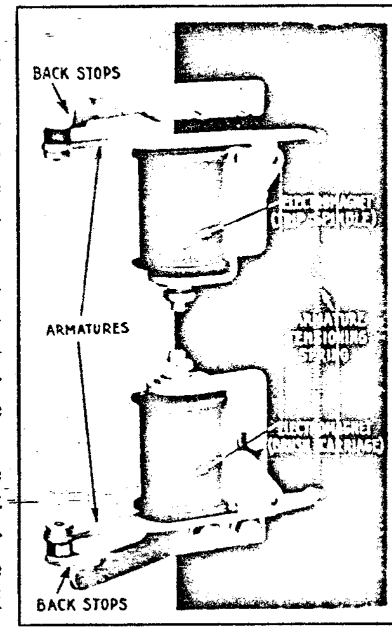


FIG. 149.—Selector clutch.

Located on the bottom of the trip-spindle shaft is a commutator which serves as a means for the register properly to place the trip-spindle for the desired group selection. This commutator consists of a series of ten metallic segments occupying corresponding positions around the periphery of the commutator face as the trip fingers on the trip spindle.

The clutch unit shown in Fig. 149 consists of an upper and lower unit for controlling respectively the reduction gear associated with the trip spindle and the lower gear forming a part of the brush carriage. Use of a helical spring is made on the selector clutch rather than a reed spring in each armature, as one spring connecting the two armatures will serve for both units and at the same time simplify adjustments.

On Fig. 150 an operating diagram of the group selector is shown with all the previously mentioned component parts in their respective positions. The brush-carriage shaft 1, supported from the switch frame on self-aligning bearings 2, is equipped with ten sets of three brushes *A-B-C* arranged in a vertical plane. The corresponding brushes of each brush set are multipled together and carried to a set of three feeder brushes *D-E-F*, located at the top of the brush carriage. Here the feeder brushes contact with three fixed collector rings *D'-E'-F'*, attached to the main switch frame, and provide a constant

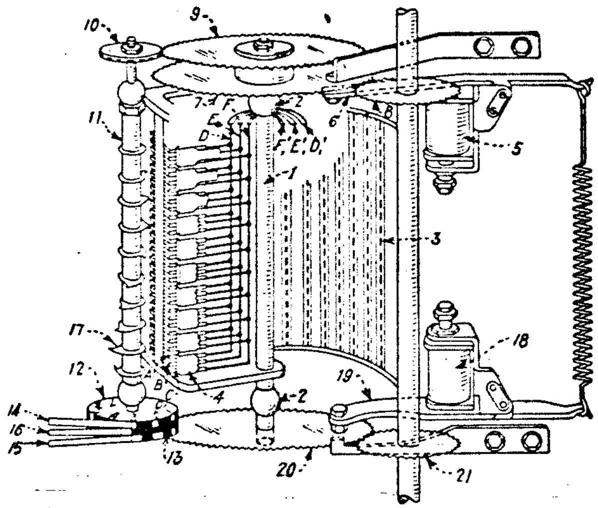


FIG. 150.—Operating diagram of group selector.

link between the moving and stationary parts of the switch. In front of the ten sets of brushes are located the corresponding ten blank levels 3, which terminate thirty three-wire circuits each.

Normally, all brushes are in a reset position with their contacting surfaces on a shorter radius than the contact surfaces of the bank contacts. Each set of three brushes is under control of a mechanically operated latch block. The complete brush-carriage unit assumes a normal start position just in front of the trip spindle, so that on its rotary motion it will first pass the trip spindle before entering the bank.

When a selector is selected for use in building up a connection, it is necessary that a brush group selection be made to place

the proper set of brushes in contact with the desired level. This selection is made by the trip spindle and is called the "trip-spindle selection." By rotating the spindle, each of the ten trip fingers is brought progressively to the unlatch position, and, if allowed to remain, the corresponding latch block is released as the brush carriage passes on the rotary movement.

A circuit closure from the register causes the upper clutch magnet 5 to operate its armature 6 and permit the lower gear 7 of the reduction gear unit, mounted on top of the brush-carriage shaft, to move from its deflected position and enter in mesh with the upper driving gear 8. Rotary power is then transmitted via the direct-connected upper intermediate gear 9 to the driven gear 10 mounted on the top of the trip spindle 11. During the rotary movement, a circular commutator 12 mounted on the bottom of the trip spindle 13, made up of a series of ten metallic segments, rotates past a set of fixed collector brushes 14-15-16.

The metallic segments correspond to the trip fingers 17 on the spindle and are so placed that, when each trip finger enters the unlatch position, the corresponding metal segment has just completed contact with the lower collector brush 15. With this arrangement, the register is capable of measuring the position of the trip spindle by electrically counting the number of segments passed by the collector brush.

The upper brush 14 also contacts on similar segments. These segments, however, are slightly retarded in relation to those for the lower brush and are used to place the selected trip finger exactly in the center of the unlatch position. The center brush 16 is for supply purposes and provides the electrical connection to the metal part of the commutator.

When the desired trip finger reaches the unlatch position, the circuit to the upper clutch magnet is opened by the register and the trip spindle comes to rest. A local circuit is now automatically closed, independent of the register, to the lower clutch magnet 18 operating its armature 19, which permits the lower driven gear 20 to enter into mesh with the lower driving gear 21.

The rotation of the brush carriage thus started is called "automatic trunk hunting." As the brush sets pass the trip spindle just before entering the bank, the desired latch block is released by the trip finger occupying the unlatch position. This released set of brushes will then protrude beyond all other brushes and contact with the selected level. After an idle trunk is found, the circuit to the lower clutch magnet is opened and the brush carriage is brought to rest.

In the first, second, and third selectors, the rotation of the trip spindle constitutes a numerical selection controlled by the register. This selection may be either the ten-thousands, thousands, or hundreds digit selection, depending upon which one of the three selectors are connected to the register. As soon as an idle trunk has been found after each selection, the control circuit from the register is extended to the next switch.

When the final selector is reached, a similar brush selection takes place to complete the tens selection. Actually, this tens selection represents a group of twenty lines as the capacity of final selector level is twenty lines. The next rotation to reach the desired subscriber's line is made by placing the brush carriage under control of the register.

The counting of the terminals is made on a commutator located on the brush carriage in a manner similar to that described for the trip spindle. One metal segment is provided for each of the twenty terminals in the bank. When the register has electrically counted the number of segments corresponding to the units digit of the desired line, the circuit to the lower clutch magnet is opened and the brush carriage is brought to rest.

As it has been previously explained, the register may count on a non-decimal basis. Therefore, if the desired units number is in the second group of ten lines on the final selector level, the register automatically discounts the first count of ten impulses from the commutator to start again in the second group of ten lines.

From the above, it will be seen that it is necessary for all selectors to return to their normal position at the completion of each call, in order that the trip spindle and brush carriage may be properly directed. It is also necessary that the set of brushes tripped for the preceding call be reset before a second set is tripped on a succeeding call.

For these reasons, the selector is made self-restoring and upon disconnection the circuits to the two clutch magnets are again closed to rotate the trip spindle and brush carriage through the uncompleted portion of their cycles to their starting points or home positions. After the brush carriage passes the last terminal in the bank, the released brushes strike against a brush-restoring bar or roller which is so positioned that it will mechanically reset

the tripped brushes and again place them under control of their associated latch block.

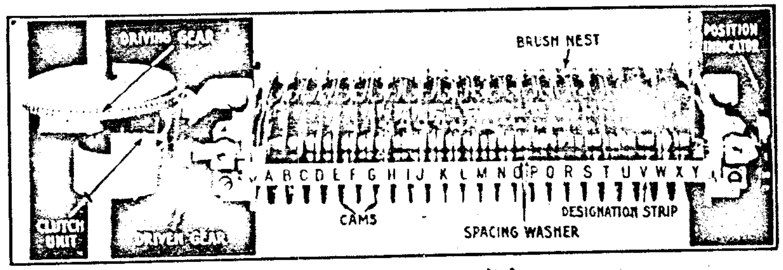


Fig. 151.—Sequence switch.

Sequence Switch.—In the rotary system as in the panel a special form of rotary switch termed the "sequence switch" is used for

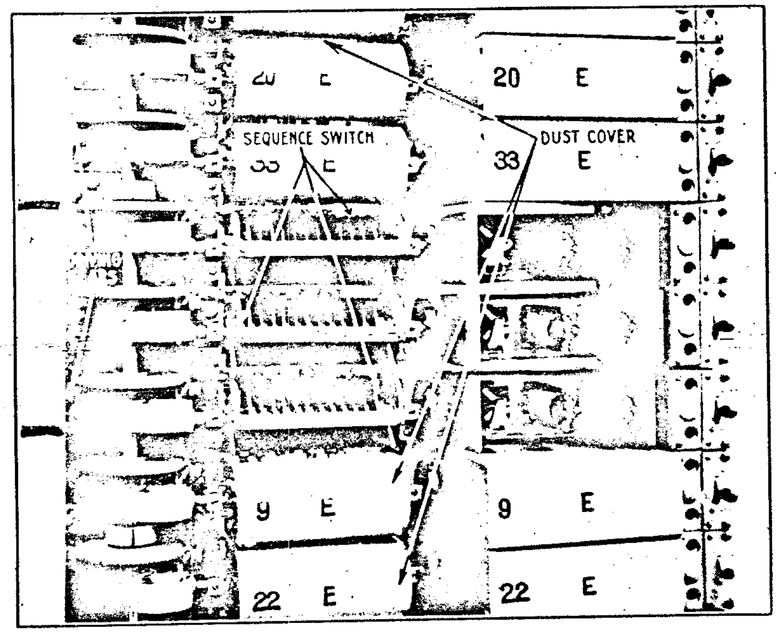


Fig. 152.—Bay of sequence switches.

the purpose of performing the functions of large groups of relays. Through the use of this switch, the number of relays required for a given circuit is materially reduced and at the same time a reliable and inexpensive substitute is obtained.

An analogous comparison of the sequence switch to regular relays may be made by calling it a large group of relays so arranged that their spring and contact relations could be switched through a very large number of combinations. The different arrangements possible are accomplished by rotating a group of from eight to twenty-four disks or cams through a series of eighteen positions, each cam within each of the positions being capable of producing a set of four connections in any possible combination.

Figure 151 shows a single sequence switch and the relation it occupies to the constantly rotating shaft from which it derives its motive power. A number of them mounted on an iron framework and constituting a sequence-switch bay is shown in Fig. 152.

The principal component parts of the sequence switch used in the rotary system, as shown in these figures, are a group of cams separated by brass rings or washers, a cam spindle, a brush

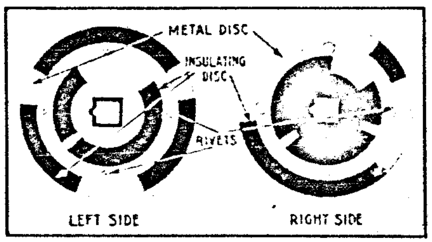


FIG. 153.—Typical sequence-switch cam.

nest for each two cams, a flexible driven gear, a clutch, a cam designation strip, and a dust cover to shield the cams and contact springs.

Each cam, as shown in Fig. 153, is composed of two metal disks and one insulating disk. The two metal disks, with the insulating disk between them, are clamped together with brass rivets which also serve to connect electrically the two outer metal surfaces. Resting against the flat sides of each cam are four contact springs, two on each face, which make contact on the same radial line.

A series of cuttings are made in the metal disks in such a manner as to present varying combinations of metal and insulation to the four contact springs. Thus, in one position some springs may rest on the metal and others on the exposed center insulating disk, whereas in another position different combinations will

obtain. In this way, by turning the shaft supporting the cams through the different positions, connection between the contact springs can be made and broken in various arrangements.

As a switch may accommodate as many as twenty-four cams, each of which has four contact springs, there may be as many as ninety-six wires connected to the switch, which, by turning the shaft, can be connected and disconnected in eighteen different arrangements corresponding to the eighteen switch positions.

Another feature of the sequence switch is that it may be used to provide circuit closures on a time basis. By applying the known

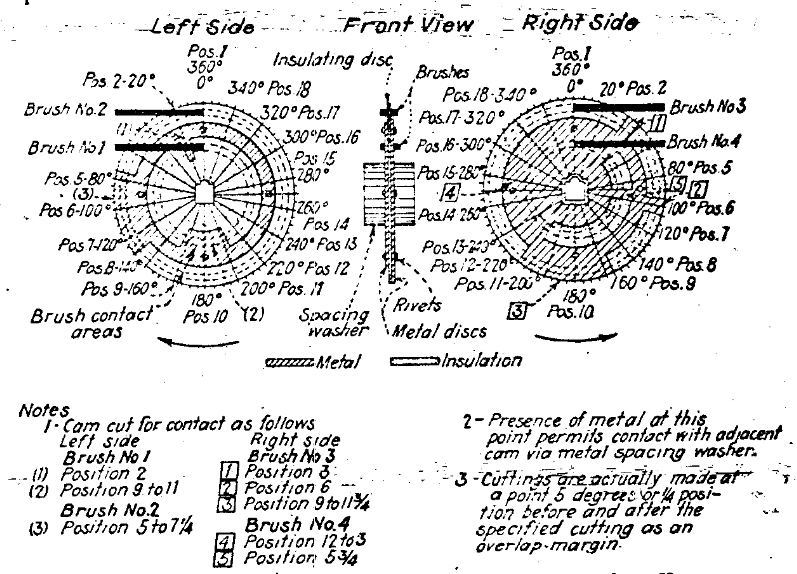


FIG. 154.—Sequence-switch cam diagram—cams *B* to *Y*.

rotary speed of the sequence switch to the time interval required, a size of cutting can be determined which will provide a contact between a set of two brushes for the desired period.

Cuttings in the metal disk can be made to permit a contact in a single position or a group of consecutive or non-consecutive positions. It is also possible to arrange for the interconnection between adjacent cams by extending the metal part of the cam toward the center, where it will contact with the metal spacing washer. Under this arrangement, the washer acts as a between-cam conductor as well as a spacer.

In Fig. 154, a diagram of a typical cam other than the control cam is shown. These cams are used to provide the various switching combinations and are designated alphabetically from *B* to *Y*. The control cam known as the *A* cam is used to control the rotary movement of the switch and will be described later.

Around each cam face may be assumed two circular paths on different radii, which represent the contact area for the fixed brushes as the switch is rotated. For the complete cam this represents four different areas and, in so far as the actual cuttings are concerned, each can be made independently of the other. The term "cutting," as it is used in the sense of sequence-switch cuttings, is that metal for a contact has been allowed to exist. Thus, the reverse meaning is actually implied, since it represents the presence of contact metal rather than the absence of it.

Since the cam face represents 360 degrees of surface, the angular difference between each of the eighteen positions is 20 degrees. When a contact is to be effected at a given position, the metal is left intact. The actual cut to terminate the metal for a specified regular or intermediate position is made 5 degrees, or one-fourth of a position, before and after the position line. This cutting plan provides for a contact area of 10 degrees for each position and is used to provide sufficient closed-contact duration, if the sequence switch is in rotation. Also, it offers a safety margin or overlap when it is desired to transfer holding circuits between cams having the same cutting.

By a regular position is meant one which corresponds to one of the eighteen positions of the switch, whereas an intermediate position corresponds to an intermediate point within any of the eighteen positions. Thus, for example, whole positions would be 1, 3, 9, and 11 and intermediate positions 1½, 9¾, and 12¼.

With reference again to Fig. 154, it will be noted that the cam shown is cut in the following manner:

Left Side—Brush 1

Position 2: Contact metal starts 5 degrees, or one-fourth position, before position 2 and stops 5 degrees, or one-fourth position, after position 2.

Positions 9 to 11: Contact metal starts one-fourth position before position 9, continues through position 10, and stops one-fourth position after position 11.

Left Side—Brush 2

Positions 5 to 7¼: Contact metal starts one-fourth before position 5, continues through position 6, and stops one-fourth position after position 7¼.

Right Side—Brush 3

Position 3: Contact metal starts one-fourth position before position 3 and stops one-fourth position after position 3.

Position 6: Contact metal starts one-fourth position before position 6 and stops one-fourth position after position 6.

Positions 9 to 11¾: Contact metal starts one-fourth position before position 9, continues through position 10, and stops one-fourth position after position 11¾.

Right Side—Brush 4

Positions 12 to 3: Contact metal starts one-fourth position before position 12, continues through positions 13 to 18 and 1 to 2, and stops one-fourth after position 3.

Position 5¾: Contact metal starts one-fourth position before position 5¾ and stops one-fourth position after position 5¾.

From the above it may be seen that in each case the contact metal has been extended over an arc from a point one-fourth position before to one-fourth position after the specified position or positions. Thus, the cuttings actually made for the cam should be as follows:

Specified Cutting	Actual Cutting
Brush 1:	
Position 2	Position 1¾ to 2¼
Positions 9 to 11	Position 8¾ to 11¼
Brush 2:	
Positions 5 to 7¼	Position 4¾ to 7½
Brush 3:	
Position 3	Position 2¾ to 3¼
Position 6	Position 5¾ to 6¼
Positions 9 to 11¾	Position 8¾ to 12
Brush 4:	
Positions 12 to 3	Position 11¾ to 3¼
Position 5¾	Position 5½ to 6

In practice, the positions or cuttings in which contact can be made are designated by the numbers corresponding to the positions involved. A single-position contact would be designated by a single numeral corresponding to the position involved, as 2, while a cutting involving a group of two or more positions would be indicated by the number of the position where the contact starts and where it stops, the numbers being separated by an oblique stroke, as 9/11. Where two or more separate cuttings are made on the same brush, the numerals corresponding to the respective cuttings are used, and the fact that they are non-consecutive is indicated by a period, as 2.9/11.

These numerals represent the cutting information as it will be found on all circuit drawings. Since the one-fourth position of metal is always allowed before and after each specified cutting this point becomes a rule and may be assumed in all cases.

All cams are mounted in alphabetical order on a cam spindle with metal separating washers between to provide spacing for the contact brushes. The cam spindle together with all cams rotate as a unit through the eighteen positions of the cycle. Rotating as an integral part is an indicator wheel with eighteen numerals around its periphery, corresponding to the positions of the switch. When the switch is stopped, a fixed pointer mounted on the switch frame indicates what position is being used at that time.

Normally, the sequence switch remains in position one, as an idle or home position. When the circuit associated with the switch is selected, the rotary circuit is closed as required to advance the switch progressively to positions 2, 3, etc., until position 18 is reached. After the switch leaves position 18, it again enters position 1, where it will remain until started on a subsequent revolution.

The eighteen positions making up the complete revolution or cycle may be used as temporary stopping points where particular functions can be performed or as pass-by positions where preparatory circuits, such as for relay operations, may be made as the switch passes through the position without stopping. It is not necessary that all positions be used; in cases where no function or feature is to be performed, the position is termed a "spare" and the switch is arranged automatically to rotate to the next working position.

As an example of the possible uses of the different positions, the functions controlled by the sequence switch associated with the final selector are shown.

Position	Function
1	Normal
2	Trip spindle rotates
3	Spare
4	Await register control circuit
5	Brush carriage rotates
6	P.B.X. idle trunk hunting
7	Spare
8	Spare
9	Called line busy

Position	Function
10	Spare
11	Restore on premature disconnection
12	Immediate ringing
13	Immediate ringing
14	Ringing at intervals
15	Talking
16	Await called subscriber to release
17	Trip spindle restored to normal
18	Brush carriage restored to normal

From the above, it may be seen that all the principal functions performed by the final selector are controlled by the sequence switch. This permits a relatively small number of relays to be used, since the major job of contact control is performed by the cam contacts.

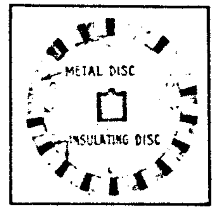


FIG. 155.—Control or *A* cam.

Control of the switch in its rotary movement is made through the *A*, or control, cam. This cam, as shown in Fig. 155, differs from the regular cams from both a design and a functional standpoint. It is constructed with only one useful face or contacting surface and is used in conjunction with a set of two brushes to control the stopping and centering of the switch in the specified stop positions.

The lower brush, held in continuous contact with the cam face, is directly connected to the sequence-switch clutch magnet. Attached to the upper brush is a local operating circuit for the clutch, which will cause the rotation of the switch on the occasion of an electrical contact between the two brushes.

Thus, assuming that switch rotation is first started from an external circuit, as soon as the upper brush contacts on the metal of the cam face, the switch will rotate until an open circuit exists for the upper brush. These open points correspond with the stop-position numbers and will permit the switch to stop in only those positions. They also serve to center the switch within the stop position, since the metal is removed only for a period corresponding to 2½ degrees before to 3 degrees after the stop position. These figures, it will be recalled, are less than the 5-degree overlap provided for each cutting on the regular cams, so sufficient metal should always be available for a contact.

A point always to be borne in mind in connection with the *A* cam is that it controls only the stopping of the switch. The start must in all cases come from an external source somewhere in the associated circuit. This is because the sequence switch is stopped in a position for the purpose of completing a particular function, and, until that function is completed, the switch should not move.

A diagram of a typical *A* cam is shown in Fig. 156.

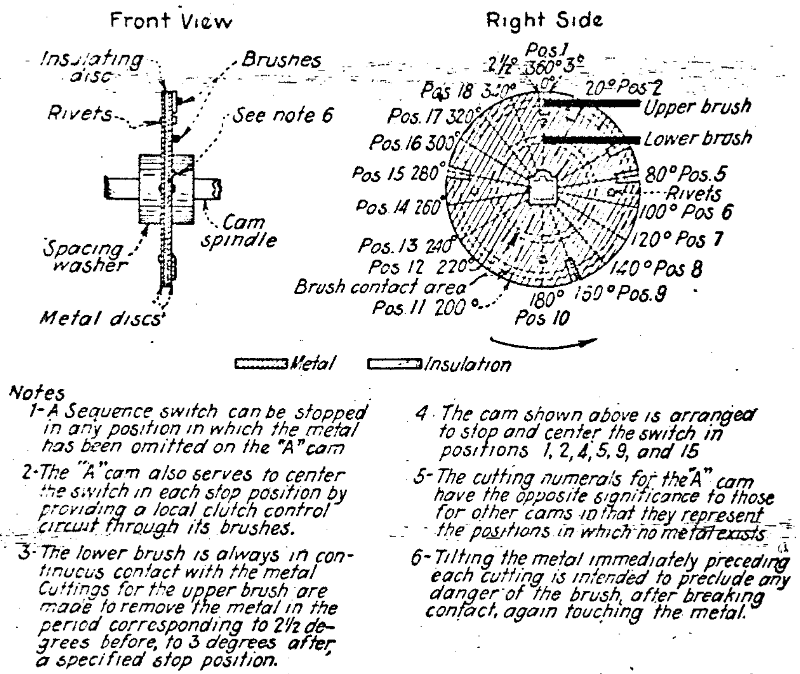


FIG. 156.—Sequence-switch cam diagram—control or *A* cam.

With the cutting arrangement shown, the switch will be stopped and centered in positions 1, 2, 4, 5, 9, and 15 progressively to perform various functions and will pass by all other positions automatically. While the switch is in a stop position, the upper brush rests on insulation, since a closure between these two brushes will cause the switch to rotate. When it is desired to move the switch, out of either the normal position or any subsequent stop position, a circuit closure for the clutch magnet must originate from a point in the associated circuit and pass through a cutting on one of the regular cams corresponding to

the then occupied position of the switch. After the switch starts to rotate, the external operating circuit is broken at the cutting on the regular cam as soon as a point 5 degrees, or one-fourth position, after the specified cutting is passed. The switch continues to rotate, however, since the upper brush of the *A* cam will set up a local operating circuit for the clutch 3 degrees after the stop position. When spare positions, or positions in which functions are to be performed but no stop made, are reached, the metal in the corresponding position of the *A* cam is not removed and the switch continues to rotate.

To number the *A* cam to agree with this cutting arrangement would be quite complicated and different from the system used on all the regular cams. In order to simplify this point, the *A* cam is numbered for all positions where no metal exists, and these numbers represent the positions in which the stops can be made. Under this arrangement, the numerals correspond to the insulated positions rather than the contact positions and have the opposite significance of the numerals on the regular cams.

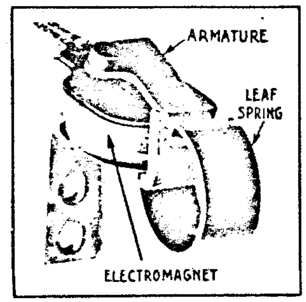


FIG. 157.—Sequence-switch clutch unit.

The clutch unit of the sequence switch, as shown in Fig. 157, is of a different design from that of the clutch used on the line finder and selector, owing to the structure of the sequence switch's being considerably different. From an operating standpoint, however, both units are identical and the flexible driven gear is brought in and out of mesh in the usual manner.

A leaf-type spring is used on the clutch to tension the armature and no back stop is included, as a part of the switch frame is used for this purpose. Also, the driven gear is at right angle to the driving gear. As all these points are structural rather than operating differences, it is felt no additional explanation is necessary.

In circuit drawings, a series of conventions similar to those shown in Fig. 158 are used for the different sequence-switch parts and features. Each cam is represented by a heavy horizontal line which terminates in a dot at one end to represent the position of the spindle or center of the cam. In reality, of course, the cam is vertical and its axis horizontal. However, for the sake of simplicity and clearness in circuit drawings, it is shown in this form with the spindle end to the left or right, depending upon which arrangement presents the most satisfactory drawing layout. The springs are represented by four shaded arrow heads just above and below the heavy line.

The two springs below the line indicate those contacting on the left-hand face of the cam and are usually referred to as brushes 1 and 2, or left-inner and left-outer. Those above the line indicate those contacting on the right-hand face of the cam and are usually referred to as brushes 3 and 4, or right-outer and right-inner. Regardless of the position of the spindle symbol on the drawing, its nearest arrows represent the inner springs, that is, the two actually nearest the spindle, and are brushes 1

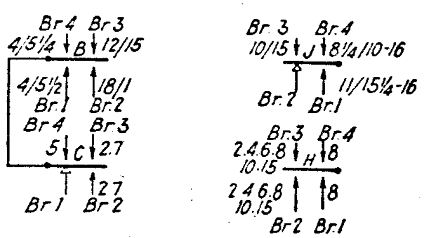


FIG. 158.—Sequence-switch conventions.

and 4, or left-inner and right-inner. The most distant arrows represent the outer springs and are brushes 2 and 3, or left-outer and right-outer.

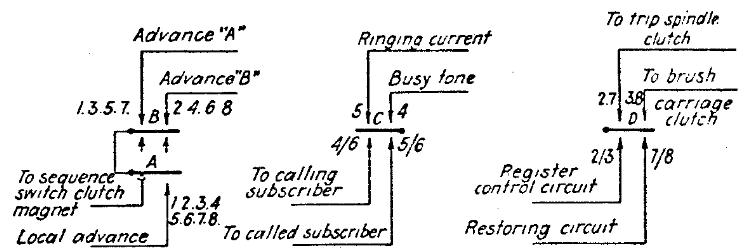
When the metal parts of two or more adjacent cams are connected together by means of the metal spacing washer, the connection is represented by a continuous line joining the two or more cam spindles.

The particular cam cuttings relating to the different brushes are indicated by placing the corresponding numerals opposite the arrows. Should a cam contact be made continuously throughout the entire eighteen positions of the switch, the cutting is indicated by an open triangle in actual contact with the horizontal line rather than the usual arrow symbol. No cutting numerals are given in this case, as the different symbol indicates the type of contact.

A simple illustration of the application of a sequence, which should give a clear idea of how it is used to control circuit functions, is shown in Fig. 159. Here the final selector is assumed

to have eight active or stop positions which are used to perform the functions listed at the bottom of the figure.

When not in use, the final selector is resting in the normal, or No. 1, position awaiting selection by a trunk-hunting third group selector. After being selected, a circuit is closed to advance lead "A" which advances the sequence switch to position 2 for trip-spindle rotation. This circuit can be traced over advance lead "A," brush 4 of cam *B* cut in position 1, electrical coupling to cam *A*, brush 1 of cam *A* cut in all positions to the lead going to the sequence-switch clutch magnet. The switch rotates and moves all cams simultaneously under control of this circuit until it is opened in position 1¼ (the



Position	Function	Position	Function
1	Normal	6	Talking
2	Rotate trip spindle	7	Restore trip spindle
3	Rotate brush carriage	8	Restore brush carriage
4	Busy back	9 to 18	Spare
5	Ringing		

FIG. 159.—Schematic illustrating sequence-switch control of principal final selector functions.

5-degree contact margin allowed for the cutting at brush 4 of cam *B*). The switch does not stop, however, as a local operating circuit for the clutch is established at 3 degrees after position 1 through brushes 1 and 2 of cam *A*. This local circuit serves to rotate the switch until brush 2 of cam *A* leaves the contact metal at a point 2½ degrees before position 2. From the foregoing, it can be seen that the starting of the switch is under external control and the centering in the next stop position is under control of brush 2 of cam *A*.

Trip-finger selection on the trip spindle is now performed by attaching the register control circuit to the trip-spindle clutch magnet through brushes 1 and 4 of cam *D* cut in position 2. When the proper trip finger is placed in line with the rotary path of the brush carriage, the trip-spindle clutch magnet circuit is opened by the register. The function completed, a circuit is closed to advance lead "B" which advances the switch to position 3 for brush-carriage rotation. Advance lead "B" serves to move the switch out of position 2 and hold the clutch magnet operated until brush 3 of cam *B* is opened at positions 2¼ and, as previously described, brush 2 of cam *A* advances the switch beyond this point until it is centered in position 3.

Terminal selection with the brush carriage is made by attaching the associated clutch magnet to the register control circuit through brushes 1 and 3 of cam *D* cut in position 3. A similar circuit to the trip-spindle clutch magnet no longer exists, as brush 4 of cam *D* is open in position 3. Reaching the desired terminal, the brush-carriage clutch magnet circuit is opened by the register, and the circuit to advance lead "A" closed to advance the switch to position 4 with the aid of brush 2 of cam *A*. If the terminal called is busy, a busy tone is returned to the calling subscriber through brushes 4 and 2 of cam *C* cut in position 4. If the terminal called is idle, a circuit is closed over advance "B" also, to provide a circuit to move the switch past position 4 without stopping. In position 5, the ringing current is then applied to the called subscriber's line through brushes 3 and 1 of cam *C*. A circuit is also established to return the ringing signal to the calling subscriber over brushes 3 and 2 of cam *C*. When the called subscriber answers, a circuit is closed over advance lead "A" to move the switch into position 6, which is the talking position. In this position, the two subscribers are connected together through brushes 2 and 1 of cam *C*.

When the conversation is completed and the subscribers hang up, advance lead "B" is closed to rotate the switch to position 7. Here the spindle is reset over brushes 2 and 4 of cam *D*. When the normal position of the spindle is reached, advance lead "A" is closed to advance the switch to position 8. In this position, the brush carriage is reset over a similar circuit traced through brushes 2 and 3 of cam *D*, after which lead "B" advances the switch out of position 8. No stop is made in positions 9 to 18, as the circuit through brush 2 of cam *A* is continuous during these positions. With the switch back in position 1, it is ready to receive a second call and repeat the same process.

From the above, it may be seen that the sequence switch provides an excellent means of switching various circuits in a comparatively simple manner. It is true, of course, that the arrangement shown is highly schematic and that a larger number of cams are required to control the different operations. However, for the basis of study it should provide a suitable illustration.

Circuits.—In order to facilitate a proper understanding of the operating features of the rotary system, a number of descriptions have been provided to cover the principal functions of the different circuits. In some cases, it may be noted that comparable operating features are performed in other systems but, since the methods and apparatus used are in most cases different, it is advisable that separate descriptions be made.

Register.—In the preceding text, the register has been referred to in a number of cases as a control unit which serves to receive the dial impulses from the subscriber and, in turn, with the information thus obtained, to direct the selecting switches until a connection has been built up to the desired line. Its operation in this capacity, together with its use to perform other functions, makes it practically a mechanical operator for the rotary system, taking the place of a human operator in a manual office.

In Fig. 160, a bay of register circuits is shown. It will be noted that each circuit consists of a relay unit and two sequence switches and that a total of five circuits, together with the associated routine test and supervisory panels, is mounted in a single bay.

A summary of the major operations performed by the register circuit may be made as follows:

1. Provide dial tone for the subscriber as an indication to start dialing.
2. Receive the dial impulses and store them until each selector is ready to function with the register.
3. Control the movement of the selectors on the basis of the selector advising the register when it is ready to function and thus save time when little or no trunk hunting is required and allow additional time when excessive trunk hunting is required.
4. Translate the subscriber's number and make the selections on a non-decimal basis.

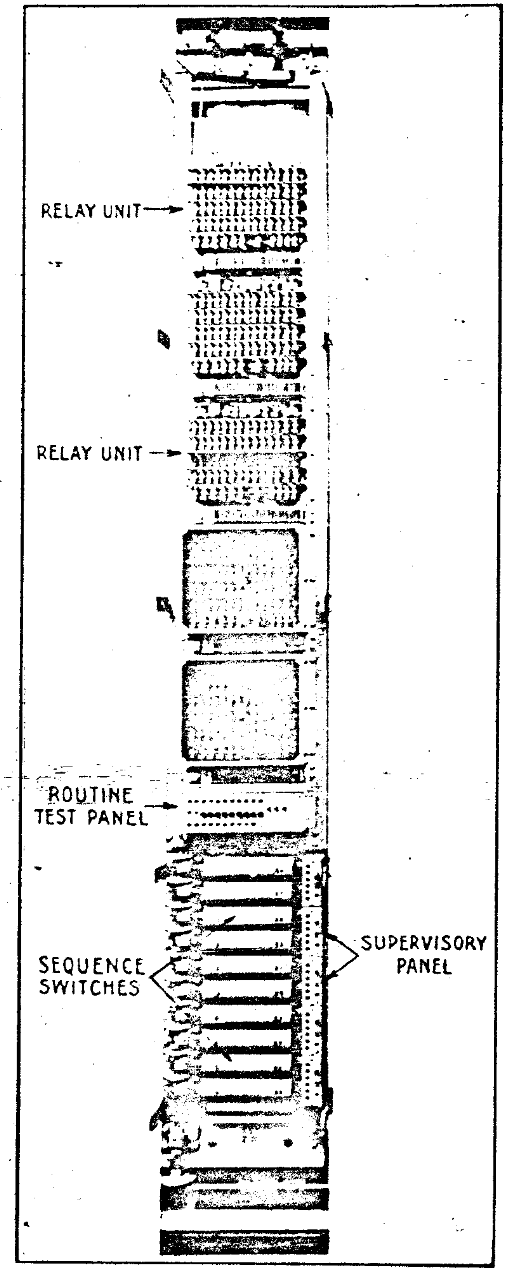


FIG. 160.—Bay of five register circuits.

5. Supervise the call until it is completely established and, in the event of trouble, free the subscriber and remove the defective equipment from service.

When a subscriber originates a call, a series of concentration switches function to route the call to a register. These operations precede any operation on the part of the subscriber other than the closure of the switch-hook contact indirectly brought about by lifting the receiver. In general, a time interval of about one-half second is usually required to reach the register.

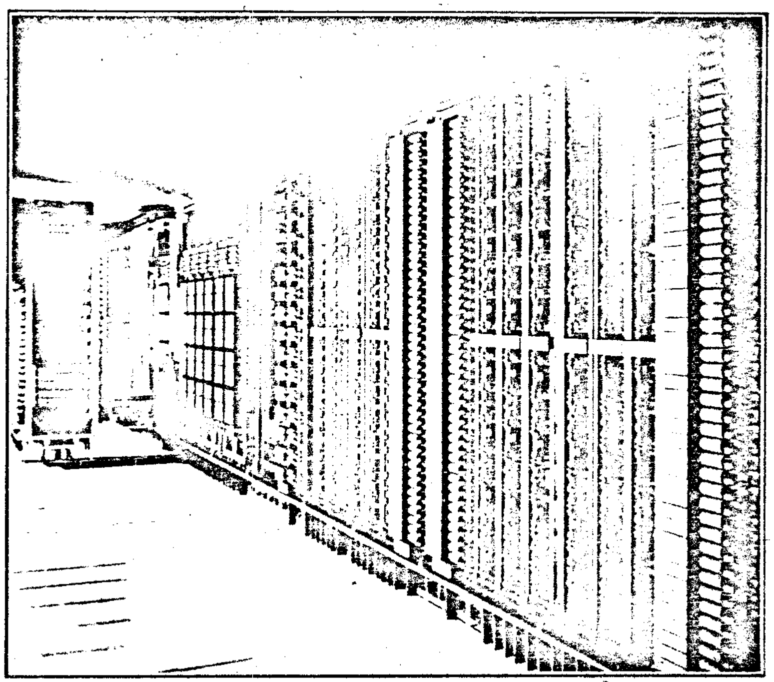


FIG. 161.—Row of selector bays.

Upon being selected, the register simultaneously sends out a dial tone as an indication for the subscriber to start dialing and prepares a recording circuit for receiving the impulses from the dial. The closed line loop, with the impulse contacts of the dial as the control point, is extended, free of attachments, to the register where it provides an operating circuit for an impulse recording relay. Under control of the contacts on this recording or "instepping relay," as it is termed, is a series of counting relays which respond to the impulses from the dial.

Digit Recording and Selector Control.—Actual recording of each digit is made on a series of six paired counting relays. The combinations necessary to provide for from one to ten pulses are obtained by using some of the relay pairs for the second time. This point can be illustrated in the following example: Impulses from one to four will operate counting relays from one to four, and five impulses will operate the fifth relay but release the preceding four relays. The sixth impulse will operate the sixth relay and any impulses after that will be received on the one to four relays again, which, in an operated position with the fifth and sixth counting relay, indicate that the number of impulses received is four plus the number of additional relays operated.

Usually in a five- or six-digit scheme only four series are used and provision is made in the register circuit to re-use the first or first and second series for the second time. Switching of the different series of counting relays, so that they will be progressively brought under control of the instepping relay, is accomplished by means of cam cuttings on the sequence switch so arranged that the rotation of the switch will bring in a different series of relays as it advances through its positions.

Each series of counting relays, in addition to serving as a recording unit for a digit, also serves to control the corresponding selection on the selector switch. This action is called the "revertive control" of the register and functions on the basis of the selector-switches sending impulses to the register similar to the impulses from the subscriber's dial.

These impulses are received from the commutators provided on the trip spindles of the various group selectors and on the trip spindle and brush carriage of the final selector. Since the register under this impulsing scheme must wait for the different selectors to send back impulses rather than send the impulses to each selector, sufficient functioning time, and no more, is guaranteed for each switch regardless of the trunk-hunting time required.

Just how many impulses will be received from each switch is determined by the numbering scheme for the office and network. Where no translations or digit corrections are made, the number of impulses received for a given digit will always be the difference between the number of impulses sent from the dial and a standard value of eleven impulses. Thus, if the figure 6 is dialed, six impulses will be received in the register and the selector performing the corresponding digit selection will send back five impulses to the register, the two values making a total of eleven impulses. These impulses from the different selectors are termed "complementary impulses," since they are always in complement to those from the dial to make up the desired total.

All impulses, from both the subscriber's dial and the selectors, are received alike on the counting relays. After the impulses for a given digit from the dial are received, the instepping relay is switched by a sequence-switch cam to the next series of counting relays for the next digit. At the same time, an impulse control relay for the selectors, called the "outstepping relay," established a circuit to the selector that is to make the corresponding selection. The contacts of this outstepping relay are now attached by means of a sequence-switch cam to the counting-relay circuit the instepping relay has just left.

Each impulse as sent back by the selector commutator will affect the outstepping relay and in turn be recorded on a counting relay. If, for example, the last impulse from the dial through the instepping relay operated the No. 4 counting relay, the first impulse from the selector through the outstepping relay will operate the No. 5 counting relay in the same counting-relay group. Further impulses will be accepted from the selector commutator in complement to the original four from the dial, until a total of eleven are received.

This value of eleven impulses is in a sense the capacity of each series of counting relays and, as soon as it is realized as a result of this two-way impulsing scheme, the last relay in the group operates and causes the selector to stop sending further impulses. This, in effect, brings about the stopping of the trip spindle, and the brush carriage in the case of the final selector, at the desired point in relation to the digit dialed by the subscriber.

It can be seen, under this impulsing plan, that the number of impulses from the selector for a given digit are at no time the equivalent of the number sent from the dial, since the total must always equal eleven which is an odd number. A very simple relation exists between the original and complementary impulses, however, since the selector sends a 1 for a 0 from the dial, a 2 for a 9, a 3 for an 8, etc. Thus, for matching the digits from the dial in the order of from 1 to 9 and 0, impulses from the selector are sent in the reverse order of from 0 to 9 to 1.

For the selector to rectify this non-decimal arrangement it is only necessary to number the levels in the reverse order, so that the trunk group corresponding to the digit 1 from the dial is on the tenth level rather than the first level, that for digit 2 on the ninth level, etc. In actual practice, this is further simplified by numbering the bank levels from top down so that the trunk groups numerically count in the usual manner from the bottom up.

In order to assist the understanding of this seemingly unusual impulsing and numbering scheme, and show that it is quite simple, the following table has been included. Here all digits are shown with number of complementary impulses received in each case and the numbering of the selector levels. For the purpose of the illustration, it is assumed that the hundreds digit on the final selector is the one in question.

Digit dialed	Impulses from selector	Level selected	Group selected
1	10	10	100
2	9	9	200
3	8	8	300
4	7	7	400
5	6	6	500
6	5	5	600
7	4	4	700
8	3	3	800
9	2	2	900
10	1	1	000

The reason this complementary impulse scheme is used in the rotary system is that it reduces considerably the amount of apparatus required in the register and thus offers, as a natural consequence, economy and less chance for circuit failures.

A circuit diagram of a set of counting relays, together with such associated control relays as are necessary to facilitate a better understanding, is shown in Fig. 162. For the purpose of this description, it will be assumed that the thousands digit is to be recorded and the information thus obtained is to control the setting of the trip spindle on the first selector.

It will be noted that seven pairs of relays make up the group and that the first four sets from the left each bear a designation of two numerals, the next two one numeral, and the last set letters. These designations are similar to those used in actual practice for the thousands digit and carry the following significance:

Each numeral indicates what numbered impulse received collectively off the contacts of the instepping and outstepping relay will cause its operation. In the case where two numerals are shown, the relay is used for two different impulses in a man-

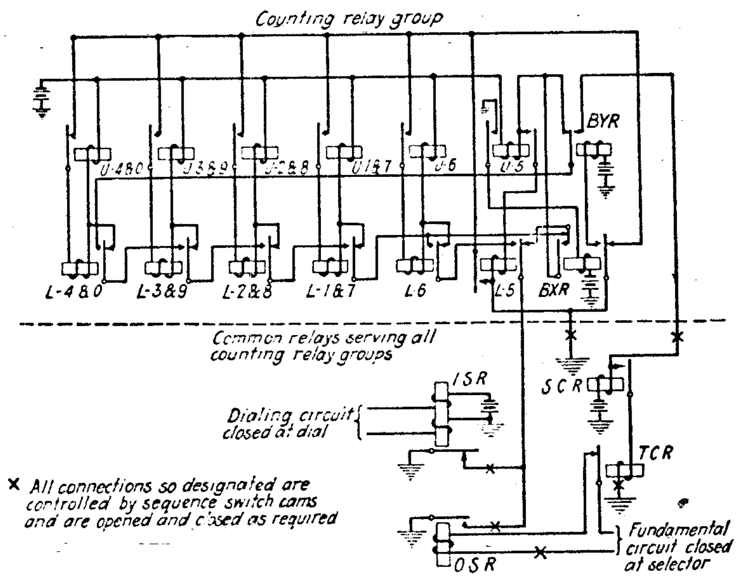


Fig. 162.—Schematic of a counting-relay group in the register.

ner that will be explained later. The lettered pair of relays provide for controlling the re-use of first four relays and for performing other switching functions. All other relays shown in the schematic are control relays and are common to all counting-relay groups. The eleventh impulse is always counted by the common control relay *SCR*.

When the register has functioned up to the point of sending dial tone to the subscriber, an operating circuit for the instepping *ISR* relay will be established out over the subscriber's line circuit to the impulse contacts of the dial. Each impulse from the dial will cause the release of the *ISR* relay and a ground circuit will be interrupted over its back contact a number of times, corresponding to the number of impulses from the dial.

Connected to the back contact of the *ISR* relay is a conductor leading to the counting relays. Control of this lead, so that it can be switched to the different counting-relay groups for recording the different digits, is accomplished by bringing the connection from the *ISR* relay first to a sequence-switch cam contact where it can be switched by means of cam cuttings to the different groups as required.

An example of the working of the counting relays can be given by assuming the subscriber will dial the digit 6. When the *ISR* relay releases on the first of the six impulses, a circuit is established from ground on the armature contact of the *ISR* relay through the contacts of the lower five (*L*-5) relay normal, the *BXR* relay normal, the *L*-1&7 relay normal to the winding of the *U*-1&7 relay to battery operating the *U*-1&7 relay. Immediately, a second circuit is established through another contact on the *BXR* relay normal, the *U*-1&7 relay operated, and the winding of the *L*-1&7 relay where it joins with the ground circuit from the *ISR* relay. The *L*-1&7 relay does not operate, however, since the ground from the *ISR* relay is in effect a short circuit on its winding. When the *ISR* re-operates at the end of the first impulse, the ground which serves to operate the *U*-1&7 relay is removed and likewise the short circuit on the winding of the *L*-1&7 relay is removed. This permits the *L*-1&7 relay to provide a holding circuit for the *U*-1&7 relay by use of the ground through its winding and thus the *L*-1&7 relay is operated.

If the circuit from the *ISR* relay is now traced, it will be seen that the operated contact of the *L*-1&7 relay has transferred the circuit formerly going to the winding of the *U*-1&7 relay to the contact the *L*-2&8 relay normal where it is now extended to the winding of the *U*-2&8 relay.

This short cycle of events starting with release and ending with operation of the *ISR* relay, bringing about the operation of first the *U*-1&7 relay and then the *L*-1&7 relay, represents the recording of one impulse from the dial. Each subsequent impulse forming a part of the digit being received will serve to repeat this cycle and operate a pair of counting relays in the register.

For the purpose of this description, it was assumed that the digit 6 was being dialed; since the recording of the first

impulse has already been described, the receipt of the five subsequent impulses will now be explained. When the *ISR* relay releases on the second impulse, ground on its back contact, through the *L*-5 and *BXR* relays normal and *L*-1&7 relay operated, causes the *U*-2&8 relay to operate. In the same manner as with the *U*-1&7 relay, a holding circuit is immediately established for the *U*-2&8 relay from ground through the contact of the *BXR* normal and *U*-2&8 relay operated and the winding of the *L*-2&8 relay. After the *ISR* relay operates

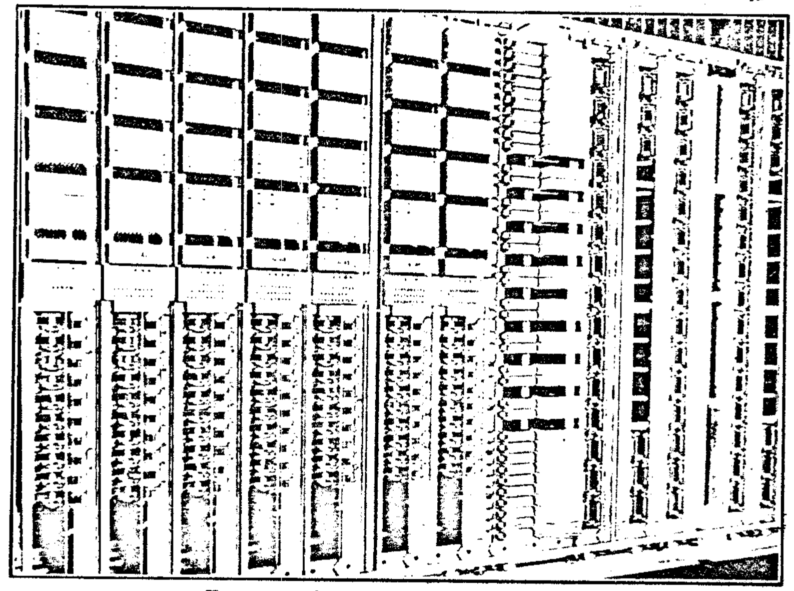


FIG. 163.—Row of first line-finder bays.

at the end of the second impulse, the short circuit on the *L*-2&8 relay is removed and it operates in series with the *U*-2&8 relay.

In operating, the *L*-2&8 relay further transfers the impulse circuit from the *ISR* relay through its operated contacts to the *L*-3&9 relay normal, where it is extended to the winding of the *U*-3&9 relay. Release of the *ISR* relay for the third impulse now causes the operation of the *U*-3&9 relay, which, in turn, establishes its holding circuit through its operated contacts and the winding of the *L*-3&9 relay. At the end of the third impulse, the *ISR* operates, allowing the *L*-3&9 relay to operate and extend the recording circuit to the *L*-4&0 relay, where it reaches the winding of the *U*-4&0 relay.

On the start of the fourth impulse, the *U*-4&0 relay is operated and at its completion the *L*-4&0 relay is operated in the same manner as with the previous counting relays, except that this time the impulse path from the *ISR* relay is extended through the *BXR* relay normal to the winding of the *U*-5 relay.

The fifth impulse passes through contacts of the *L*-1&7, *L*-2&8, *L*-3&9, *L*-4&0 relays operated and of the *BYR* relay normal and operates the *U*-5 relay in the usual manner. When it operates, however, additional changes occur. The *BXR* relay is now operated from ground on an operated contact on the *U*-5 relay and it serves to transfer the circuit from the *ISR* relay over its operated contact to the *U*-5 relay direct, and independent of all lower counting relays with the exception of the *L*-5 relay. When the *BXR* relay opens its normal contacts, it removes the ground supply for holding each of the 1&7, 2&8, 3&9, and 4&0 counting relays and these four pairs of relays are thus released.

An operated contact on the *BXR* relay also operates the *BYR* relay but this relay does not perform its function until the 1&7, 2&8, 3&9, and 4&0 relays are operated the second time. Since the operation of both the *BXR* and *BYR* relays is accomplished as soon as the operation of the *U*-5 relay is caused on the fifth impulse, it naturally occurs before the *ISR* relay again operates at the end of the impulse.

Therefore, in the usual way, as soon as the *U*-5 relay is operated, a holding circuit is established through its operated contact and the winding of the *L*-5 relay. This time, however, the ground is supplied direct to the *L*-5 relay, since the path supplying the other counting relays is now open, owing to the operation of the *BXR* relay. When the *ISR* reoperates at the end of the fifth impulse, the short circuit on the *L*-5 is removed and it operates in series with the *U*-5 relay.

The sixth impulse, representing the last for the digit 6 used in the illustration, causes the release of the *ISR* relay again and a ground circuit is closed through the operated *L*-5 relay and normal *L*-6 relay to operate the *U*-6 relay. The *L*-6 relay in turn operates at the end of the impulse in the usual manner.

Between each series of impulses the *ISR* relay is in its operated position and, since this time interval is considerably longer than that between the impulses of a given digit, the register uses this indication to advise it as to when to switch the *ISR* relay to the next counting-relay group. As soon as the sixth impulse referred to above was received, the *ISR* relay remained operated long enough for a slow-releasing relay to release, which closed a circuit to the sequence-switch clutch and brought about the transfer to the next relay group.

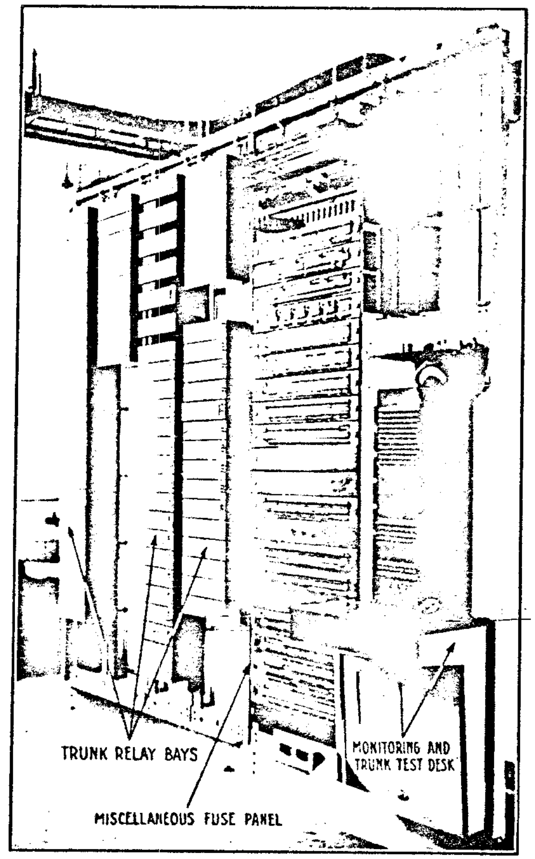


FIG. 164.—Row of miscellaneous bays.

In the new position of the sequence switch a circuit is closed from the outstepping *OSR* relay to the selector circuit which is to make the selection corresponding to the digit just received. This operating path is called the "control" or "fundamental" circuit and serves for the purpose of placing the trip spindle of the selector in the proper position.

It will be noted on the drawing that the operated contact of the *OSR* relay is now connected to the same lead the *ISR* relay formerly controlled. When the trip spindle starts to rotate, the metal segments on its commutator serve to short-circuit the *OSR* relay and bring about its release. In this way, a series of impulses are, in effect, returned to the register the same as those from the dial, the only difference being that the impulse circuit to the counting relays is interrupted over the operated contact of the *OSR* relay instead of the normal contact.

Since the No. 6 pair of counting relays was the last operated by the *ISR* relay, the operated contact of the *OSR* relay closes a ground circuit through the operated *L*-5 and *L*-6 relays and the now normal *L*-1&7 relay to operate the *U*-1&7 relay for the second time. This time, however, it is serving to count the seventh impulse rather than the first. As in the previous case, the operated *U*-1&7 relay establishes a holding circuit through the *L*-1&7 relay to be effective as soon as the *OSR* relay is released, the ground circuit formerly supplied through the normal *BXR* relay being substituted by ground through operated *L*-5 relay.

When the first metal segment on the commutator contacts with the collector brush, it produces an effect in the selector circuit which acts as a short circuit of the operating circuit for the *OSR* relay and for the duration of its contact causes the *OSR* relay to be released. When this occurs, the *L*-1&7 relay operates in series with the *U*-1&7 relay and the *OSR* relay circuit is extended to the winding of the *U*-2&8 relay. In this way, the 2&8, 3&9, and 4&0 relays are operated until the *L*-4&0 relay operates and closes the *OSR* circuit through the operated *BYX* relay to the winding of the *SCR* relay. On the next operation of the *OSR* relay, the *SCR* relay operates similarly to the regular counting relays and prepares a holding circuit for itself through the winding of the *TCR* relay.

When the next metal segment on the selector commutator contacts with the collector brush, the *OSR* is released and the *TCR* operates in series with the *SCR*. This time, however, the operating circuit for the *OSR* relay is permanently opened upon the operation of the *TCR* relay.

This function of the *TCR* relay serves to open the so-called "fundamental" circuit and the selector trip spindle is thus brought to rest. Another function of the *TCR* relay in its operated position is to close the sequence-switch advance circuit, so that the next numerical selection can be made as soon as the corresponding digit has been recorded.

In the above description it may be seen that for the six impulses sent in from the subscriber, operating the 1&7, 2&8, 3&9, 4&0, 5, and 6 counting relays, five impulses have been sent from the selector, operating the 1&7, 2&8, 3&9, 4&0, and *SCR* & *TCR* counting relays, making a total of eleven impulses. In accordance with the plan of level numbering previously described, the fifth level in the selector thus selected corresponds to the sixth numerical group.

Digit translations as made in the rotary system are accomplished through the use of two different methods: one is made directly on the contacts of the counting relays and can take care of all requirements of average-size networks and the other is made by use of a separate translator switch and is employed only for very large networks, such as Paris and Copenhagen, where complete office-code translations are desired.

Counting-relay Translations.—The most common scheme is the one employing cross-connections on the counting-relay contacts and it offers the following principal features.

1. Canceling of particular numbers of a given digit when necessary.
2. Pairing of numbers so that the capacity of levels can be doubled.
3. Discounting final selector impulses and thus permitting twenty lines on a level.

Digit Canceling.—Canceling of particular digits of a given number offers a ready method of obtaining the advantages offered by placing a mixed network of large and small offices on a common numbering basis without utilizing extra apparatus in the small offices to absorb unnecessary digits. An example of this usage can be shown by considering small offices of less than one thousand lines working in the same network as larger offices of up to ten thousand lines.

Any subscriber within a small office, when it is considered as a single unit, could be reached by another subscriber in the same office with a three-digit number. However, when a subscriber in a small office wishes to call a number in one of the larger offices, it is necessary to dial five digits, one to select the desired office and the remaining four to reach the desired terminal in the selected office.

To permit the assignment of five-digit numbers to the small-office subscribers, it is necessary to provide a means of canceling the first two digits on local calls. In the rotary register this feature is accomplished by cross-connecting the contacts of the counting relays in the small offices so that, when the relay combination representing the number of the digit to be canceled is operated, a circuit is automatically closed to advance the sequence switch past the position where the corresponding switch selection is normally made.

Digit Pairing.—In order to double the capacity of a selector level as, for example, making each level of a second selector in a five-digit scheme have a capacity of 2,000 lines rather than the usual 1,000 lines, a system of pairing of digits is used which permits the register first to consider two different numbers as a single number of a digit and, later, in the next selection, to make a distinction which will direct the succeeding selector to the proper point.

This feature offers a double advantage, since it permits the use of 20,000-line units in larger centers and at the same time increases the trunk-group efficiency in either a 10,000- or 20,000-line unit, owing to the use of larger trunk groups. In the case of a 10,000-line unit, only five levels in the second selector would be employed and the remaining five levels held as spare.

The actual operation of the register under this operating arrangement is as follows: each adjacent even and odd number is paired together as a single combined number, so that the ten impulses of a digit are treated as five digits in the following order, 0 and 1, 2 and 3, 4 and 5, etc.

In order to effect this pairing and later to readjust it in the next selection, it is necessary that the register perform two operations. First, it must contribute an extra impulse to the even number of each pair, so that the same operated counting-relay combination will exist as for the associated odd number which represents one impulse more. Second, it must take some record that this addition has been made, so that the succeeding selector will adjust for the added artificial impulse and make its selection accordingly.

When an even digit is dialed, an extra control relay, connected to the operated contacts of all even numbered counting relays, operates. As soon as the sequence switch leaves the recording position, a momentary impulse is passed to the counting relays through the operated contacts of this relay, which causes

the operation of an extra pair of relays. In this way, a digit 2 dialed by the subscriber now is recorded as the digit 3 and, when the fundamental circuit is closed to make the corresponding selection on the selector, the same level will be picked for the digit 2 as for the digit 3.

On the third selector the same double-capacity rule applies and each level offers trunk outlets to 200 lines rather than 100 lines. As it has been previously explained, the second selector has access to 2,000 lines on each level; these 2,000 lines represent the total capacity of the 10 levels in the bank of the third selector. The bank is so connected that the odd thousand trunks appear on the odd levels, that is, 200 lines on each of levels 1, 3, 5, 7, and 9; and the even thousand trunks appear on the even levels, that is, 200 lines on each of the levels 2, 4, 6, 8, and 0.

When the subscriber dials the hundreds digit, the register must first accept the impulses from the dial and then decide whether it is to be paired or not and, also, whether it is a part of an odd or even thousand number.

The register performs these operations by first adding an impulse, if the digit dialed is an even one, so it will be paired with the next higher following odd number by means of a special impulse control relay in the same manner as with the second selector. This operation will combine the dialed digit into one of five paired-number combinations. The next function of the register is to determine whether the number should go to an even numbered level or an odd numbered level. If the thousands digit dialed was odd, the call should be routed through one of the five odd levels, which from a selection standpoint are one level higher than the even levels.

An example of this can be made by considering that the zero and one hundred of the even two thousand group are on the tenth level and the zero and one hundred of the odd three thousand group are on the ninth level. In this case, if the zero or one hundreds digit is dialed, following the odd thousands digit 3, it would be necessary for the register to furnish an extra impulse, so that the selector would be required to send one impulse less and thus be stopped on the ninth level rather than the tenth level. This extra impulse for the hundreds digit is provided through the normal contact on the control relay, which was previously described as being operated only when an even thousands digit was dialed.

A better understanding may be had of this digit-pairing scheme and of the odd and even thousand discriminating feature by reviewing the following tables which show the functions performed by the register and selector depending upon which digit is dialed. It will be noted in all cases that the total of the impulses recorded in the register combined with the number received from the selector will always equal eleven.

THOUSANDS DIGIT DIALING

Digit dialed	Extra impulse relay operated on even digit	Total impulses recorded	Impulses from selector, also level number	Numerical group
0*	Yes	1	10	0000 and 1000
1	No	1	10	0000 and 1000
2	Yes	3	8	2000 and 3000
3	No	3	8	2000 and 3000
4	Yes	5	6	4000 and 5000
5	No	5	6	4000 and 5000
6	Yes	7	4	6000 and 7000
7	No	7	4	6000 and 7000
8	Yes	9	2	8000 and 9000
9	No	9	2	8000 and 9000

HUNDREDS DIGIT DIALING FOLLOWING THE EVEN TWO THOUSAND DIGIT

Digit dialed	Extra impulse relay operated on even digit	Extra impulse for odd thousand, previous extra impulse relay normal	Total impulses recorded	Impulses from selector also level number	Numerical group
0*	Yes	No	1	10	2000 and 2100
1	No	No	1	10	2000 and 2100
2	Yes	No	3	8	2200 and 2300
3	No	No	3	8	2200 and 2300
4	Yes	No	5	6	2400 and 2500
5	No	No	5	6	2400 and 2500
6	Yes	No	7	4	2600 and 2700
7	No	No	7	4	2600 and 2700
8	Yes	No	9	2	2800 and 2900
9	No	No	9	2	2800 and 2900

* When the digit 0 is dialed, the ten impulses are recorded in the regular way; the operation of the control relay, however, on a digit 0 recording releases all operated relays and then operates one counting relay from its operated contacts in the usual way. This operating arrangement is employed in order that the digit 0 may be paired with the digit 1.

HUNDREDS DIGIT DIALING FOLLOWING THE ODD THREE THOUSAND DIGIT

Digit dialed	Extra impulse relay operated on even digit	Extra impulse for odd thousand, previous extra impulse relay normal	Total impulses recorded	Impulses from selector, also level number	Numerical group
0*	Yes	Yes	2	9	3000 and 3100
1	No	Yes	2	9	3000 and 3100
2	Yes	Yes	4	7	3200 and 3300
3	No	Yes	4	7	3200 and 3300
4	Yes	Yes	6	5	3400 and 3500
5	No	Yes	6	5	3400 and 3500
6	Yes	Yes	8	3	3600 and 3700
7	No	Yes	8	3	3600 and 3700
8	Yes	Yes	10	1	3800 and 3900
9	No	Yes	10	1	3800 and 3900

* When the digit 0 is dialed, the ten impulses are recorded in the regular way; the operation of the control relay, however, on a digit 0 recording releases all operated relays and then operates one counting relay from its operated contacts in the usual way. This operating arrangement is employed in order that the digit 0 may be paired with the digit 1.

From the above it may be seen that the register can easily combine two numbers in order to obtain the advantages of larger trunk groups and then later, in a succeeding selection, make the necessary discrimination that will send the call over the proper route.

Final Selector Counting.—In applying the double-capacity feature to the final selector, the assignment of twenty lines rather than ten lines on each level necessitates that additional counting-relay facilities be made available for counting over from one to twenty terminals.

The numerical layout of the bank terminals is somewhat different from that employed on the group selectors and, instead of an odd and even hundred's being placed on the odd and even levels respectively, an even hundred is placed in the first sector and an odd hundred in the second sector of the bank. Since each sector consists of ten levels of ten terminals each, a straightforward numbering scheme is used for both level and terminal numbering.

The third sector in the bank is not ordinarily used except in those cases where it is desired to provide additional P.B.X. trunks without using regular numbered lines. When this plan is in effect, the final selector, when in its trunk-hunting position, is permitted to hunt beyond the last terminal on a given level in the second sector to what additional non-numbered trunks may be provided in the third sector. In this way, as many as thirty trunks, twenty numbered and ten non-numbered, may be assigned to a single P.B.X.

A typical numbering diagram of a final selector bank with third sector equipped is shown in Fig. 165.

Since the corresponding ten numbers of the even and odd hundred are on the same level and the entire ten levels are used, no pairing is necessary for the tens digit, regardless of what hundreds digit it follows. The impulses of the tens digit

Level	Even Hundred (2) First Sector	Odd Hundred (3) Second Sector	Non-numbered Hundred Third Sector
1	00 09 08 ... 01	00 09 08 ... 01	00 09 08 ... 01
2	90 99 98 ... 91	90 99 98 ... 91	90 99 98 ... 91
3	80 89 88 ... 81	80 89 88 ... 81	80 89 88 ... 81
4	70 79 78 ... 71	70 79 78 ... 71	70 79 78 ... 71
5	60 69 68 ... 61	60 69 68 ... 61	60 69 68 ... 61
6	50 59 58 ... 51	50 59 58 ... 51	50 59 58 ... 51
7	40 49 48 ... 41	40 49 48 ... 41	40 49 48 ... 41
8	30 39 38 ... 31	30 39 38 ... 31	30 39 38 ... 31
9	20 29 28 ... 21	20 29 28 ... 21	20 29 28 ... 21
0	10 19 18 17 16 15 14 13 12 11	10 19 18 17 16 15 14 13 12 11	10 19 18 17 16 15 14 13 12 11

FIG. 165.—Numbering diagram of final selector bank.

are recorded and, without performing any further function, the register proceeds to accept impulses from the final selector trip spindle until the complement of eleven impulses are received.

For the units digit, however, the register must perform an additional function, since it is necessary, when an odd hundred group of lines is desired, to pass over the first ten lines on the level selected, which are associated with the even hundred lines, until the second group of ten lines is reached.

This pass-by feature is accomplished by having the register count ten impulses from the final brush-carriage commutator, representing the first ten terminals, as a preliminary step before the counting-relay group, on which the units digit of an odd hundred has been recorded, is connected to the outstepping relay.

To record and count out these extra impulses, one of the counting-relay groups which had previously been used in recording a preceding digit is placed in the outstepping circuit ahead of the units relay group.

The preliminary count is limited to ten impulses in this case rather than the usual eleven impulses since the *SCR* and *TCR* relays of the control circuit, which normally operate on the eleventh impulse after the 4&0 counting relay operates, are placed after the 4&0 counting relay of the units counting-relay group.

Control of the extra set of counting relays, so that they will be placed in the circuit when desired, is made by utilizing a contact on the extra impulse control relay of the hundreds digit, which operated on an even digit and functioned to supply an extra impulse for pairing purposes.

In this way, an odd hundred digit is indicated by this relay in its normal position and the extra counting-relay set for the units digit is automatically cut into the circuit by routing the impulse path from the outstepping relay through its normal contacts.

Translator-switch Translations.—When the separate translator switch is used in the very large networks, a complete revision of what are termed the "office-code digits" is possible. This scheme is used only where central-office lettered prefixes of two or three digits are dialed.

The impulse information, in the form of a number combination corresponding to the letters dialed, serves to position the translator switch on a particular terminal in its bank. A series of cross-connections between the different terminals in the bank and a separate set of outstepping counting relays permit of rearrangement of the number dialed into any desired combination by means of varying the tap-off point on the counting relays.

The methods and advantages of making translations in office codes have been described for the panel system in the preceding chapter. No additional information concerning this feature in the rotary system is necessary here as the two systems are about alike in this respect.

Call Supervision.—Supervision of a call while it is under control of the register is performed by means of an associated timing device, so arranged that if at the end of an interval of, say, 30 seconds the call is not established and the register dismissed, the register will function independently of the subscriber to take care of the abnormal condition.

The two principal faulty conditions which the register may supervise in this capacity are false calls, such as permanent signals when a line is in trouble, and blocked calls when the subscriber has completely dialed a number and the call is not being completed owing to an equipment or apparatus failure.

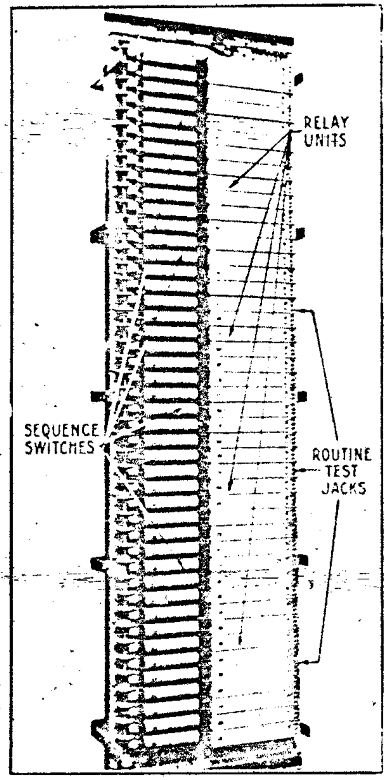


Fig. 166.—Relay and sequence-switch unit.

In the first case, the register functions to route the call to a trouble desk by means of an artificial number code it provides for the necessary selections. When the subscriber is brought to this point, the register releases as in a regular call and the attention of the maintenance forces is directed to the line in trouble.

In the second case, the register functions first to free the subscriber so he may originate another call and at the same time holds the faulty equipment out of service until it is cleared as a result of an alarm given to the maintenance forces.

Selector.—Essentially all selectors are identical in so far as their principal operating functions are concerned, with the exception of the final selector which makes two numerical selections and also performs the ringing and busy signaling under control of the condition of the called subscriber's line.

In Figs. 166 and 167, the relay and sequence-switch unit and selector-switch unit are shown. One of the former, having a capacity of forty-five circuits, is grouped with three of the latter, each having a capacity of fifteen circuits, to make up a complete

group of forty-five circuits. A summary of the principal selector features is as follows:

Trip-spindle selection.
Continuous hunting.
Double testing.

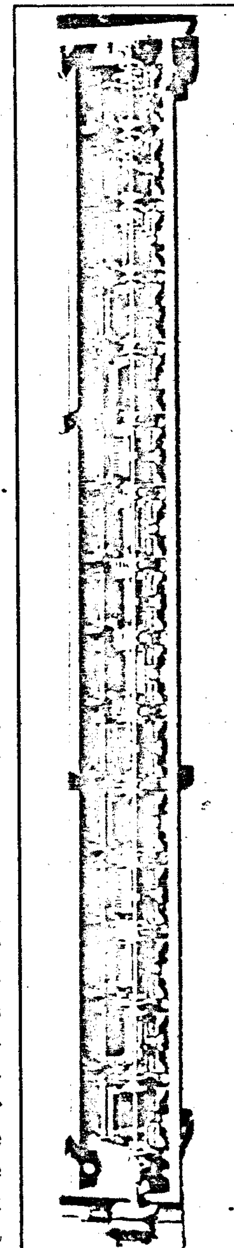


Fig. 167.—Selector-switch unit.

Trip-spindle Selection.—Setting of the selector trip spindle so it will be brought into the proper position to trip the desired brush set is a function performed by the register counting relays. The circuit controlling the selector trip-spindle clutch circuit is closed over a loop extending to the register and the duration of this closure is measured by counting the number of metal segments on the trip-spindle commutator passing a fixed collector brush as it rotates.

Each metal segment, in passing the collector brush, has the effect of an impulse for the duration of its closure, which in this form is used as a short circuit on the loop or fundamental circuit to the register. Thus each impulse or short circuit causes the release of a relay in the register forming a part of the fundamental circuit and, by counting the times this relay is released, the register can determine the position of the trip spindle.

A total of ten segments is provided around the periphery of the commutator and they correspond in position with respect to the collector brush the same as the ten latch-block tripping fingers in relation to the unlatch position. The fundamental circuit to the register is under control of the last counting relay of the group involved in the selection and, once established, this circuit will remain closed until the trip spindle sends back sufficient impulses to operate all counting relays. From one to ten impulses may be required, depending upon the digit dialed by the subscriber, and in this way the setting of the trip spindle may be controlled.

A schematic drawing of the parts of the selector and register which are involved in the trip-spindle selection is shown in Fig. 168 and its operation is as follows:

When the sequence switch associated with the selector enters position 2, a circuit is closed from battery through the winding of relay *GLR*, cam *D* brushes 4 and 3 cut in position 2, loop, normal contact of the *TCR* relay in the register and winding of the *OSR* relay to ground. In position 3, the operating circuit

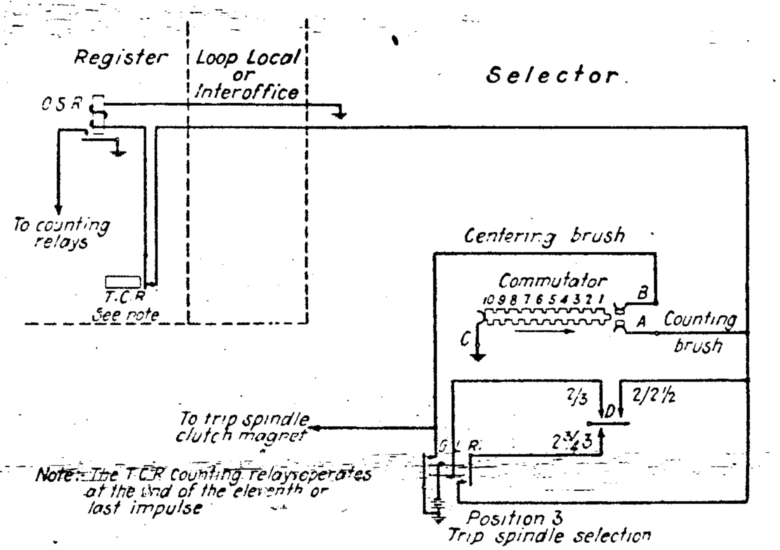


FIG. 168.—Schematic of selector trip-spindle selection.

for the *GLR* relay is opened at brush 3 of cam *D* but a holding circuit is established through brushes 4 and 1 and its operated contact. The *OSR* outstepping relay also operated in series with the *GLR* relay and closed over its operated contact a circuit to operate the first counting relay.

Ground on the operated contact of the *GLR* relay operates the trip-spindle clutch magnet and causes the trip spindle and commutator to rotate. As the lower metal section of the commutator enters in contact with the *A* collector brush, ground is closed from the feed brush *C* to the operating path of the *GLR* relay, which holds the *GLR* relay operated but causes the release of the *OSR* relay due to the short-circuiting effect. When

the *OSR* relay is released, an impulse in effect is counted and the impulse circuit is transferred to the next counting relay.

As each of the commutator segments numbered 1 to 10 enter in contact with the *A* brush, this short-circuiting effect is repeated. After sufficient impulses have been received from the *OSR* relay to operate the *TCR* counting relay, the *TCR* relay operates and the fundamental circuit is permanently opened and the *GLR* relay will release as soon as the *A* brush breaks its contact with the segment.

The upper commutator brush *B* is used for centering the trip spindle so that the selected trip finger will be in the center of the unlatch position. This feature is accomplished by having the *B* brush segments lag somewhat behind the *A* brush segments.

In the final selector, the brush-carriage setting is made under the same operating arrangement as with the trip spindle, except that the commutator is mounted on the base of the brush carriage. A total of twenty segments is provided for the brush-carriage selection, since it may be necessary in selecting a number in the odd hundred group to pass over as many as twenty terminals.

Continuous Hunting.—In the description of the selector switch, it was explained how the brush carriage rotated in a single direction and that upon the completion of a call it continued in the same direction until it reached the starting point.

By permitting the brush-carriage clutch circuit to remain closed after the switch has failed to find an idle trunk in the group selected, it will continue in rotation until it reaches the first trunk again and the hunting cycle will be repeated, the tripped brushes reset by the restoring roller being retripped by the trip spindle. This action is called "continuous hunting" and is a feature of all group selectors and is very effective in converting lost calls into delayed calls.

Another advantage obtained with the selectors operating on a continuous-hunting basis is that there is no necessity for trunk overflow terminals or "all trunk busy" signals to the subscriber.

Double Testing.—Double testing is a feature of all selectors and of all finder switches as well. It consists of second test on each terminal selected and, if it is found that the terminal has been picked simultaneously by another switch, one of the switches will be forced to leave the terminal.

Line Finder.—The first line-finder switch used in the rotary system serves a group of 100 subscribers and, in conjunction

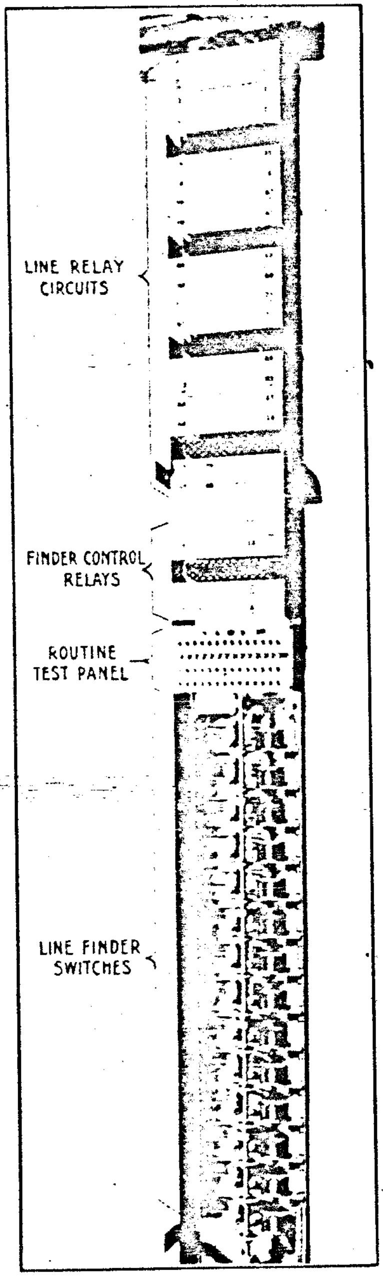


FIG. 169.—Bay of first line finders.

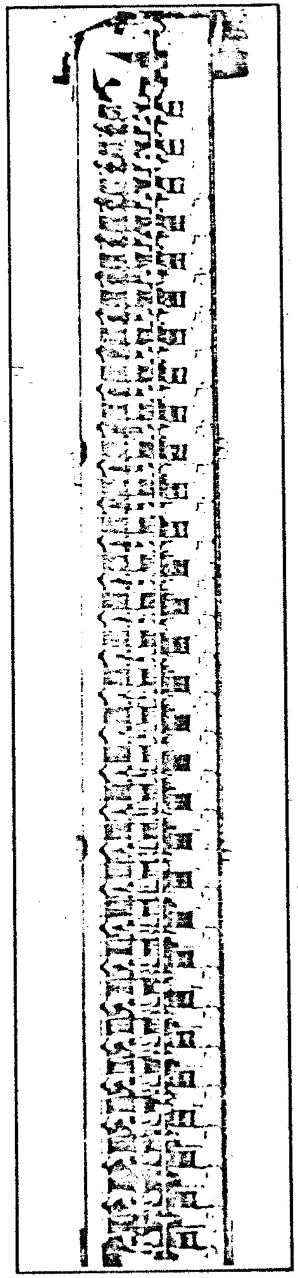


FIG. 170.—Bay of second line finders or register choosers.

with the second line finder of a similar capacity, it functions to concentrate the traffic into the register and selector circuits.

In Fig. 169, a bay of first line finders is shown and it will be noted that the finders, associated control relays, and 100 line relays are all mounted on the same bay as a self-contained unit. Figure 170 shows a bay of second line-finder switches, these being also used as register-choosing switches. The positions of the first and second line-finder switches and the register choosers in the switching train were indicated in Fig. 134.

When the subscriber lifts his receiver to originate a call, all available first line finders in that group will rotate to find the calling line. This operating arrangement tends to shorten the waiting time on the part of the subscriber and, since the double-test feature is a part of the finder switch, no danger of a double connection exists.

CHAPTER VI

THE ALL-RELAY AUTOMATIC SYSTEM[1]

Inception.—The idea of an automatic telephone switching system in which all the switching operations at the central office would be performed by relays, instead of by step-by-step or by steadily moving switches, has long appeared attractive on account of the mechanical simplicity of the electromagnetic relay and its reliability of operation. In the all-relay system, as pointed out in Chap. I, conducting paths are permanently wired from every point to every other point between which connections may be required, these paths being normally held open at the relay contacts and closed as required by selectively operating the relays in proper combinations. Mechanically, therefore, all parts of the system are static, except for the slight movements of the relay armatures and the consequent flexing of their contact springs.

The pioneer in the inception and development of the all-relay system seems to have been Mr. Edward E. Clement, of Washington, D. C., to whom also the automanual system is due. As early as 1906 he had made a practical demonstration of an automatic system of connection involving only relays. As far as I am aware, the first commercial embodiment of the all-relay plan of connection in actual exchange working was in the line-finder and primary selection part of the automanual exchange equipment installed by the North Company at Lima, Ohio, in 1914, this company operating under the Clement patents. Here the whole "concentrating" operation, by means of which the calls arising on any of several thousand lines were brought to and distributed among a few operators' key sets, was performed by relays. In each case, without the aid of any progressively moving switches whatever, the relays acted automatically and instantaneously, upon the lifting of a calling subscriber's hook, to connect an operator's idle key set with the calling line. Based on this line-finder system, which is still in successful operation (1932), the North Company later commercially developed its all-relay dial-controlled system, in which not only the line-finder function

[1] The photograph of Fig. 179 and the blue prints from which the circuit diagrams of this chapter were adapted were furnished by courtesy of the North Electric Manufacturing Company.

but the subsequent selector and connector functions as well were performed by groups of relays. This, as far as known the only all-relay system made in the United States, will be described here.

Relays of North All-relay System.—The relays of the North system are of three general types:

First, the "control" relays which are small unit-type relays (Fig. 171) following the generally accepted lines of telephone-relay design already discussed in connection with other systems.[1] These are used in various ways in the control of another type of relays which actually establish the connections between subscribers. They may be given different speed characteristics within the ordinary limitations of relay practice as affecting fast and slow operation

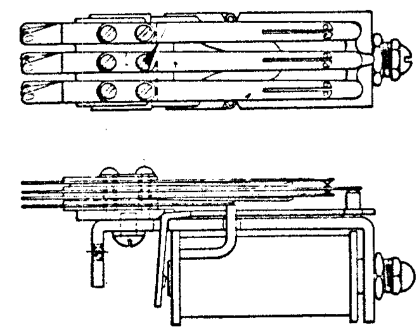


Fig. 171.—Type of relay used in controls.

Second, the multi-contact "connection" relays (Fig. 172) which, under control of the "control" relays, actually establish the connections proper. These are characterized principally by the large number of "make" contacts they carry and by the fact that these contacts are of the "sliding-blade-switch" type involving no precious metals.

Third, the "pendulum"-type relay (Fig. 173) which is used to secure longer time elements in the operation of the system than can be attained by the ordinary types of slow-action relays.

Control Relays.—In Fig. 171, the relay used for control purposes where comparatively few contacts are to be made or broken is of the single-coil type with a bell-crank armature moving on two knife-edge bearings formed by two notches in the frame near its rear end. The air gap is adjustable by moving

[1] "Manual Switching and Substation Equipment," pp. 179–194.

the core in the frame where it is held by lock nuts. Both the heel and the forwardly projecting toe of the armature are provided with "residual" studs to prevent magnetic "sticking." Slow action is provided for, where necessary, by surrounding the core with a thick copper sleeve throughout its length or with a heavy copper slug adjacent to the armature.

A feature to be particularly noted in this relay is the provision of double contact points for each spring. To this end, the bottom and top spring of each pile-up is bifurcated about 3/4 inch back from its tip, each branch carrying a contact point which registers with a corresponding point on the long center spring. All contacts are of gold-platinum alloy. By thus using two contacts in parallel, either of which alone ordinarily would serve the purpose,

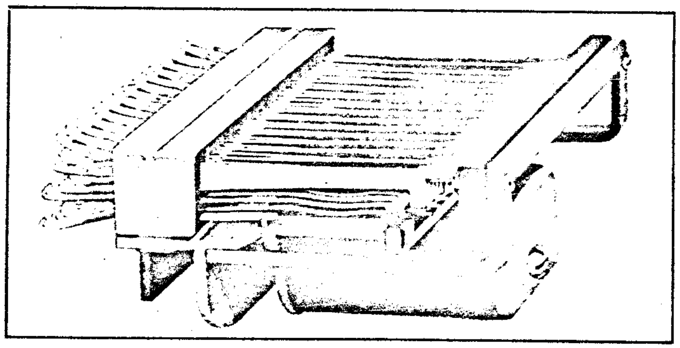


FIG. 172.—Type of multi-contact relay used in connections.

the reliability of the relay action has been greatly augmented. Contact failures, such as those arising from the chance lodgment of particles of dust between the contact surfaces, are thus practically eliminated.

Connection Relays.—The multi-contact relay (Fig. 172) is, like the one just described, of the single-coil type with an L-shaped armature operating on a knife-edge bearing on the rear part of the frame. Its contact members, of which there are thirty-three pairs in the relay shown, are rigidly mounted *en bloc* on the rear end of the frame and extend forwardly so that one of each pair will be moved by the forward end of the armature. Each pair of contacts consists of a phosphor bronze blade and a twin pair of German silver springs, the blade being adapted, when the armature is attracted, to slide up between the two springs after the manner of the ordinary knife-blade switch.

There are thus two parallel points of contact at each closure, and the sliding action of the blade in its movement between the twin springs makes for clean contacts without the use of precious-metal points. Besides the thirty-three-contact relay shown in Fig. 172, this same type of relay is made in three other sizes with twenty-three, twelve, and five contacts respectively. All are made with make contacts only and the five-contact relay is made up in a five-in-one assembly—that is, five distinct five-point relays are made on a single frame so as to occupy about the same mounting space as the single thirty-three-point relay.

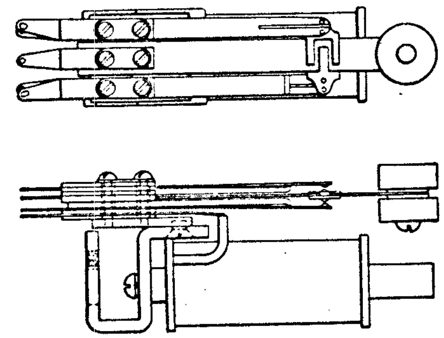


FIG. 173.—Pendulum relay for long time elements.

Pendulum Relay.—The third, or pendulum, type of relay (Fig. 173) is composed of a magnet coil mounted on an abbreviated frame with the core projected well beyond the end of the spool head. Parallel with the core, a spring reed is mounted in a center pile-up, its free end carrying an iron weight which determines the rate of oscillation of the reed and also acts as an armature. This reed also carries contact points adapted, when the reed is vibrating with sufficient amplitude, to engage alternately contacts on the two other springs carried in the adjacent pile-ups.

When the coil is energized, the armature is attracted and upon its release it vibrates with unvarying frequency but with gradually decreasing amplitude. The associated springs are adjusted to be alternately engaged until the amplitude of vibration decreases below the point of contact. Associated slow-release relays are held energized by the intermittent impulses of current allowed to flow by the rapid succession of contacts thus made and, of course, are released when the vibration dies down to a point where the contacts are no longer made. Since the amplitude of the reed movement gradually decreases, the time periods determined by the adjustment of the springs can be made of such length as to be measured in seconds rather than in fractions of a second, as in the ordinary slow-release relays.

Use of Pendulum Relay.—This so-called "pendulum" relay presents a phase of timed relay action not yet dealt with in this work and we may consider, in connection with Fig. 174, a specific example of its application before proceeding with the more general discussion of the all-relay system. The circuit of Fig. 174 relates to the application of ringing current to a subscriber's line in such

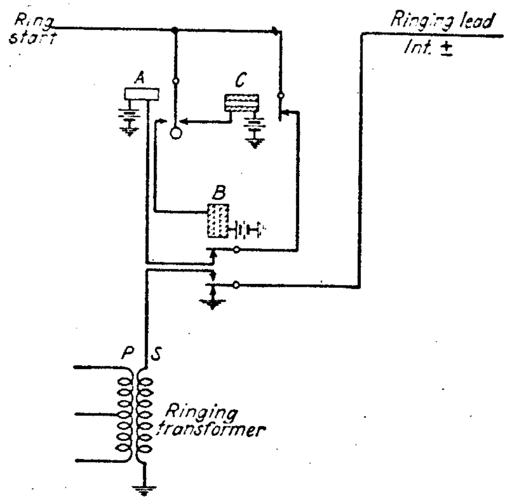


Fig. 174.—Illustrating use of pendulum relay.

alternate "ringing" and "silent" periods as may be desired. The ringing operation is to be started by applying ground to the start wire and is to result in periodically interrupted ringing current being sent over the ringing lead from the secondary of the ringing transformer. *A* is a pendulum-type relay such as shown in Fig. 173, and *B* and *C* are ordinary slow-release relays of type similar to that shown in Fig. 171.

Upon grounding the start wire, *A* is energized, deflecting the pendulum to the left. Upon closing its left contact, *B* is energized from the ground on the start wire, thus releasing *A* and closing the ringing circuit. The reed of *A* now vibrates resulting in rapid successions of impulses through both *B* and *C* to the ground on the start wire. These impulses occur so rapidly that the

armatures of the slow-release relays *B* and *C* do not have time to fall back as long as they continue. The contacts of *A* are so adjusted that, as the amplitude of vibration of the reed decreases, it will cease to engage the left contact considerably before the right. As soon as contacts at the left cease, relay *B* falls back, stopping the ringing. As the vibrations continue to decrease in amplitude, contacts on the right cease, releasing relay *C*. This results in *A* being again energized to again throw its reed into vibration to repeat the cycle just described. Thus, for instance, if alternating ringing and silent periods of 1 and 4 seconds respec-

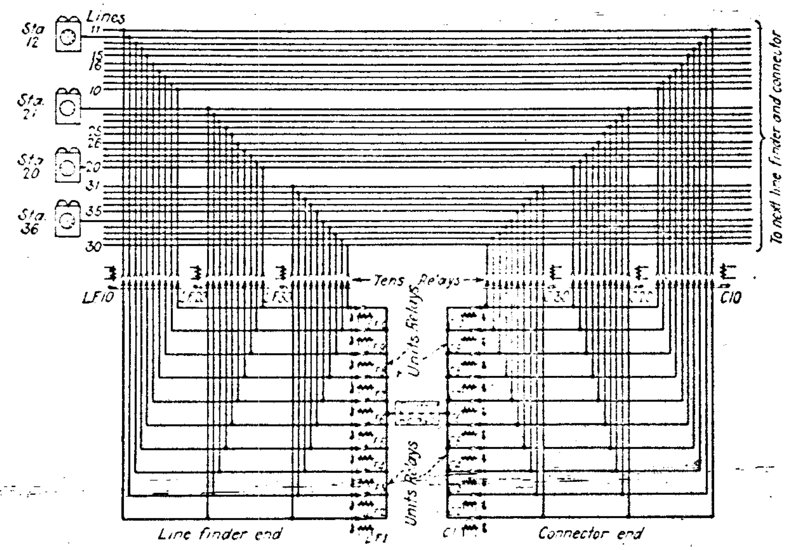


Fig. 175.—Schematic of connecting relays in one link of 100-line system.

tively are desired, the left contact of *A* is so adjusted that it will cease to be engaged by the reed after 1 second, and the right contact after 5 seconds, of vibrations from the time of starting. The intermittent ringing will continue as long as the ground is retained on the start wire.

Outline of Operation of All-relay System.—After this preliminary discussion of the apparatus involved, we may return to the broader features of the all-relay system. Figure 175 shows in schematic form the arrangement of connecting relays in one "link" of a two-digit or 100-line system. The control relays and the control circuits, by means of which these connecting relays are operated, are omitted from this figure. Each link comprises a line finder and a connector wired together "tail to tail," both line finder and connector carrying a full multiple of the 100 subscriber lines. Only 30 lines are shown, it being understood that the 70 others are connected in exactly similar manner. A single line on the drawing represents a subscriber line, which actually consists of three wires within the office and two outside.

From the connections shown on Fig. 175, it will be clear that the wires of the subscriber lines are connected respectively in groups of ten, to the outside contacts of ten "tens" relays, L.F.10, L.F.20, etc., to L.F.00 of the line finder and also to the outside contacts of ten tens relays, C.10, C.20, etc., to C.00 on the connector. These are called "tens relays" because each of them functions only in connection with the ten lines designated by a particular *tens* digit in the numbering system, such, for instance, as the digit 2 in 21, 22, 23, etc., to 20. When any one of these tens relays is operated, it serves to extend its particular ten lines (all bearing the same tens digit) to a grid or multiple of extension wires, all normally open at both ends, leading from the outside contacts of the tens relays to the outside contacts of ten "units" relays, L.F.1, L.F.2, etc., to L.F.10; or C.1, C. 2, etc., to C.10. These are called "units relays" because each of them functions only in connection with the ten lines designated by a particular *units* digit, such, for instance, as the digit 3 in 13, 23, 33, etc., to 03.

The distribution of the normally open extension wires leading from the outside contacts of the tens relays to the outside contacts of the units relays is exactly the same for both the line-finder and the connector ends of the link. Referring to the line-finder end, for instance, it will be seen that the No. 1 (left-hand) contacts of all the tens relays of a link are multipled together and extended to the contacts of the No. 1 units relay L.F.1. Likewise the No. 2 contacts of the tens relays are multipled together and extended to the contacts of the No. 2 units relay L.F.2, and so on. The inside contacts of all units relays of the link are wired together and carried to the control relays.

With this arrangement, it will be seen that by the operation of a certain tens relay and a certain units relay in the line-finder circuit, any line of the 100 lines in the group may be extended to the control relays without in any way disturbing any of the 99 other lines. For example, should it be desired to "select" or connect to line 23 in the line-finder circuit, tens relay L.F.20

and units relay L.F.3 would be energized. All ten lines of line group 21 to 20 would, by the operation of the tens relay L.F.20, be extended to the grid of extension wires leading to the units relays but, as only units relay L.F.3 is operated, only line 23 would be connected through, the others remaining undisturbed. Never, in either line finder or connector, is more than one tens and one units relay energized in any one relay selection. Should more than one of either be operated, crossing of the subscribers' lines in the relay multiple would result. This system of extending line groups of diminishing size toward the point at which actual connection is made is fundamental to the all-relay system and should be firmly grasped.

The link indicated in Fig. 175 corresponds in general function to the cord circuit of a manual board and, since more than one connection at a time must be provided for, a plurality of links is necessary. The additional links are connected with the line multiple in exactly the same way as the one shown, as indicated by the legend at the right of Fig. 175. The circuits must, of course, provide for the automatic selection of an idle link and for preventing interference by others with the ones already engaged.

Each subscriber line has a line relay operating when the station receiver is lifted. This has three contacts, two of which close the circuits of the line-finder tens and units relays respectively, corresponding to the tens and units digits of the calling subscriber's number. Thus, when any subscriber raises his receiver, his line relay is energized to close the circuits of the tens and units relays corresponding to the digits of his own number. In this way, the circuit of any calling lines is automatically and instantaneously connected through the line finder to the control relays.

The connection from these control relays to the called line through the connector is made in exactly the same manner by operating the tens and units relays of the connector that correspond to the tens and units digits of the called line number. Here, however, the method of bringing about the operation of these two connecting relays must differ from the operation of those in the line finder, since the calling subscriber has no control of the called subscriber's line relay. It is done by the action of the control relays in response to the current interruptions produced by the calling subscriber's dial. As the calling subscriber dials the tens digit of the called number, the dial interruptions are received and registered in a part of the connector circuit known as the "dial-impulse register." As the series of interruptions corresponding to the tens digit ceases, the dial-impulse register energizes and locks the connector tens relay corresponding to the tens digit dialed, thus extending the ten subscribers' lines, in which the called line appears, toward the connector commons, but leaving these ten lines undisturbed because they are all open at the units relays of the connector. The dial-impulse register then restores to normal.

As the units digit is dialed, the interruptions are received and registered in exactly the same manner and, at the pause after dialing, one of the ten units relays of the connector extends the called line to the connector control relays, leaving the nine other lines open at their respective units relay contacts. The dial-impulse register then restores to normal and the ringing of the called party or the other functions necessary to complete the operation are carried out by conventional circuits.

The foregoing very general description pertains to a two-digit selection. Where the system is for more than 100 lines and thus involves at least three-digit selection, all-relay selectors are provided. In a 1,000-line system the selectors are wired direct to the line-finder circuits, one selector per line finder. The connectors are then placed in 100-line groups by themselves. The selector circuit embodies a dial-impulse register as a part of its equipment, and, as the hundreds digit of the called number is dialed, it receives and registers the impulses. At the cessation of the interruptions, the selector causes the call to be placed before the connectors serving the hundred-line group which includes the called line. An idle connector of that group, by means of an automatic relay selector-finding action, engages the circuit of the selector, thus extending the calling line to the particular connector chosen. The operation of this connector in completing the connection with the called subscriber's line is, as already outlined, in response to the dialing of the tens and units digits.

All of the relays of Fig. 175 are of the multi-contact type with make contacts only. The tens relays are of the thirty-three-point type (Fig. 172), thus caring for the three wires of ten lines with three extra contacts. The units relays are of the same general type with five contacts each, five relays being mounted in one unitary structure.

Line-finder Operation.—As an example, to show somewhat more in detail how the principles of automatic all-relay selection above outlined are carried out, Fig. 176 may be referred to. This shows how the operation of the line relay results in energizing the proper tens and units line-finder relays to effect the line-finder connection. Each line has a line and a cut-off relay of conventional type (Fig. 171), but in Fig. 176 the cut-off relays are not shown. The two contacts of the line relays involved in this part

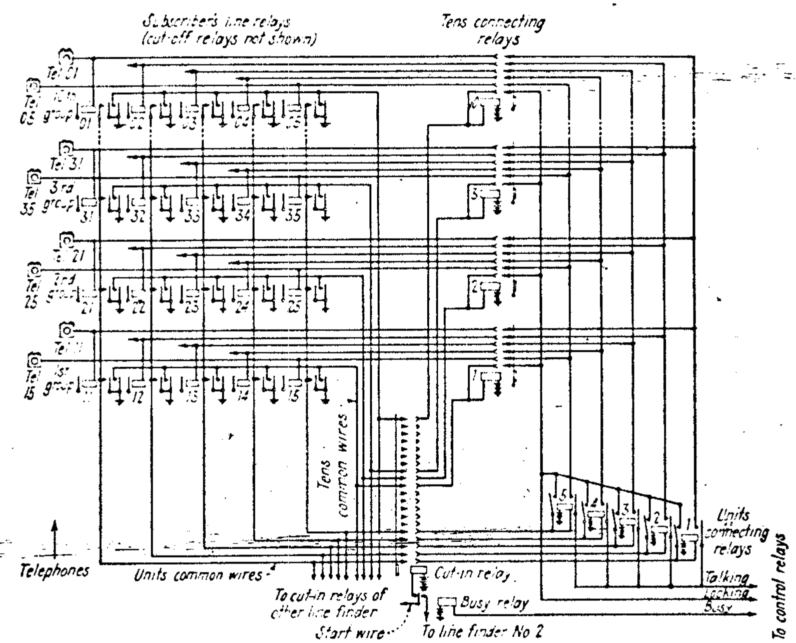


Fig. 176.—Line-finder operation.

of the circuit are connected to two sets of common wires serving the line relays in groups of ten corresponding respectively to the tens and units digits of their line numbers. Thus the No. 1 tens common wire is grounded by the operation of the line relays 11, 12, etc., to 10; the No. 2 tens common is grounded by the line relays 21, 22, etc., to 20. Similarly, the units common wires are grounded by the operation of line relays in groups according to the units digit of the line numbers. That is, units common wire 3 is grounded by line relays 13, 23, etc., to 03; and units common wire 4 is grounded by line relays 14, 24, etc., to 04. Thus, when any line relay is energized, the tens and units common wires corresponding in number to the numerical designation of the energized line relay will be grounded.

There is a "cut-in" relay and a "busy" relay for each line finder. Upon the initiation of a call on any line the cut-in relay of the first idle line finder will be energized over a "start" wire (not shown) which is common to the third contacts of all the line relays. Through the contacts of the cut-in relay, all tens and all units common wires (twenty in all) will be connected simultaneously to the windings of the corresponding tens and units relays of that line finder. As the tens and units common wires corresponding to the digits of the calling line will have been grounded by the line relay, as described, one tens and one units relay will be energized and will lock in position. The calling line will thus be extended to the control relays and the line relay and cut-in relay will release. The link "busy" relay now pulls up, guarding the link and holding it busy until the calling subscriber hangs up, when all the line-finder relays will restore to normal.

The start wire is grounded by the third contact of the line relay whenever a call originates on any line. The start circuit always terminates in the cut-in relay of an idle line finder but, upon the operation of the busy relay of that finder, it is transferred to the cut-in relay of the next line finder that is idle. As any busy relay is released, its cut-in relay is again placed in the start wire circuit, thus placing its line finder again in position to receive calls. In the latest all-relay practice, the start circuit is divided in such a way that the traffic load is distributed evenly among the line finders of the group.

Connector and Dial-impulse Register Operation.—All of the operations of the line-finder circuit are automatic in that the subscriber's act of lifting his receiver starts the sequence of operations that is carried through without further act on his part. After the completion of the line-finder operation, the equipment is ready to respond to further acts of the subscriber, by receiving the break-impulses from his dial and translating them into the settings of the tens and units relays of the connector as required to complete the desired connection. This function is carried out mainly by a group of relays called the "dial-impulse register," of which each connector in a two-digit system has one.

In the step-by-step switch-type system, the motor magnets of the switches respond to the dial interruption so that the final positions of the switch wipers indicate the number dialed. In the all-relay system, the dial-impulse register, consisting of a chain of ten counting relays and three associated sequence relays, receives the dial interruptions and determines, according to the digit dialed, the setting of the connecting relays through which the connections are completed. The relays of the counting chain are operated progressively by the dial interruptions, each relay locking through an associated sequence relay. At each succeeding dial impulse, the pair of counting-chain and sequence relays locked up by the preceding impulse are released so that, as the dial impulses cease, only the counting-chain relay corresponding in number to the digit dialed with its associated sequence relay will remain energized. At the cessation of a series of dial interruptions, a ground on the connector start wire operates a cut-in relay, which directs ground from the springs of the energized counting-chain relay to its corresponding tens or units relay, as the case may be, in the connecting relay group, locking this relay in position. The dial-impulse register will then be restored to normal position in preparation for further dialing.

As has been shown, the line finder makes connection with the *calling* line by the pulling up of a tens and a units relay as determined by the line relay. The connector makes connection with a *called* line by the pulling up of a tens and a units relay as determined by the setting of the counting-chain relays in response to the dial operation. Here, however, the action of the tens and units relays is successive rather than simultaneous. The tens relay pulls up first, in response to the dial movement for the tens digit, then, after "wiping out" the registration on the dial-impulse register, the units relay pulls up in response to the dial movement for the units digit.

Detailed Operation of 100-line System.—Referring to the companion figures (177 and 178), we may now, somewhat more in detail, give the successive steps in the operation of a 100-line North all-relay system. These figures show, in simplified form, the line-finder and the connector ends respectively of a connection through a 100-line system, with simple ringing, in which all calls are made by two "pulls" of the dial. As will be pointed out later, more particularly, certain liberties have been taken with these circuits in order to facilitate an understanding of their underlying principles. In the 100-line system, the four terminals 6, 7, 8, and 9 of the line finder (upper right corner of Fig.

177) are permanently connected to the correspondingly marked terminals on the connector (upper left corner of Fig. 178).

Station 11 *Calls Station* 22.—Assuming that station 11 is calling station 22, the successive steps are as follows:

1. Line relay L.R. of line 11 is energized as the receiver at the calling station is removed from its hook.

2. Cut-in relay of the line finder, carrying twenty-three make contacts (including one for each tens and one for each units

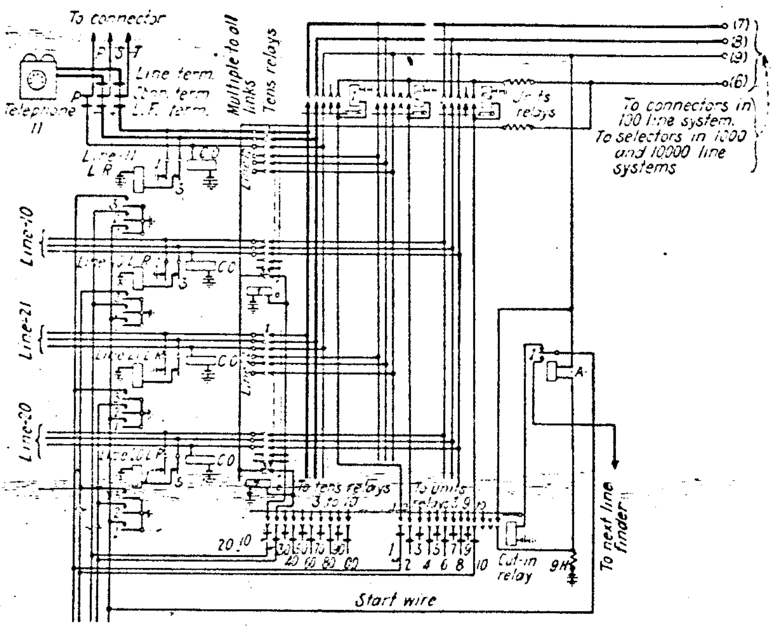


Fig. 177.—Connection through 100-line all-relay system—line-finder end.

relay of the group) is energized from start wire to ground at spring 1 of line relay.

3*a*. Tens relay 1 is energized from ground at spring 2 of line relay.

b. Units relay 1 is energized from ground at spring 3 of line relay.

The calling line 11 is now connected to terminals 7 and 8 of the connector circuit (Fig. 178).

4. Relay *B* is energized over the metallic circuit of the calling line.

5. Relay *G* is energized and, being slow releasing, remains so until the calling party hangs up. The ground it puts on wire 9 (leading to terminal 9) makes the calling line test busy to other lines attempting to connect with it.

6. The cut-off relay *CO* of line 11 is energized from ground on wire 9 at spring 2 of relay *G*.

7*a*. Line relay L.R. of line 11 is de-energized, its circuit being opened at the cut-off relay springs.

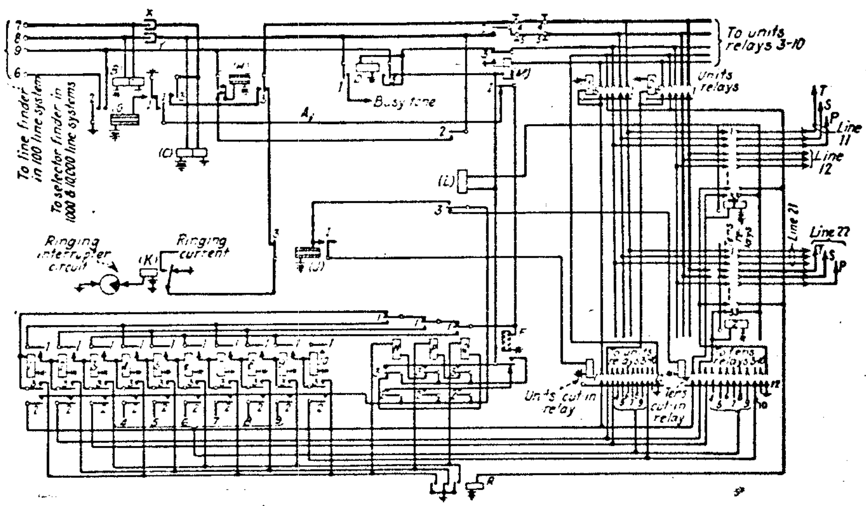


Fig. 178.—Connection through 100-line all-relay system—connector end.

b. The tens and units relays of the line finder remain energized over locking circuits through their own contacts to wire 6 (leading to terminal 6) and to ground at relay *G*.

8. The cut-in relay of the line finder is de-energized and removes a short circuit from coil of relay *A*.

9. Relay *A* is energized over wire 9 to ground at spring 2 of relay *G*. (Energizing relay *A* makes the line finder busy and passes the next call to another line finder.)

These actions have occurred instantaneously as a result of closing the line circuit at the calling station. The selection of the calling line by the line finder is now complete and the circuit stands ready to receive dial interruptions from the calling telephone. Up to this point, the selection has been "non-numerical," being determined entirely by the identity of the line relay energized.

As the calling subscriber dials the first, or tens, digit 2 of the called number:

10. The dial springs momentarily open the line circuit.

11. Relay *B* is de-energized, grounding wire *A*, leading to the dial-impulse register.

12*a*. Slow relay *F* is energized and remains so during the rapid dial interruptions.

b. Counting chain relay 1 is energized. (Sequence relay *N* is not energized at this instant, being shunted by ground on wire *A*.)

13. Dial springs close the line circuit.

14. Relay *B* is energized, removing ground from wire *A*.

15. Sequence relay *N* is energized over wire 9 to ground at relay *G*, this being a locking circuit for counting-chain relay 1. (The operation for the first dial impulse of the tens digit of the called number is now complete.)

16. Dial springs open the line circuit.

17. Relay *B* is de-energized, grounding wire *A*.

18. Counting chain relay 2 is energized.

19. Dial springs close line circuit.

20. Relay *B* is energized, removing ground from wire *A*.

21. Sequence relay *P* is energized to ground over wire 9, locking counting-chain relay 2.

22*a*. Sequence relay *N* is de-energized, its circuit being opened at springs of relay *P*.

b. Counting-chain relay 1 is de-energized as its locking circuit through relay *N* is opened.

Operation for the second dial interruption of the tens digit 2 of the called number is now complete, counting-chain relay 2 and sequence relay *P* remaining energized in series to ground on wire 9.

Had a higher digit number than 2 been pulled on the dial, the operations for the succeeding impulses would have been much the same as that described for the first and second, the counting-chain relays operating and locking progressively. At the end of any digit series, the counting-chain relay corresponding in number to the digit pulled will remain locked in series with its corresponding sequence relay. Sequence relay *N* locks the counting-chain relays for impulses 1, 4, 7, and 10, sequence relay *P* for impulses 2, 5, and 8, and sequence relay *Q* for impulses 3, 6, and 9. Each sequence relay, in pulling up, releases the counting-chain and sequence relays locked up by the preceding impulse.

As no further dial interruptions beyond the second follow in the case assumed, relay *B* remains energized and ground is removed from wire *A* for a sufficient time to allow the armature of slow relay *F* to fall back.

23. Slow relay *F* is de-energized. This does not release counting relay 2 and sequence relay *P*, which remain locked in series through back contact 3 of relay *Q* and front contact 3 of relay *P* to ground on wire 9.

24. Tens cut-in relay of connector is energized by ground at relay *G* on wire 9, through springs of relays *L*, *P*, *F*, and *D*.

25. Tens relay 2 is energized by the same ground on wire 9, through springs of the tens cut-in relay, chain relay 2, and relays *P*, *F* and *D*.

26. Shunting relay *R* is energized by ground on spring 12 of the tens cut-in relay, through spring 32 of No. 2 tens relay.

27. Sequence relay *P* is de-energized, being shunted by springs of relay *R*, which also hold counting-chain relay 2 locked.

28*a*. Tens cut-in relay is de-energized, its circuit being opened by springs of relay *P*. The tens cut-in relay is so adjusted that it will not hold up through the 1,000-ohm resistance of relay *L*.

b. Relay *L* is energized over a locking circuit for tens relay 2. Spring 3 of this relay transfers the cut-in circuit from the tens cut-in relay to relay *J*, and thence to the units cut-in relay.

29. Relay *R* is de-energized, its circuit being opened at springs of the tens cut-in relay.

30. Counting-chain relay 2 is de-energized, its locking circuit being opened by relay *R*.

At this point the first, or tens, digit of the called number has been dialed and its interruptions received and registered. As the first train of dial impulses ended, tens relay 2 was operated and locked, extending the ten subscriber lines 21 to 20 to the normally open contacts of the units relays of the connector.

The calling subscriber now dials the second, or units, digit 2 of the called number.

31. Dial springs open the line circuit.

32. Relay *B* is de-energized, grounding wire *A*.

33*a*. Relay *F* is energized and remains so during rapid interruptions of the dial.

b. Counting-chain relay 1 is energized.

34. Dial springs close the line circuit.

35. Relay *B* is energized, removing ground from wire *A*.

36. Relay *N* is energized by ground on wire 9, this forming a locking circuit for counting-chain relay 1.

This completes the operation for the first dial impulse of the units digit of the called number.

37. Dial springs open the line circuit.

38. Relay *B* is de-energized, grounding wire *A*.

39. Counting-chain relay 2 is energized.

40. Dial springs close the line circuit.

41. Relay *B* is energized, removing ground from wire *A*.

42. Relay *P* is energized, being in a locking circuit for counting-chain relay 2.

43*a*. Relay *N* is de-energized, its circuit being opened at springs of relay *P*.

b. Counting-chain relay 1 is de-energized, as its locking circuit through relay *N* is opened.

Operation for the second dial interruption of the units digit of the called number (22) is now complete and counting-chain relay 2 and sequence relay *P* remain energized in series. As no further dial interruptions follow, relay *B* remains energized and ground is removed from wire *A* long enough to permit relay *F* to fall back.

44. Slow relay *F* is de-energized.

45. Slow relay *J* is energized by ground on wire 9 through front contacts of relays *L* and *P* and back contact of relay *F*. Relay *J*, by opening its contact 3, prevents ringing current being applied to the connector commons at this time.

46. Units cut-in relay is energized by ground on wire 9, through the springs of relays *J*, *L*, *P*, *F*, and *D*.

47. Units relay 2 is energized by the same ground on wire 9, through the springs of the units cut-in relay, counting relay 2, and relays *P*, *F*, and *D*.

This closes the called line (22) through the contacts of the tens and units relays to the connector commons.

Busy Test.—Whether or not the connection is finally cut through and the called party rung will depend on whether line 22 is idle or busy. If busy, its third, or private, wire *P* will be grounded by a connection already existing, either from spring 3 of relay *M*, if it was the *called* line of the connection (item 51′*a* following), or from spring 2 of relay *G*, if it was the *calling* line of the connection (item 5). If the line is idle, the wire *P* will be ungrounded.

Assume first that the called line (22) is busy. Then immediately upon the pulling up of units relay 2:

48*a*. Busy relay *D* is energized by ground placed on the private wire of the called line by an already existing connection. The busy relay locks to ground on wire 9 at relay *G*.

b. Shunting relay *R* is energized by ground on spring 12 of units cut-in relay through spring 4 of units relay 2.

49*a*. Busy tone is sent to the calling subscriber from contact 1 of relay *D*.

b. Tens and units relays of the connector are de-energized, their locking circuits being opened at contact 3 of relay *D*.

c. Units cut-in relay is de-energized, its circuit also being opened at contact 3 of relay *D*.

d. Sequence relay *P* is de-energized, being shunted by ground at springs of relay *R*.

e. Relay *L* is de-energized.

50. Shunting relay *R* is de-energized.

51. Counting-chain relay 2 is de-energized, its circuit being opened at springs of relay *R*.

The circuit is held in this condition until the calling party abandons the call, at which time all the relays of the line-finder and connector circuits restore to their normal position and are in readiness to receive another call.

Assume now, instead, that the called line (22) is not busy and consequently has no ground on its private wire. Then following the pulling up of the units relay 2 as in item 47:

48′. Shunting relay *R* is energized by ground on spring 12 of the units cut-in relay through the fourth spring of units relay 2.

49′. Sequence relay *P* is de-energized, being shunted by ground at the springs of relay *R*, which also holds counting-chain relay 2 locked.

50′*a*. Relay *M* is energized to ground on wire 9 at relay *G*, this being a locking circuit for units relay 2.

b. Units cut-in relay is de-energized, its circuit being opened at the springs of relay *P* (adjusted not to hold through relay *M*).

c. The circuit of relay *J* is opened but, being slow in releasing, its armature does not fall away at this time.

51′*a*. The operation of relay *M* completes the circuit from the called line to the connector by closing contact 2 and places ground on the third or private wire *P* of the called line, operating the cut-off relay and providing a busy-test condition.

b. Relay *R* is de-energized, its circuit being opened by the springs of the units cut-in relay.

52. Counting-chain relay 2 is de-energized, its circuit being opened by the springs of relay *R*.

53. Relay *J* falls back, its circuit having been opened by operation 50′*c*.

At this point, dialing of the called number has been completed and the called line, having been tested and found *idle*, has been connected to the link.

Ringing Operation.—When relay *J* fell away (item 53), it permitted ringing current to be applied intermittently to the called line.

54. Ringing relay *K* is energized periodically, either by a machine-driven interrupter or by a pendulum-relay arrangement, such as that of Fig. 174. Each time the ringing circuit is closed:

55. Ringing current passes to the line through springs of relays *J*, *H*, units relay and tens relay, returning through the springs of the tens and units relays, relays *M*, *L*, and *H*, to negative battery through the winding of relay *H*. Relay *H*, because of the high impedance of the subscriber's ringer, is not operated by this current. A portion of the ringing current also returns through one winding of relay *C* to negative battery. The ring-back tone to the calling subscriber is set up by a small portion of the ringing current being diverted to the line-finder conductors and to the calling telephone through the condenser *Y*.

Called Party Answers.—When the called subscriber answers:

56. Circuit of called line is closed through station transmitter at hook switch.

57. Relay *H* is energized over the comparatively low impedance circuit through contacts of relays *H*, *L*, and *M*, thence over the metallic circuit of line 22, and to ground at relay *K* through contacts of relays *H* and *J*.

58*a*. Ringing current is cut off from called line.

b. The talking circuit is closed through from the calling to the called line.

c. A locking circuit for relay *H* is closed over wire 9 to ground at spring 2 of relay *G*. The release of relay *H* is thus placed under control of the calling subscriber.

The connection between the two subscribers' lines is now complete, the calling line receiving its transmitter current through the two windings of relay *B* and the called line through the two windings of impedance coil *C*.

Release of Connection.—The release and restoration of the apparatus to its normal condition at the end of the conversation are under the control of the calling subscriber.

59. Calling line circuit opened as calling party hangs up.

60. Relay *B* is de-energized.

61. Relay *G* is de-energized (delayed).

62*a*. Line-finder tens and units relays are released by removal of ground from wire 6.

b. Cut-off relay *CO* of calling line is released by removal of ground from wire 9.

c. Line-finder relay *A* is released by removal of ground from wire 9, placing the line finder again under control of the start wire.

d. Connector tens relay and relay *L* are released by breaking of ground connection from wire 9.

e. Connector units relay and relay *M* are released by removal of ground from wire 9.

f. Connector relay *H* is released (delayed) by removal of ground from wire 9.

63. Cut-off relay of called line is released, restoring the normal line relay connection.

Thus all relays are restored to normal, so that the line finder, connector, and both of the lines are available for other calls.

A 100-line capacity all-relay dial-automatic switchboard equipped with 90 lines and 9 links is shown in Fig. 179. This is composed wholly of the three types of relays shown in Figs. 171, 172, and 173, and its only moving parts are the armatures and contact springs of these relays. The wiring on the rear side consists of permanently soldered connections between fixed apparatus terminals. The apparatus is completely enclosed in a sheet-steel cabinet as a protection against dust and mechanical injury.

Thousand-line System.—Up to the present time, the use of the all-relay dial system has in commercial practice been confined in large measure to small exchanges. This is because of its relatively higher first cost in comparison with switch-type equipment, when applied under parallel conditions to large exchanges. However, disregarding first cost considerations, the all-relay system is capable of indefinite expansion above the two-digit capacity so far considered, by adding all-relay selectors between the line finders and connectors, in much the same manner as selector switches are added to the selecting train in switch-type systems. Because of its potential importance in larger systems, if first costs could be reduced, the opera-

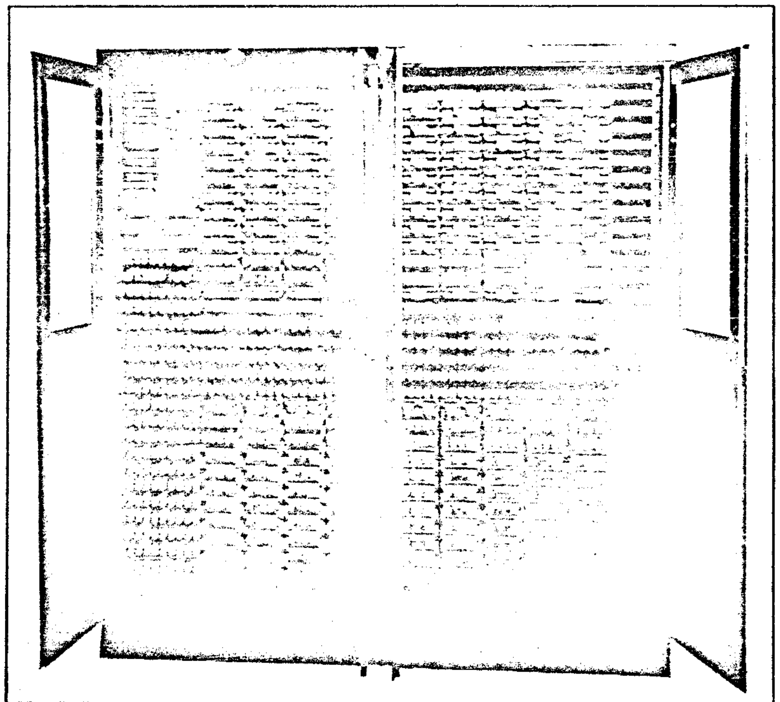


FIG. 179.—A 100-line all-relay dial automatic switchboard.

tion of a 1,000-line system will be briefly described. As in the case of the 100-line system, the description is based on the apparatus of the North Company and, in general, on its circuits. Some liberties have been taken in the circuits, however, sacrificing some of their refinements in order to make clearer their fundamental method of operation.

In the 1,000-line system each line finder (Fig. 177), instead of being wired direct to a connector, has its four terminals 6, 7, 8, and 9 permanently strapped to four similarly marked

terminals of a selector circuit (left-hand portion of Fig. 180), the function of which is to accept the dial impulses of the first, or hundreds, digit of the called number, register them in the counting-chain relays of the selector, and, as the dial interruptions cease, direct the call to an idle connector in the group of connectors serving the hundred subscriber lines in which the called line appears.

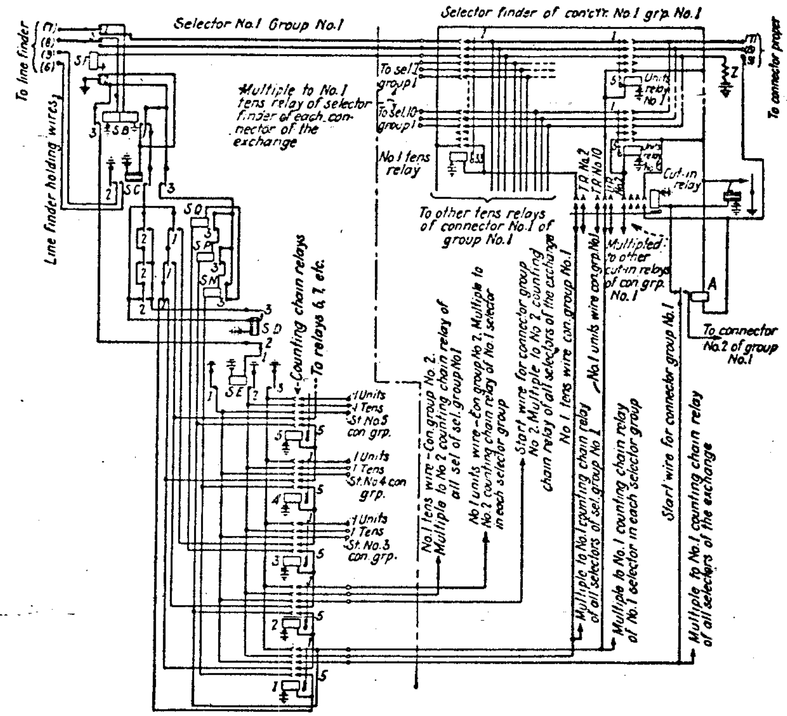


FIG. 180.—Selector and selector finder—1,000-line all-relay system.

Each connector in the 1,000-line system, in addition to the equipment shown in Fig. 178, is equipped with a complete all-relay "selector finder" (right-hand portion of Fig. 180), the terminals 7, 8, and 9 of the two figures being permanently strapped together. This selector finder thus becomes a part of the connector circuit, its function being to seize the conductors of a calling selector on which a call for a line served by its group of connectors has originated. In a 1,000-line system, therefore, the selector and selector-finder circuit of Fig. 180 is interposed between the line-finder and the connector circuits of Figs. 177

and 178 respectively. The change from a 100-line to a 1,000-line system is thus readily made. To accomplish it, the straps between the line finders and connectors are removed and the selectors and selector finders inserted to provide for the added digit.

For simplicity, the 1,000-line system will be considered with 10 per cent trunking throughout. There will be, therefore, 10 groups of 100 subscribers' lines each, and each subscriber-line group will be served by 10 line finders. As each line finder is permanently wired to a selector circuit, there will be in the exchange 100 selectors which are numbered, for purposes of identification in the later selections, as No. 11 to No. 00. That is, selector 1 of selector group 1 is numbered 11 and selector 5 of selector group 3 is numbered 35, etc. These numbers are significant, as they designate the tens and units relays to be operated in the selector finders of the connector circuits.

The connectors of the 1,000-line exchange are divided into 10 groups of 10 connectors each, each connector group serving 100 subscriber lines. The 10 selector finders of each connector group form a complete system for connecting their associated connector circuits to the conductors of any of the 100 selectors in the exchange, by a selection almost identical with that of the subscriber line-finder selection previously described. Thus, when a given hundreds digit is dialed, it is registered on the counting relays of a selector that is at the time associated through a line finder with the calling line, whereupon a selector finder proceeds to associate a connector in the corresponding hundreds group with this selector.

Station 111 *Calls Station* 122.—The two subscribers' lines 11 and 22 (Figs. 177 and 178), used in describing a typical connection in a 100-line system, will each be considered as having corresponding numbers in the first hundred group of the 1,000-line exchange—their numbers therefore becoming 111 and 122 respectively. The sequence of operations in establishing a connection between them in the 1,000-line system will be as follows:

1. Line relay 111 (L.R.-11 in Fig. 177) is energized when the calling subscriber lifts his receiver.

2. The cut-in relay of a line finder in the first, or 100, group is energized from ground at line relay spring 1.

3*a*. Line-finder tens relay 1 is energized by ground at line relay spring 2.

b. Line-finder units relay 1 is energized by ground at line relay spring 3.

The calling line is now connected to selector terminals 7 and 8 (Fig. 180).

4. Selector relay *SB* is energized, through calling line and telephone.

5*a*. Selector relay *SC* is energized and remains so throughout the call.

b. Cut-off relay *CO* of line 111 is energized by ground on wire 9 at relay *SC*, spring 2.

6. Line relay L.R. of line 111 is de-energized, its circuit being opened by cut-off relay.

The line-finder tens and units relays remain locked to ground on wire 6 at relay *SC*, spring 2.

7. Line-finder cut-in relay is de-energized and removes a shunt from line-finder relay *A*.

8. Line-finder relay *A* is energized by the ground on wire 9 at relay *SC*, making the line finder busy to other calls.

The selection of the calling line is now complete and the selector circuit stands ready to receive the series of dial impulses corresponding to the first digit (1) of the called number (122).

9. Dial springs momentarily open the calling line circuit.

10. Selector relay *SB* is de-energized.

11*a*. Selector slow relay *SD* is energized and remains so during the rapid dial interruptions.

b. Selector counting-chain relay 1 is energized.

12. Dial springs close the line circuit.

13. Selector relay *SB* is energized.

14. Selector sequence relay *SN* is energized over a locking circuit for counting-chain relay 1.

As no further dial interruptions follow, selector relay *SB* remains energized and the circuit of slow relay *SD* is opened for a sufficient time to allow its armature to fall back.

Selector counting-chain relay 1 now becomes in effect a "line relay," as it places a call before the selector finders of the group of connectors serving the subscriber-line group in which the called line appears. This causes the first idle connector of that group to engage the conductors of the calling selector by means of a relay selection similar to that of the line finder.

(Had the subscriber called a number in the 400 group, for instance, the selector counting-chain relays would have operated progressively in response to the dial impulses, locking in through their associated sequence relays *SQ*, *SP*, or *SN*, and, as dialing ceased, counting-chain relay 4 would have been locked in. This would have placed the call before the selector finders of the connectors serving the 400 subscriber-line group, causing seizure of the calling selector by the relays of one of these selector finders.)

15. Selector slow relay *SD* is de-energized.

16. Selector relay *SE* is energized, placing ground on first, second, and third springs of all counting-chain relays.

17*a*. Selector-finder cut-in relay is energized through the third contact of counting-chain relay 1.

b. Selector-finder locking relay *L* is energized through the same contact.

18*a*. Selector-finder tens relay 1 is energized, through the second contact of counting-chain relay 1.

b. Selector-finder units relay 1 is energized, through the first contact of counting-chain relay 1.

19*a*. Selector relay *SF* is energized by battery through selector-finder tens and units relay springs and coil *Z*.

b. Spring 2 of selector relay *SF* passes ground to the winding of selector relay *SC*, holding that relay energized for the duration of the call.

The calling line is now extended to terminals 7 and 8 of the connector proper.

20*a*. Connector relay *B* (Fig. 178) is energized through calling line and telephone.

b. Selector relay *SB* is de-energized, being cut off from the line at the contacts of relay *SF*.

c. Selector relay *SE* is de-energized at spring 2 of relay *SF*.

d. Selector sequence relay *SN* is de-energized.

e. Selector counting-chain relay 1 is de-energized.

f. Selector-finder cut-in relay is de-energized.

g. The circuit of selector-finder locking relay *L* is opened, but the delayed action of this relay holds ground on the windings of the selector-finder tens and units relays 1, until those relays are locked through selector-finder relay *A* by the next operation.

21. Connector slow relay *G* (Fig. 178) is energized from relay *B*, locking the selector-finder tens and units relays over wire 9 through selector-finder relay *A*.

Connector relay *G* controls the locking of all relays of the connection and remains energized until the calling subscriber releases the call.

22. Selector-finder relay *A* is energized, making the connector busy by passing the start wire to another connector of the group.

At this stage of the call the line finder and selector have completed their functions. The selector finder of the connector is operated, extending the calling line to the connector commons. The dial interruptions of the tens and units digit follow and completion of the call by the connector is exactly as before described. The progress of the call from this point on may be traced by taking up the description of connector operation in the 100-line system at item 10 (page 322).

The simplification of these drawings used in describing the all-relay system, made as stated to facilitate an understanding of the principles involved, has resulted in the omission of a number of features actually incorporated in practice. One is the provision against interference among simultaneous calls, which must be made in any successful type of automatic system. In the North all-relay system a series of "guard" relays are incorporated in the line-finder and selector-finder circuits, assuring freedom from interference between simultaneous calls or between succeeding calls which are placed during the fraction of a second in which a selection is taking place. Another feature provided is the arrangement for the distribution of traffic over various units of equipment. To accomplish this, the start wire, which at each selection directs the call to various units of apparatus, is by simple means so connected as to bring about any desired distribution. At the same time, a protection against service interruption due to defective units of apparatus is provided by the use of a timed element in the circuit, which, after a call has remained uncompleted in the selection relays for a time greater than the normal operating time of the selection, advances the start wire and brings an entirely different set of units into action. Thus one defective equipment unit may not cripple the service in a group of lines or trunks.

CHAPTER VII

POWER PLANTS

Broadly speaking, the equipment which furnishes the various kinds of current required in the operation of a telephone system may be referred to collectively as the power plant. In a magneto exchange, the power plant, under this broad definition, is highly subdivided, each subscriber's station deriving its talking and signaling current from its own local battery and magneto generator. In this case, the central-office power plant is reduced to its simplest terms, ordinarily consisting merely of suitable battery supply for the operators' transmitters and ringing-current supply for actuating the subscribers' bells. In common-battery or central-energy exchanges, however, all sources of electric energy for supplying all the requirements of the system are concentrated at the central office. The central-office power plant is thus made much more complex and costly. But whether magneto or common battery, small or large, simple or complex, the importance of the central-office power plant must be realized. It is the heart of the system. Even in a small magneto exchange, the service stops if the operators cannot talk to or signal the subscribers. In usual telephone parlance, whether referring to magneto or common-battery exchanges, the term "power plant" refers to this collection of power equipment at the central office, ignoring the fact that in magneto systems much of the signaling and talking current is generated at the subscribers' stations.

Sources of Energy.—The primary sources of energy used in telephone power plants are:

1. Prime movers, such as steam or gas engines, water wheels, or human muscular effort in cases where magneto generators are used.

2. Primary electrochemical batteries, which derive their energy directly from the chemical disintegration of their own elements.

A third primary source of current, the thermocouple, deriving its energy from the heat of an external source applied to a joint

between dissimilar metals, may be mentioned as having at various times received attention. It may be dismissed from consideration here, because practically it is not used as a source of current in telephone operation. It does find incidental use in telephony, however, as a part of a laboratory device for measuring minute alternating currents.

Central-office power plants, as a rule, receive the greater part of their electrical energy requirements from commercial power lines, and thus from the first of the primary sources just mentioned. In order to provide against possible breakdown of the commercial service, however, it is customary for them to have a reserve source, in the form either of a gas-engine driven dynamo on the central-office premises or of a second commercial source, completely independent of the first with respect to power station and power mains.

The current received from the commercial power lines may be alternating or direct, single-, two-, or three-phase, and of various voltages according to the nature of the available commercial service, but in any event it usually is not suitable in the form received for the highly specialized uses of telephony. For this reason, the energy received from these primary sources must be converted into different kinds of current suitable in voltage, frequency, and other characteristics for direct use in carrying out the many different functions of the telephone system. The central-office power plant, therefore, consists principally in a collection of electrical translating devices with the necessary auxiliary devices for control, distribution, and protection. The translating devices consume the energy received from the available primary sources and convert it into currents adapted for the special needs of the telephone equipment. They are principally: motor generators, transformers, mercury-arc or other static rectifiers, storage batteries, rotary or vibrating circuit breakers, and in some cases vacuum-tube oscillators. By such means, currents of any required voltage, frequency, or other characteristics are produced for use within the telephone system.

Batteries.—An electric battery is a device for the direct transformation of chemical energy into electric energy. A battery usually consists of a number of practically identical voltaic cells connected together, in series where greater voltage than that of one cell is desired or in multiple if current capacity rather than voltage is to be increased. Each cell consists of a positive and a negative electrode immersed in an electrolytic solution held in a suitable container. Batteries are of two types: primary and secondary.

In the primary battery, the active electrode of each cell, practically always of the metal zinc, is actually consumed in the action of producing electricity. In the secondary battery, the chemical and electrical actions are reversible. The chemical conditions within the cell, altered by the discharge of current from it, may be restored by causing current from an outside source to flow through the cell in the opposite direction. Thus the secondary battery, unlike the primary, is not an original source of current. It must first be charged from another source in order to be brought into such chemical condition as to be able to act itself as an electrochemical generator of current. Because of its ability thus to receive a charge of electric energy and later to give it back again, the secondary battery is commonly called a "storage battery" or an "accumulator."

Primary Batteries.—The primary battery, once the principal source of current in telephone work, has, with the advance of the art, been relegated to a position of relatively minor importance. This is principally because the generation of electricity by the chemical consumption of zinc is inherently an expensive method as compared with its generation by the combustion of coal or oil or by water power.

Notwithstanding this, the primary battery is distinctly useful in the telephone field. It serves as a convenient source of current where limited amounts are required intermittently for short intervals, or as a convenient source of electromotive force where differences of potential are required with practically no current drain. A principal example of the former use is in the supply of transmitter current in local-battery telephone sets at magneto exchanges. An example of the latter use is in supplying the requisite voltages in cable-testing work and capacity measurements. In small offices having no outside source of power, primary batteries furnish current for operators' transmitters, night-alarm circuits and other direct-current uses, and even in larger offices they are largely used in the various forms of "pole changers" which, by interrupting and reversing their direct currents, transform them into alternating or pulsating currents suitable for ringing the bells at subscribers' stations. Also, they are used in practically all cases where relatively

small currents are required and where connection to the central-office storage battery is not convenient or cannot be used because that battery is grounded. In fact, on account of the smoothness of their current, their portability, and the convenience with which they may be adapted to special uses within their capacity, primary batteries are used for a multitude of incidental purposes in telephone operation.

Dry Batteries.—The dry cell is by far the most widely used primary cell. It is a modification of the older Leclanché cell, which used carbon and zinc electrodes immersed in an electrolyte composed of a solution of sal ammoniac in water contained in a glass jar. The carbon electrode was held in an inner cup of porous clay, containing also a closely packed mixture of crushed carbon and manganese dioxide, the latter serving as a depolarizer.

The chemical action of the Leclanché cell in generating current is about as follows: The sal ammoniac is decomposed, its chlorine leaving the ammoniac to unite with the zinc, thus forming chloride of zinc and setting free ammonia and hydrogen. The ammonia is immediately dissolved in the water of the cell and the hydrogen goes over to the carbon, where it would speedily polarize the cell but for the fact that it encounters the dioxide of manganese. This, being rich in oxygen, gives up part of it to form water. The reaction is expressed in chemical symbols as follows:

$$Zn + 2NH_4Cl + 2MnO_2 = ZnCl_2 + 2NH_3 + H_2O + Mn_2O_3.$$

In the dry cell, which has generally supplanted the older wet Leclanché cell, substantially the same electrode and chemicals are used, but the glass jar, porous cup, and free liquid are dispensed with. Instead, the electrolyte is held absorbed by the porous contents of the cell which are thus kept in a moist state. The whole is contained within a cup of sheet zinc, which itself forms the active electrode. The zinc cup is sealed with an asphaltic compound which prevents evaporation and keeps the cell so "dry" externally that it may be shipped, handled, and stored without danger of spilling its contents. The whole is surrounded by a cardboard container which serves to insulate the outer zinc shells of adjacent cells from each other when they are placed close together.

The construction of the Blue Bell dry cell, which has long been standard with Bell System companies, is shown in Fig. 181. This is cylindrical in form with external dimensions 2½.

by 6 inches. When new, it has a potential of about 1½ volts and an internal resistance of about 0.2 to 0.3 ohm. Its voltage decreases and its internal resistance increases with age. The capacity of the cell may be roughly stated as between 20 and 30 ampere-hours, and its life in telephone service is generally longer than the cells designed primarily for high rate of output.

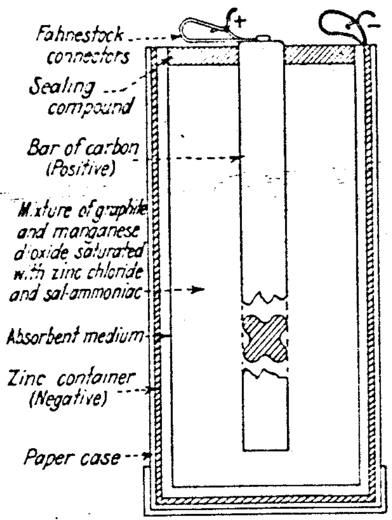


Fig. 181.—Cross-section of dry-battery cell.

The output characteristics of dry cells of the same size vary widely according to the uses for which they are principally intended. For them, long life and heavy duty are conflicting requirements. Some are purposely made for heavy duty with a high rate of output and relatively short life, and others, like the Blue Bell, for long life with a lower rate of output.

A cell of the most common size, 2½ by 6 inches, such as is ordinarily purchased for general use, will have an initial open-circuit voltage of from 1.5 to 1.6 volts, 1.55 being about average. It will give about 18 amperes for a few moments on short circuit and throughout its useful life a total of perhaps 30 ampere-hours as a maximum. Its effective voltage during its useful life may average about 1 volt and, if during this life it gives a total discharge of 30 ampere-hours, the fair energy rating of the cell will be about 30 watt-hours. This may not be taken as anything like an accurate figure, however, as the total watt-hour capacity of a cell depends not only on the make of the cell but on the rate of its discharge. Moreover, the voltage at which a cell ceases to be useful differs widely for different uses.

In the Bell System, it is recommended that a dry cell shall be rejected from service when it will not sustain a current of 0.125 ampere through a resistance of 5 ohms for 5 seconds. Other points to be kept in mind in connection with the maintenance of dry batteries are: They are essentially for open-circuit use and

should never be left in permanently closed circuits except those of very high resistance. The cardboard covering is the only insulation between the zinc electrodes of adjacent cells in a battery, and, if it is not kept dry, the cells affected are likely to be more or less short-circuited. New dry cells should never be connected in parallel with old ones, since the greater voltage of the new cell will cause a wastage of its energy through the old one. When the cells of a battery are to be connected in series-parallel relation, to gain more current capacity than that afforded by a single string in series, they may be connected in either of the ways shown in Fig. 182. If the cells were all exactly alike, the two methods would give the same results, but, since even new cells differ among themselves, the method shown at the right has been found to have some advantages with regard to the deterioration of the individual cells.

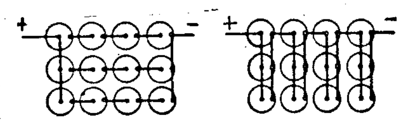


Fig. 182.—Series-parallel connection of cells.

Wet Batteries.—While the dry cell on account of its cleanliness, compactness, ease of handling, and other advantages has driven nearly all other types of primary cells from the telephone field, there are some requirements of telephone service that it cannot effectively meet. Heavy-traffic subscribers' stations on long lines sometimes require, for good transmission, more transmitter current than can reach them from the central-office battery or than can be supplied by dry cells without too frequent renewals. Again, the current required for motive power in the continuously vibrating pole changers required for ringing or that for operators' transmitters in busy small offices that have no commercial power often make desirable a primary cell with greater ampere-hour capacity than that of the dry cell.

For such purposes, a special form of the old Lalande cell, known as the "Edison primary battery," is used. In fact, it is about the only form of wet primary cell that has survived in telephone service in the United States. In this, in the size most used in telephone work, the electrodes consist of one plate of black oxide of copper (positive terminal) mounted between two parallel plates of zinc (negative terminal). The electrolyte is a solution of caustic soda (NaOH) in water. The copper oxide serves not only as an electrode but as a depolarizing agent, the liberated hydrogen in the electrolyte uniting with its oxygen to form water and free metallic copper. The chemical reaction on discharge is

$$Zn + 2NaOH + CuO = Na_2ZnO_2 + H_2O + Cu.$$

The container is a heavy rectangular glass jar, 5½ by 6½ by 12¼ inches, and is provided with a porcelain cover through which the terminals project. The electrolyte is covered with a layer of mineral oil to prevent evaporation and also chemical action with atmospheric elements.

This cell is good for either open- or closed-circuit work. It has a rated capacity of 500 ampere-hours. Its open-circuit voltage, when new, is 0.95 volt and between 0.6 and 0.7 volt when discharging at the rate of 30 milliamperes. Its maximum recommended output rate is 2 amperes for continuous discharge and 3 amperes for intermittent discharge, its pressure holding at about ⅔ volt under these larger discharges.

Secondary or Storage Batteries.—A secondary battery cell is one in which the chemical conditions are changed by the passage of current through it in one direction, and in which they tend in marked degree to revert to the original state when current is allowed to flow through it in the opposite direction. In other words, the passage of current from an outside source through the cell in one direction causes such electrochemical action to occur as to convert the two electrodes immersed in the electrolyte into an effective voltaic couple. This couple is then capable, by the reverse electrochemical action, of causing current to flow in the opposite direction when a suitable external conducting path is afforded. The electrical energy of the original or *charging* current is thus *stored* in the cell as chemical energy, to be given back later in the electrical energy of the *discharge* current. Hence the names "storage battery" or "accumulator."

In the storage cell almost universally used in telephony, the two electrodes, in their neutral state, are of lead and the electrolyte is of dilute sulphuric acid. The containers, in the form most used in telephone work, are glass jars or lead-lined wooden tanks.

The fundamental chemical action of the lead-acid-lead storage cell is about as follows: When the cell is in its charged state, the positive element is lead peroxide (PbO_2) and the negative is pure lead in a form known as "spongy lead." In discharging, the current from the positive to the negative plate through the external circuit passes from the negative to the positive through the electrolyte. In doing so, it breaks the sulphuric acid of the dilute electrolyte into its two component positive and negative ions H_2 and SO_4 respectively. At the negative plate, the SO_4 combines with the spongy lead to form $PbSO_4$. At the positive plate, a part of the oxygen of the lead peroxide combines with the hydrogen of the electrolyte forming water (H_2O) and converting the positive plate into pure lead. A similar breaking up of the sulphuric acid at the positive plate forms more water and converts some of the lead of that plate into lead sulphate by the same action that takes place at the negative plate. In chemical symbols, the principal actions on discharge are expressed as follows:

At the negative plate:

$$Pb + H_2SO_4 = PbSO_4 + 2H.$$

At the positive plate:

$$PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O.$$

Combining these the principal action within the entire cell on discharge is:

$$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O.$$

The action on charge is the reverse of that just described and may be expressed in chemical symbols by reading the last of the equations just given from right to left.

It will be noticed that, as the discharge progresses, more and more water is formed in the electrolyte, which thus becomes more dilute with lower specific gravity. The measurement of its specific gravity, as will be shown, constitutes one of the best methods of determining the state of charge of the cell.

The type of storage battery most used in telephone power plants is that known as the "chloride accumulator," manufactured by the Electric Storage Battery Company of Philadelphia. The name "chloride" was derived from a now discarded process in the manufacture of the plates which involved the use of lead chloride crystals.

In the chloride accumulator most used in telephone work, the positive plates are of the Manchester type, a portion of one being shown in Fig. 183. This consists of a grid of cast lead-antimony alloy, perforated with circular openings slightly tapered toward the center, into which are forced the rosettes or buttons of pure lead which constitute the active portions of the plate. These buttons are formed of strips of lead corrugated crosswise and rolled into spirals as shown in Fig. 184.

Originally these corrugated buttons were filled with lead chloride crystals which were then reduced to spongy lead electrolytically. Then the current was reversed and the spongy lead was reduced to lead peroxide. The method now used in forming the active material consists of inserting the buttons into the grid and then reducing a portion of their substance, in an electrolytic bath, first to spongy lead and then, by reversing the current, to lead peroxide. Several reversals of current are required. The expansive action of this forming process, combined with the "hour-glass" shape of the openings, securely locks the buttons in place.

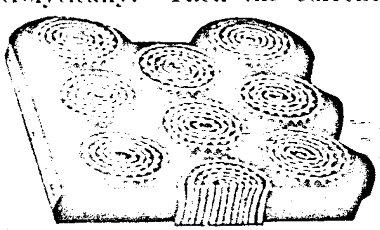


Fig. 183.—Portion of Manchester type of positive plate. (*Courtesy of Electric Storage Battery Company.*)

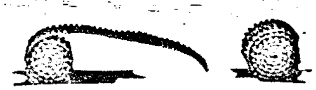


Fig. 184.—Method of forming Manchester button. (*Courtesy of Electric Storage Battery Company.*)

The alloy of which the plate grid is made resists the electrolytic action in the cell. The reserve lead in the buttons is gradually converted into active material as needed, to replace that which may be dislodged in service, and thus serves to prolong the life of the plate.

In combination with the Manchester positive, either of two different forms of negative plate may be employed. One is the so-called "box negative" plate. The grid of this is of lead-antimony alloy and is formed of a series of horizontal and vertical bars spaced about 1 inch apart, forming square pockets closed on both sides by perforated sheet lead. These pockets contain the active material in the form of spongy lead which is thus permanently retained in position. In this way, a strong acid-resisting framework is provided for the active material which must remain in a porous and finely divided state, in order that the capacity of the cell may not deteriorate.

The other form of negative plate used with the Manchester positive plates in chloride accumulators is the "pasted plate." In this, the grid consists of a series of heavy vertical bars joined

by lighter horizontal ribs. The active material is applied in the interstices thus formed in the form of a paste of lead oxide

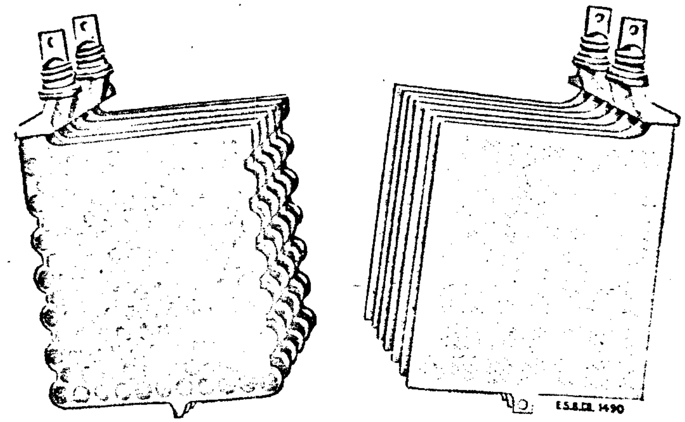


Fig. 185.—Group of positive and negative plates. (*Courtesy of Electric Storage Battery Company.*)

which cements itself strongly to the members of the grid. On charge, this paste gives up its oxygen and becomes spongy lead.

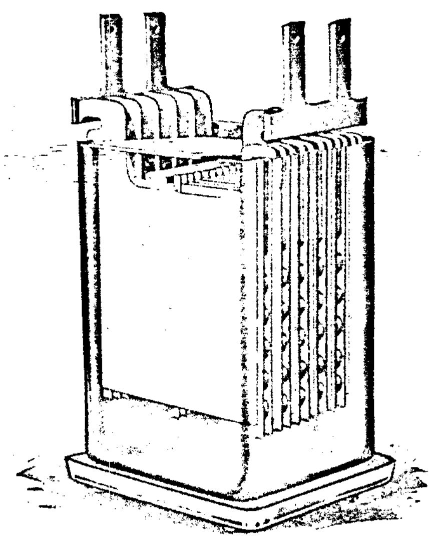


Fig. 186.—Complete storage cell—glass-jar type. (*Courtesy of Electric Storage Battery Company.*)

In all except very small capacity cells, a number of positive and also negative plates are connected together to their respective cell bus-bars, so that when in place in the cell they will be interleaved without touching. Such groups, one of Manchester positives and one of box negatives, are shown in Fig. 185. When groups of interleaved positive and negative plates are thus used, there is always one more of the negative than of the positive plates. Figure 186 shows a complete cell comprising two such groups of plates, with somewhat different forms of terminal connections, mounted in a glass jar.

The following table shows the chloride accumulator cells that have been adopted by the American Telephone and Telegraph Company as standard for the use of Bell System companies.

STANDARD CHLORIDE ACCUMULATORS FOR TELEPHONE USE

Type	Number of plates	Size of plate, inches	Amperes per positive plate*
CT	2	5 by 5	1½
PT	2	8¾ by 5	3
ET	2	7¾ by 7¾	4½
D	3 to 13	6 by 6	2½
E	5 to 15	7¾ by 7¾	5
F	9 to 27	11 by 10½	10
G	11 to 85	15 5/16 by 15 5/16	20
H	21 to 95	15 5/16 by 30 11/16	40

* At normal charging rate or 8-hour discharge rate. To find the discharge rate for the D, E, F, G, and H types, take one less than the number of plates, divide by 2, and multiply by the amperes per positive plate.

Discharge Rates and Ampere-hour Capacity.—Storage batteries are given "normal" capacity ratings expressed in the number of ampere-hours they can give under certain working conditions. The actual ampere-hour capacity of a given cell will vary somewhat with different rates of discharge, and it is therefore customary to base it on the number of ampere-hours it can deliver at such a rate as will discharge it in 8 hours.

The cell shown in Fig. 186 is a type F cell with twenty-one plates. The table on page 345 shows for cells of this type, equipped with from nine to twenty-seven plates each, the current in amperes that will discharge them at different rates of discharge.

This well illustrates the falling off in ampere-hours capacity that occurs when cells are discharged faster than their normal 8-hour rate. For example, it will be seen that the 21-plate cell will deliver 800 ampere-hours on an 8-hour basis, 700 on a

CURRENT FROM TYPE F CELLS AT VARIOUS RATES OF DISCHARGE

Number of plates	9	11	13	15	17	19	21	23	25	27
Discharge in amperes for:										
8 hours	40	50	60	70	80	90	100	110	120	130
5 hours	56	70	84	98	112	126	140	154	168	182
3 hours	80	100	120	140	160	180	200	220	240	260
1 hour	160	200	240	280	320	360	400	440	480	520
Normal charge rate	40	50	60	70	80	90	100	110	120	130

5-hour, 600 on a 3-hour, and only 400 on a 1-hour basis. There is no particular harm, as far as the battery itself is concerned, in discharging them at any rate that the current-carrying capacity of the connected wiring and apparatus will withstand. Discharges of enormous amperage may occur, depending only on the resistance and carrying capacity of the external circuit, but always at a sacrifice of ampere-hour capacity.

Storage-battery Voltage.—The voltage of each cell is approximately 2, when on open circuit, but is higher when the battery is being charged and lower when being discharged. The nominal voltage of a battery may be taken as the number of cells multiplied by 2. The voltage at any time on discharge or charge depends upon several factors, such as the current rate, the state of charge or discharge, and the temperature. No general averages to cover all conditions can therefore be given. In usual 6- to 8-hour discharge service, the average cell voltage during discharge is roughly 1.95 volts with a final voltage of about 1.75 volts. As soon as the cell is put on charge, its voltage rises to about 2.15 volts and then increases during charge until at the end it is between 2.4 and 2.7, depending upon local conditions. The average voltage during entire charge is usually considered 2⅓ volts.

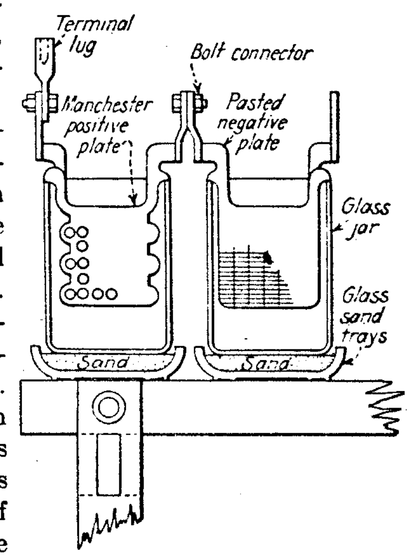


FIG. 187.—Method of connecting and mounting cells with glass jars.

Mounting and Connecting Cells.—The smaller types of cells, up to and frequently including Type F, employ glass jars.[1] A typical method of setting up and connecting such cells is shown in Fig. 187, which shows one end of a battery of Type E chloride cells. Lugs, cast integral with the plate grids, serve to support the weight of the plates by resting on the upper edges of the jars. Such cells are usually provided with strap-type terminals adapted to be connected to the terminals of adjacent cells by bolts as shown. Each individual cell rests on its own sand tray, usually of glass though sometimes of wood in the larger sizes of cell. The sand tray helps to prevent moisture from causing leakage between the cells.

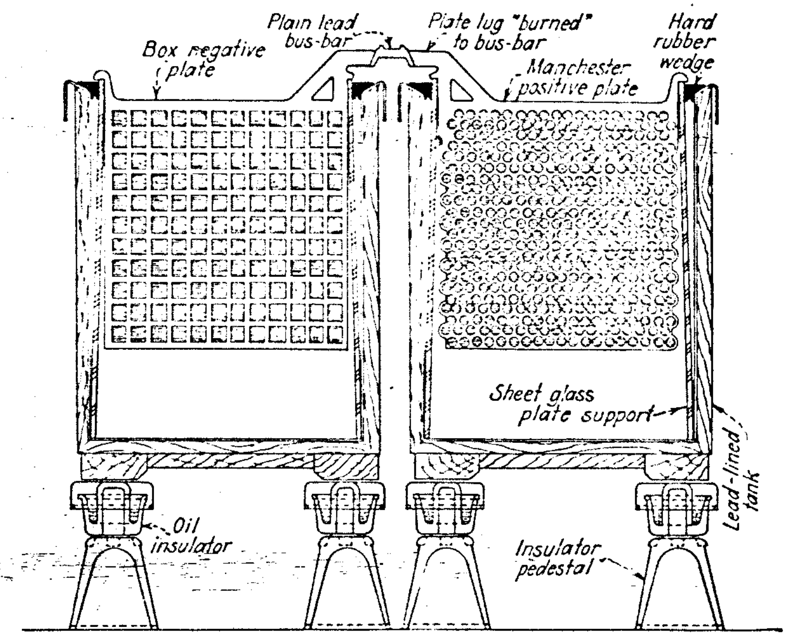


FIG. 188.—Method of connecting and mounting cells with lead-lined tanks.

The larger types of cells are almost always in lead-lined tanks to avoid the greater danger of breakage inherent in larger glass jars. Figure 188 shows part of a typical installation of Type G cells. The plates are supported within their tanks by heavy plate-glass sheets set vertically, against the upper edges of which the plate lugs rest. The cells themselves are mounted on insulation pedestals surmounted by oil insulators, as shown. After the positive and negative plates have been put in place in the tanks, their terminal lugs are "lead-burned" to a channel-shaped lead bus-bar, so that the two connected plates and the bus-bar between them form a continuous integral structure. The process of lead burning consists in first thoroughly cleaning the surfaces of the parts to be joined and then fusing them together in an integral weld by means of an oxy-hydrogen or similar gas flame or an electrically heated carbon.

[1] Formerly open glass jars, such as that of Fig. 186, were used. Now cells of types CT to F inclusive are also available in sealed glass jars.

Specific Gravity of Electrolyte.—As has been stated, the relative amount of sulphuric acid and water in the electrolyte varies with the state of charge of the battery, the electrolyte becoming more strongly acid, and therefore of greater specific gravity, as the charge progresses. This changing specific gravity of the electrolyte affords the best single index of the state of charge at any time. The other index is, of course, the voltage, the range of which during charge and discharge has already been given.

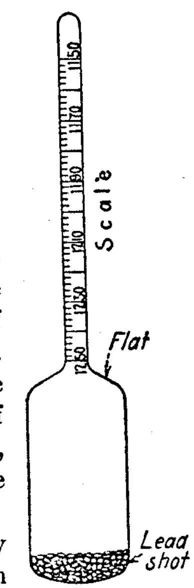


FIG. 189.—Storage-battery hydrometer.

The specific gravity is most conveniently measured by a hydrometer such as is shown in Fig. 189. The weight at the bottom makes the hydrometer float in an upright position and the stem is so graduated that the reading at the surface level of the liquid will indicate the specific gravity. Of course, the greater the specific gravity the higher in it will the hydrometer float. The specific gravity of pure sulphuric acid is 1.8342 but the electrolyte, before it is put into the cells, is diluted with water until its specific gravity is 1.210 at a temperature of 70°F. Corrections in hydrometer readings are required when taken at other temperatures, since the mixture expands with heat and lowers its specific gravity. A rise of temperature of three degrees Fahrenheit means a reduction of 0.001 in specific gravity and *vice versa*. Thus, as an example, if the temperature is 85°F., the hydrometer reading of the mixture would be reduced five "points" or to 1.205. Temperature corrections on this basis are required on all storage-battery hydrometer readings.

After placing the electrolyte in the cells to a height of about 1 inch above the top of the plates, the battery is given an initial overcharge and is then ready for regular operation. During the initial charge, as well as in subsequent charges and discharges in regular operation, the specific gravity of the electrolyte, the voltage of the battery, and the amount of gassing observed are all indications of the state of charge and should all receive due consideration. Both the specific gravity and the voltage serve as indications of the proper limits of charge and discharge, but, after both voltage and corresponding specific gravity readings have once been determined throughout the entire range, the specific-gravity readings afford the best indices for the subsequent routine handling of the battery.

Ordinarily, the variations in all of the cells in a battery will be the same and it is therefore convenient to choose one cell, termed a "pilot cell," for taking the regular specific-gravity readings and to consider these readings as representative of all the others. The readings of the other cells need then be taken only occasionally to assure that their individual performances are consistent.

It is not possible to state for all batteries the limits between which the specific gravity of the electrolyte will vary on charge and discharge because, among other things, the ratio of the amount of electrolyte to the amount of plate surface varies widely, according to whether a cell is equipped with its full quota of plates or is only partially equipped, with an allowance for the later addition of plates to meet the requirements of growth. Obviously, the amount of water withdrawn from the electrolyte on charge and restored to it on discharge will be smaller for a cell partly equipped with plates than for one fully equipped, with a consequently smaller change in the specific gravity of the entire volume of electrolyte. The specific gravity of the electrolyte at a temperature of 70°F., fully charged and with the surface level 1 inch above the plates, should be between 1.200 and 1.215. For the reasons given in the preceding paragraph, the allowable drop below these full-charge figures cannot be generally stated for all cases. For chloride cells of Types F, G, and H, on an 8-hour discharge basis, they range from 57 points for the Type H cell fully equipped down to 22 points for the Type F cell only partially equipped, depending on the size of the tanks and the proportion of their plate capacity that is installed.

Floating Method of Operation.—Modern practice in telephone storage-battery work tends toward the "floating" method of operation, in which the charging machines are kept in operation throughout the 24 hours of the day, at a rate sufficient to take care of the exchange load plus the internal losses of the battery. This is "continuous floating" and is Bell practice. Some of the independent companies vary this practice by charging throughout all except the hours of very light night traffic at a rate just sufficient to take care of the average exchange load throughout the 24 hours plus the internal losses in the battery. In these ways, the battery is kept nearly fully charged at all times. This method has been found to give longer life to the battery and to maintain a more nearly constant voltage than the older "charge-and-discharge" method of operation, in which the battery was carried through a wider cycle of charge and more complete discharge at regular intervals.

For floated chloride batteries of the types used in telephone power plants, the voltage at the battery terminals should average very close to 2.15 volts per cell and should be kept between 2.10 and 2.20 volts per cell. If continually below 2.10, the charging is insufficient, in which case gravity readings taken from time to time will show a gradual falling off. If continually above 2.20, charging is excessive, in which case unusually frequent addition of water will be required and short life will result. Variations outside of these limits, of short duration, are not harmful and may occur as incidental to normal good operation.

General Rules.—In setting up, giving the initial charge, and in subsequent handling, the directions of the maker for the particular battery and the particular type of service involved should be followed. A few very general rules, applicable to all types and services may, however, be given:

Keep the outside of the battery clean and dry.

Keep the plates always covered with solution. Do this by adding regularly either distilled water or water that has been competently approved. Do not fill higher than 1 inch above the top of the plates.

Except in emergency, stop discharge before the voltage becomes too low for satisfactory service. The drop in specific gravity should not exceed the number of points specified by the manufacturer for the particular battery.

Always charge at rates low enough to keep the cell temperature below 110°F. This applies particularly to the initial charges of the battery. While the cells are gassing never charge at rates higher than the normal 8-hour rule.

Ventilate battery room when charging and never bring a lighted match or other exposed flame near the battery.

Never add electrolyte or acid, except to replace electrolyte that has been spilled or otherwise lost out of the cell. Never allow any foreign matter of any kind to get into the cells.

Handle strong sulphuric acid with extreme care. In diluting, carefully pour the acid into the water—*never the water into the acid.*

Ammonia or soda solution or powdered air-slaked lime will neutralize the effects of spilled acid if applied immediately.

Counter Electromotive Force Cells.—Storage batteries in power plants of machine switching exchanges require somewhat closer voltage regulation than those in manual exchanges. Either of two plans may be used for compensating for the rather wide differences of battery voltage during periods of charging and discharging. One of these is to switch a number of counter electromotive force cells into the discharge leads, while charging, to offset the rise in voltage caused by the charging current.

Counter electromotive force cells are simply lead-acid-lead cells, like storage cells, except that they have no active material in their plates. When placed in series with a main battery, they set up an electromotive force of about 2.8 volts per cell, in opposition to the discharge current. They are no more efficient than mere resistance in opposing current flow, but they have two great advantages over resistance, in that they introduce practically no impedance in the common-supply lead to the talking circuits and that the voltage drop through them does not vary greatly with the current. The energy absorbed in them is spent in electrolyzing the water they contain. For this reason, they require frequent water replacement.

When counter electromotive force cells are used, arrangements are provided for switching one or more of them into or out of the main battery discharge circuit, so that the opposing electromotive force may be made available to the degree desired during periods of charging.

End Cells.—This term, in storage-battery parlance, has reference to one or more regular cells at one end of the battery that may be switched out of the series for the purpose of reducing the voltage. End cells are used in battery-voltage regulation in the reverse manner from counter electromotive force cells, being included in the battery to increase rather than reduce its total voltage. During charge, therefore, when the voltage exceeds the desired limit, one or more end cells are cut out, to be cut in again while not charging or when the voltage falls too low.

With floated batteries in power plants of machine-switching telephone exchanges, the end-cell method is now more commonly used in voltage regulation than the counter electromotive force cell method. While the load is being carried by the charging equipment and the batteries are charging, the extra voltage of the end cells is not needed; but when the load is being carried by the battery alone (in case the charging equipment is out of commission), one or more end cells may be brought into play to keep the battery voltage up to the required limit.

Charging Machines.—The dynamos in the telephone power plant that are used for charging the storage batteries must, of course, generate direct current. Before discussing their other characteristics, we may briefly refer to direct-current dynamos in general. The electromotive force set up in the armature is, as in the case of the magneto generator[1] already considered, caused by the movement of the armature conductors across a magnetic field of force. Unlike the magneto generator, however, the magnetic field, in which the armatures of most dynamos revolve, is derived from electromagnets instead of permanent magnets. Much stronger fields are thus obtained than can be secured from permanent magnets.

The electromotive force and current generated in the armature conductors are essentially alternating in character because, as the armature revolves, its conductors successively cut through the field in alternate directions. In order to "straighten out" the electromotive force and current in the circuit supplied by the dynamo, a commutator is provided on the armature shaft which, with its cooperating brushes, reverses the connection between the outside circuit and the successive armature con-

[1] "Manual Switching and Substation Equipment," pp. 68–75.

ductors just at the times the electromotive force and current in the armature conductors are reversing. The two simultaneous reversals offset each other, with the result that the electromotive force at the brushes does not change its sign and only unidirectional current can flow from the dynamo through the external circuit. The provision of the commutator on direct-current dynamos and motors for reversing the connection between the armature conductors and the line at each half cycle of armature current is the fundamental distinction between direct- and alternating-current dynamo electric machines. Alternating-current motors for driving the charging dynamos are usually of the induction type, requiring no connection between stator and rotor. The rotor usually has a squirrel-cage winding.

The current for energizing the field magnets of a direct-current dynamo may be derived from an outside source, such as a battery

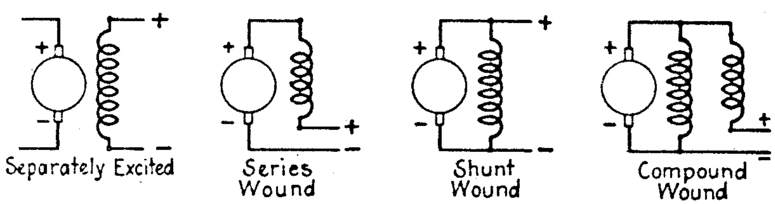


FIG. 190.—Schematic diagram of direct-current generators.

or another direct-current dynamo, in which case the machine is said to be "separately excited." It is more common, however, to energize the field coils of a direct-current machine by the current generated in its own armature. In this case, it is said to be "self-excited." In self-excited direct-current machines, there are three principal ways of associating the field and armature windings, resulting in important differences in operating characteristics. In the "series-wound" machine, the field winding is in series with the armature, so that all the current generated in the armature passes through the field and thence through the load. In the "shunt-wound" machine, the field winding shunts the armature, so that the current generated in the armature divides between the field winding and the load. The compound-wound machine has two field windings, one in series with and the other in shunt with armature. The four types of direct-current machines, separately excited, series wound, shunt wound, and compound wound, are represented schematically in the four diagrams of Fig. 190. The characteristic curves showing

the variation of voltage at the machine terminals as the load increases, for these four types, are shown in Fig. 191.

The electromotive force induced in the armature of a dynamo is dependent, among other things, on the strength of the magnetic field in which the armature revolves. In the separately excited machine, therefore, the electromotive force generated is not affected by changes in the armature current, the field being energized by current from an independent source. The comparatively slight falling off in the voltage generated as the load increases, noticeable in the curve of this machine, is due principally to the IR drop through the armature conductors.

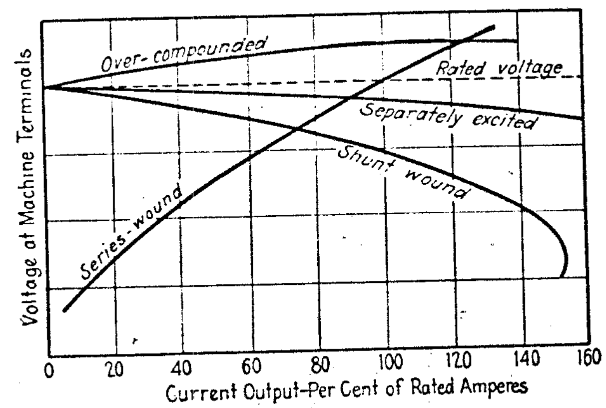


FIG. 191.—Characteristic curves of direct-current generators.

With all the self-excited machines, however, the voltage at the machine terminals is affected in greater or less degree by changes in the connected load. In the series-wound machine, the field current varies directly with the load, since all of the generated current passes through the field. There is, therefore, a marked rise in armature electromotive force as the load increases. The reverse is true of the shunt-wound machine. Here the load shunts the field winding and, as it increases, tends to reduce the field current and therefore the field magnetism, with a consequent falling off of armature electromotive force. In the compound-wound machine, the series and shunt windings both contribute to the field magnetism and it is the intent that, as the load increases, the fall in armature voltage characteristic of the shunt field will, to a greater or less degree, be offset by the rise characteristic of the series field. The upper curve of Fig. 191 is for an "overcompounded" machine, that is, one in which the series-field effect predominates, so that there will be a slight rise in voltage as the current output increases to meet an increasing load.

The generator most used for charging storage batteries in telephone power plants is of the shunt-wound type. Of the standard types of machines it will be seen from the characteristic curves of Fig. 191 that the shunt machine best meets the requirements, since the voltage of the machine *automatically* increases as the load on it decreases.

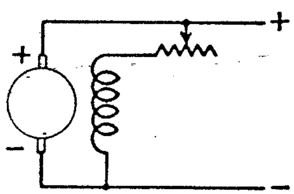


FIG. 192.—Shunt-wound generator with field rheostat.

The charging generator commonly has a voltage about 30 per cent above that of the rated voltage of the battery it is to charge. In addition to its inherent voltage regulation, the voltage of a shunt-wound machine is subject to further modification for a given speed by adjusting the current through its field winding. This is usually done by means of a rheostat in series with the field winding, as shown in Fig. 192.

The electromotive force of the ordinary commercial type of direct-current generator, while constant enough for power, lighting, and most other purposes, has a series of minute rapidly recurring variations that tend to cause noises in connected telephone circuits. These periodic noise-producing variations may be due to slight differences of potential of the different commutator bars as they pass successively under the brushes, to variations in magnetic flux due to the passage of successive teeth of the armature core under the pole pieces, to mechanical vibrations of different parts of the machine with respect to each other, or to a slight eccentricity of the armature with respect to the field pole pieces. This lack of "smoothness" in the electromotive force and current of ordinary commercial machines has until recently prevented their general use as charging machines in telephone power plants, for reasons that have been pointed out in Chap. VIII of the preceding volume.[1]

Special Smooth-current Generator.—To meet the specific need for telephone charging generators with regard to the greatest possible smoothness of current, the Western Electric Company

[1] "Manual Switching and Substation Equipment," pp. 254–267.

developed a line of special telephone generators which has long been standard equipment in power plants of the Bell Companies. In these machines, the armature winding and the commutator are highly subdivided, resulting in many more commutator segments than are usually provided. This reduces the changes in potential that occur while a commutator segment is in contact with its brush and also those occurring when the brush passes from one segment to another. Metal gauze brushes instead of the more common self-lubricating carbon variety are used, further contributing to the almost complete elimination of "commutator noise." Another feature tending toward the production of a "quiet" current is that the armature conductors are wound on a smooth instead of a slotted core. This avoids the periodic changes in magnetic flux, as the core teeth of a slotted armature pass under the pole pieces, and, in large measure, eliminates "slot noises," as the current fluctuations and harmonics due to that cause are called. In addition to these two special features of design, great attention is paid to accuracy in manufacture in so far as it might affect eccentricity, lack of balance, or smoothness of mechanical operation. As a result, these machines are remarkably free from electrical noises and from room noises as well. These advantages, however, are rather costly. The first cost of the machines is more than double that of the ordinary commercial types of equal rating. Some loss of efficiency is involved in the design and the machines are somewhat more expensive to maintain, principally on account of the metal brushes.

The current and kilowatt ratings on a 30-volt basis, and efficiencies of these special telephone charging machines are given below:

SPECIAL TELEPHONE-TYPE CHARGING GENERATORS

Type	M-1	M-2	M-3	M-4	M-5	M-5½	M-6	M-8	M-10	M-15
Amperes	25	50	100	175	225	400	600	800	1,000	1,500
Kilowatts	0.75	1.50	3.00	5.25	6.75	12.0	18.0	24.0	30.0	45.0
Efficiency	60.00	69.50	74.00	77.20	78.50	81.2	83.4	84.8	85.0	85.0

One of these Type M generators directly coupled to an induction motor is shown in Fig. 193. The much larger size of the generator than of the motor is to be noted. This is due, in large measure, to the fact that the special features in the design of this generator result in lower flux and current densities. The size, in combination with the lower-quantity production and other factors involved in the special design, contributes to its greater cost.

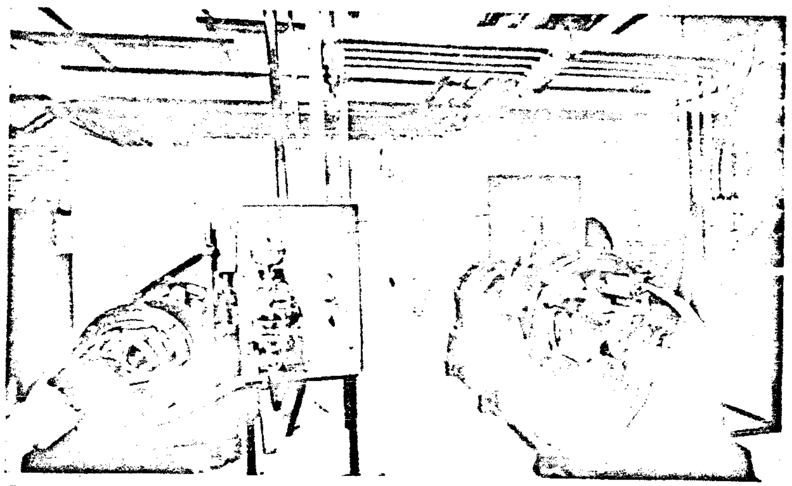


FIG. 193.—Type-M charging machine driven by induction motor. (*Courtesy of Bell Telephone Laboratories.*)

Commercial-type Charging Generator.—Figure 194 is taken from an oscillograph record of the momentary voltage variations in the output of a commercial-type direct-current generator operating nominally at 60 volts. Such variations are not objectionable in ordinary power and lighting work, for which these machines were originally intended, but, as all of them shown on this record are within the audible range of frequency, it is not difficult to see that, unless effectively smoothed out, the currents flowing in telephone circuits from such a source would be extremely noisy.

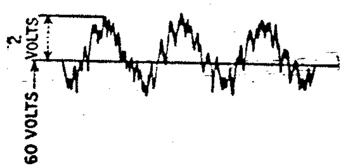


FIG. 194.—Voltage wave of typical commercial-type generator.

The development of the electrolyte condenser,[1] whereby very large capacitance may be had in small space and at little cost, led to a practical method of making these commercial-type generators available for charging purposes in telephone power plants. The method already described in connection with Fig. 246 of the preceding volume,[2] may be again alluded to here

[1] "Theory and Elements," p. 429.
[2] "Manual Switching and Substation Equipment," p. 266.

in connection with Fig. 195. The reactance coil and condenser, located as near the battery terminals as possible, form together a low-pass filter for the common talking-current supply lead, which effectively eliminates the noisy alternating components from the charging machine current.

The required product LC for determining the desired cut-off point of this filter is, as stated, obtained by using a high capaci-

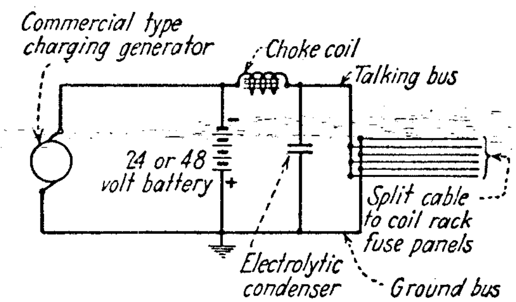


FIG. 195.—Filtering current of commercial-type generator.

tance C and a comparatively low inductance L. The high capacitance is easily obtained by the electrolytic condenser, but even the low inductance needed presents a more formidable problem, particularly in large power plants, because of the necessity that the reactance coil must carry all the current for all the talking circuits continuously. In order to get the required direct-current carrying capacity, the copper conductors must be heavy and short, necessitating comparatively few turns. Then, in order to secure the desired reactance with so few turns, a large amount of high-permeability iron is required in the core and the return part of the magnetic circuit.

Reactance coils designed for the use of the Bell System in power-plant filters range from the smallest, weighing 50 pounds with carrying capacity of 25 amperes and inductance of 2.7 millihenries, up to the largest, weighing 2½ tons with carrying capacity of 1,000 amperes and inductance of 0.98 millihenry.

The design and construction of these coils are interestingly dealt with in an article by A. R. Swoboda entitled A Thousand-Ampere Choke Coil.[1] The largest coil so far developed by the Bell Laboratories was that for the group of telephone offices of the New York Telephone Company, in the Barclay-Vesey

[1] *Bell Laboratories Record*, p. 109, November, 1929.

Building in New York City. It has a current capacity of 1,000 amperes, its winding being made up of a conductor of 44 strips of annealed copper 1 inch wide by 0.052 inch thick. The total direct-current resistance is only 0.00032 ohm, while the inductance is about 1 millihenry. The magnetic circuit is made up of thin laminations of silicon steel, there being four air gaps, each $^{15}/_{32}$ inch wide, separating the two ends of the core from the two branches of the return magnetic circuit. The coil complete stands over 4 feet high on a base 3 feet square and weighs over $2\frac{1}{2}$ tons.

FIG. 196.—Commercial-type generator driven by synchronous motor. (*Courtesy of Bell Telephone Laboratories.*)

Such coils and the condensers for the talking-supply filter equipment are, of course, expensive, but the saving made by the use of commercial-type generators instead of the highly specialized telephone generators much more than justifies their cost.

One of the commercial-type generators driven by a synchronous motor is shown in Fig. 196. The generator in this is seen to have been reduced to a size not differing greatly from that of its motor.

The Diverter-pole Generator.—Recently an interesting type of generator has been developed by the Electric Products Company, of Cleveland, Ohio, which is intended to have characteristics specially desirable for floating a telephone-exchange battery. This is called the "diverter-pole" generator, deriving its name from the fact that it has small poles midway between the main poles, each of these being magnetically attached to the hindward tip of its adjacent main pole. These intermediate poles divert a small portion of the main flux at no load and are equipped with a series coil, so that, as the load comes on, this diverted flux is re-diverted to the armature, becoming useful flux and compensating for the voltage loss due to speed drop and internal IR drop, thereby tending to give constant voltage regardless of load.

This generator is claimed to give a more constant voltage than the compound-wound generator, since the magnetic changes necessary to produce the compensating magnetic flux occur in a portion of the magnetic circuit which is not magnetically saturated, and hence there is more nearly a straight-line relation between the change of current in the series coils on the diverter poles and the change in the useful magnetic flux. With the compound generator, there is not a straight-line relation between the change of current in the series winding and the change of magnetic flux, so that the voltage curve has an appreciable hump. The straight voltage curve of this machine, when charging a floated battery, is intended to give a greater stability of action than can be secured with a compound-wound machine. Moreover, it is said to be safe against reversal of polarity in case of back feed from the battery, functioning as a motor as safely as a shunt generator.

The actual performance of one of these machines, through a daily cycle of operation in charging a telephone-exchange battery, is shown in Fig. 197. The battery in this case comprised 22 cells of 1,280 ampere-hour capacity, its nominal voltage being 48. Here the generator is shut down during the night when the operating load is light. When reconnected to the battery, it starts charging at a high rate, returning the night discharge within 3 hours. During the remainder of the day, the generator carries the whole exchange load, the battery merely floating and receiving the small amount of current necessary to keep it fully charged ready for an emergency. Meanwhile, the voltage on the exchange bus-bars is kept well within operating limits without supervision.

Charging Machine Motors.—As a rule the charging generators are driven by directly coupled electric motors, each generator with its motor constituting a motor-generator charging set of which typical ones are shown in Figs. 193 and 196. For emergency or "stand-by" purposes, however, these electrically driven sets are often supplemented by others, wherein the motor is a gas engine, either belt-connected or directly coupled to

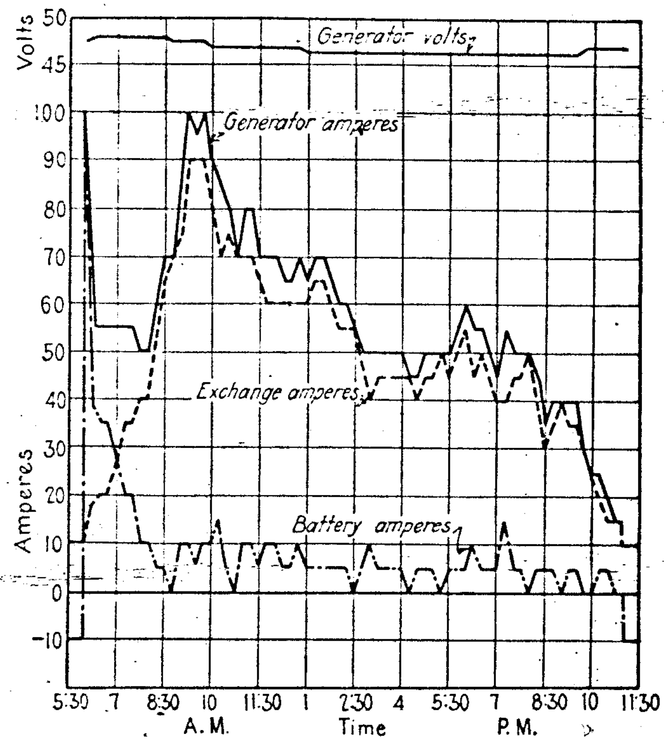


Fig. 197.—Diverter-pole generator charging floated central-office battery.

the generator. Sometimes the gas engine, instead of furnishing power directly to its charging generator, drives another generator capable of furnishing the same kind of current as the regular commercial supply, in which case either of the two charging generators may be run either from the regular power mains or from the emergency gas-engine-driven generator.

Sometimes two entirely separate sources of outside electric power are available, one of which can serve as the regular and the other as the emergency supply. If one of these sources is

alternating current and the other direct, the motors of both charging sets may be made alike, each adapted for the alternating-current source. In this case, another motor-generator set is provided for converting the direct current from the outside source into alternating current like that obtained from the outside alternating source. In this way, either charging set may be run from either of the outside sources.

Suitable electric motors for any type of commercial power current are available, since telephone battery-charging service imposes no especially exacting requirements on them. They should, of course, be of ample power to secure the full output of the generators and of good efficiency and regulation, as in other lines of service.

The availability of the synchronous motor as the driving element in charging sets has been used in some large offices to improve the power factor of an entire installation. This motor can be operated at a leading power factor and thus tend to offset the lagging current of induction motors used for other purposes in the central-office building.

The importance of the internal-combustion engine in telephone power-plant practice is due to the basic policy, generally adopted by telephone managements, of giving uninterrupted service, as far as is humanly possible, even in the face of calamities which may disable other public services. In the largest telephone offices, the storage battery acts as a reservoir for enough energy to supply the full load of the switchboard and associated equipment for at least three hours, and in smaller offices enough to meet all demands for one or more days. The storage battery, therefore, can of itself readily take care of any minor interruptions of the outside power supply, but it is considered essential that provision be made for bridging longer periods, such as might be caused by earthquakes, fires, floods, or other calamities. It is as a reserve source of primary power to safeguard the telephone service during these longer periods of outside power failure that the gas engine is often used.

Mr. H. H. Lowry, in an article on which I have freely drawn, gives much information about reserve power equipment in the Bell System.[1] He cites a case where a flood, having put out the fires of the city power station, reached also the telephone

[1] Power Equipment for Safeguarding Telephone Service, *Bell Laboratories Record*, p. 93, May, 1926.

building and put its emergency plant out of commission. But in spite of this, a gas engine saved the day. The rear wheels of a Ford were jacked up and belted to the charging generator which had not been reached by the flood.

The engines used by the Bell System for emergency plants range in size from small single-cylinder affairs, such as have been developed for farm-lighting purposes, up to large high-speed multi-cylinder ones of 325 horsepower. Figure 198 shows a Delco house-lighting set, consisting of a small kerosene engine directly coupled to a direct-current generator. Sets of this kind, while developed for other than telephone purposes, have been used to a considerable extent in capacities ranging from 750 watts up to 2½ kilowatts in small common-battery central offices. To make their current sufficiently smooth for charging purposes, it is necessary to use choke coils in the charging circuit.

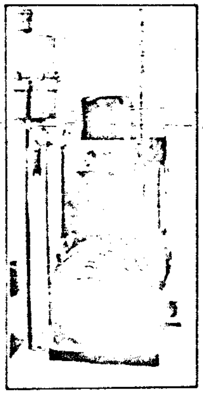


FIG. 198.—Small direct-connected emergency set.

In the earlier manual offices, where a power plant was required to serve only one large switchboard unit, engines of not over 50 horsepower sufficed and simple, slow-speed, single-cylinder engines of commercial design were employed, each belt connected to its charging generator. Later, however, where several full-size switchboard units were housed in the same building and served by a common power plant, larger engines were required. The advent of the power-driven machine-switching system served further to increase the power required. To meet these demands, two-, three-, and four-cylinder engines were developed in sizes from 50 up to 325 horsepower. These, because of their comparatively slow speeds, were usually belt-connected to the charging generators. One of these installations with a two-cylinder engine is shown in Fig. 199.

This type of plant, however, on account of the amount of floor space occupied and the head room required in case of repairs on the engine, left room for improvement. Present practice tends toward the use of multi-cylinder engines direct-connected to alternating-current generators, as shown in Fig. 200. The engine is started by an electric motor through a Bendix drive, as in automobile and motor-boat practice.

This type of direct-connected sets has been developed with four-, six-, and eight-cylinder engines rated from 25 to 200 horse-

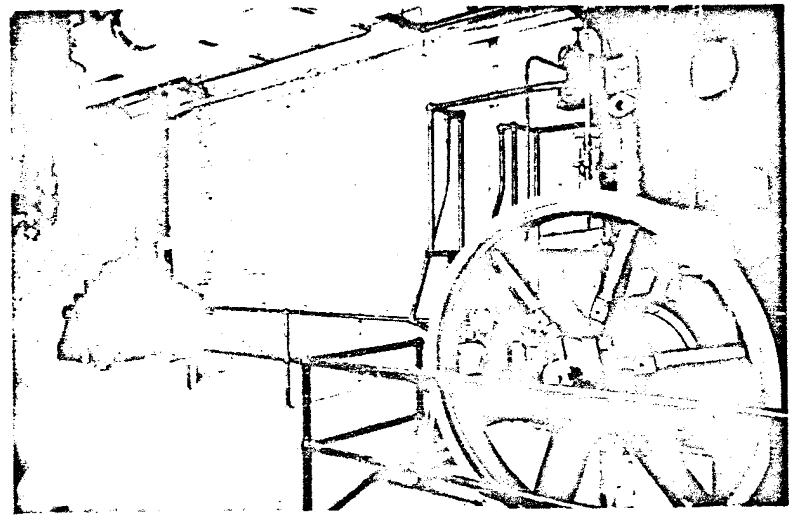


FIG. 199.—Two-cylinder gas engine belted to charging generator. (*Courtesy of Bell Telephone Laboratories.*)

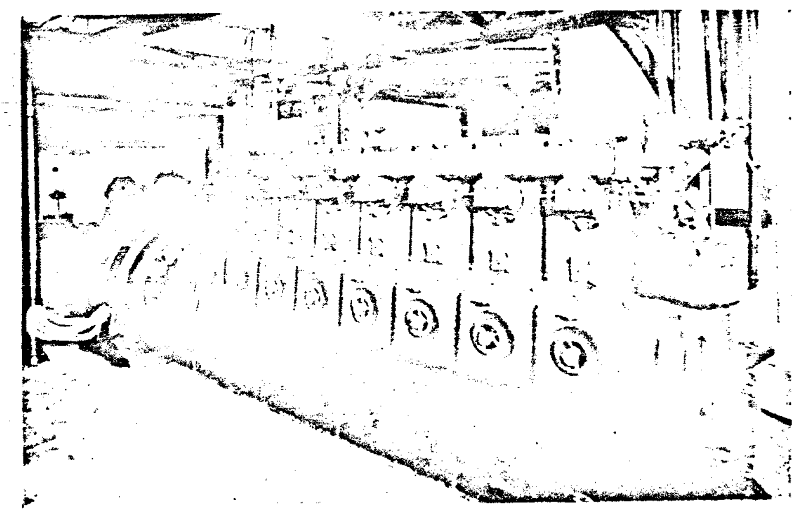


FIG. 200.—Two-hundred-horsepower gas engine direct-connected to alternating-current generator. (*Courtesy of Bell Telephone Laboratories.*)

power. The set shown in Fig. 200 is of the 200 horsepower rating. Emergency plants rated as high as 800 horsepower are contemplated, thus requiring in one plant as many as four such sets. In practically all, except the small farm-lighting sets, the engines run from gas taken from the city gas mains, but failure of this source is provided against by the provision carburetors for the use of gasoline as in automobiles.

As stated earlier in this chapter, the gas engine sometimes drives the charging generator, in which case the emergency plant constitutes, in itself, only a reserve charging set. In the larger multi-office installations, however, the more common practice is to have the gas engine drive an alternator capable of delivering current that is equal in amount and kind to that furnished by the regular outside service. When this is done, the emergency plant constitutes, in itself, a complete reserve power supply for all uses of the central-office building. Under this plan, the lighting, elevator, and other services of the building need not be interrupted by a failure of the outside power.

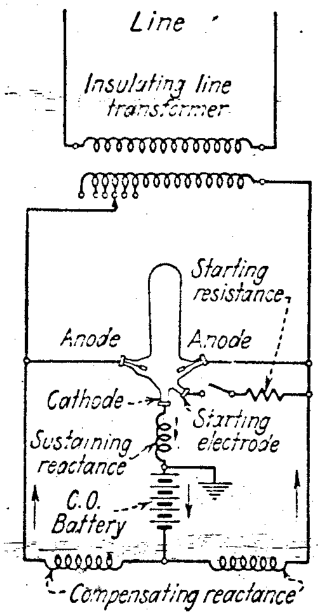


FIG. 201.—Principles of mercury-arc rectifier.

"Static" Rectifiers.—So far we have considered only dynamo electric machines driven by various kinds of motors as sources of current for charging the central-office batteries. All of these depend on the movement of a coil of wire in a strong magnetic field. Another important class of battery-charging devices requires consideration. These are static in their action, requiring no mechanically moving parts. Their operation depends on the fact that certain devices, like the two-electrode vacuum tube, have the peculiar property of conducting electricity in one direction and not in the other, that is, of unidirectional conductivity. These devices have relatively small outputs and for this reason are mainly used in smaller plants. They are generally long lived and efficient, but their principal value in telephone power-plant service lies in the fact that their operation, involving no moving parts, requires a minimum amount of attention and other maintenance expense. The

mercury-arc, "tungar," and copper oxide rectifiers are prominent examples of this static class of charging devices.

The Mercury-arc Rectifiers.—The principles of the mercury-arc rectifier may be considered in connection with the simplified diagram of Fig. 201. The rectifier tube consists of an exhausted glass bulb containing two anodes and a cathode, the latter consisting of a small pool of mercury at the bottom of the tube. As shown, the two anodes are connected across an alternating-current source of proper voltage and the cathode with one terminal of a circuit that is to be supplied with direct current. After starting conditions have been established, current will flow alternately from each of the two anodes to the cathode, and never in the opposite direction. The cathode thus becomes a source of positive potential, current flowing from it through the direct-current circuit (battery) and returning to the respective sides of the alternating source as they alternately become negative. The tube thus acts as two two-element vacuum tubes would act when connected for full-wave rectification.[1]

In order to cause a continuance of current flow during the intervals while the potential of the alternating source is too low to sustain it, a reactance or "sustaining" coil is put in the circuit in series with the cathode, which by its inertia effect prolongs the current from one anode until the electromotive force at the other anode had built up sufficiently again to sustain it. Other reactance coils assist in smoothing out the current so that it is sufficiently quiet to permit charging while the battery is furnishing current to the battery circuits.

The mercury-arc rectifier is not inherently a self-starting device. For this reason, an auxiliary or starting electrode is provided near the surface of the mercury, but normally out of contact with it. To start the action, the tube is tilted until the mercury completes a circuit through this electrode. The arc which follows the breaking of this circuit sets up the condition necessary for the continuing discharge of electrons from the surface of the mercury. In the "automatic-starting" mercury-arc rectifiers, a small motor device is arranged to tilt the tube and restore it whenever the current from it fails for any reason. This automatic operation is brought about by a relay in series with the load which, upon releasing, closes the circuit of the tilting

[1] "Theory and Elements," pp. 254 *et seq.*

motor to bring it into action. The series starting relay also closes an alarm circuit to call attention to the failure.

The transformer at the top of Fig. 201 serves the double purpose of reducing the line potential to that required for the operation of the rectifier, and also of insulating the rectifier from the line. The rectifier and the telephone apparatus beyond it are thus protected against the hazards of normal or abnormal potentials from the line, and grounds on the line are prevented from causing trouble in connection with the battery ground at the central office.

Figure 202 shows the circuits of an automatic-starting mercury-arc rectifier. Operating on 60-cycle alternating current at a voltage of 110 or 220, it may be used to charge either 24- or 48-

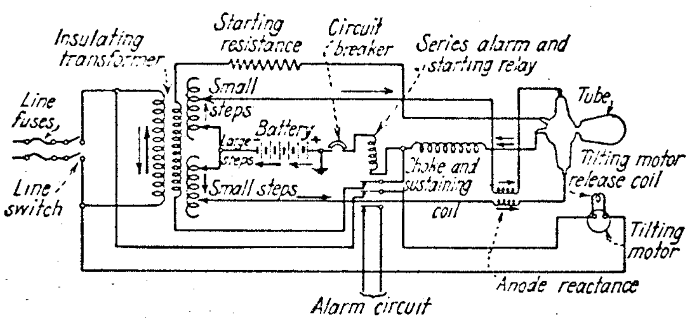


FIG. 202.—Circuits of mercury-arc rectifier set.

volt batteries at a normal rate of 50 amperes. This is the largest capacity available in a single rectifier unit, but larger charging currents may be obtained by using the required number of units in multiple. Fortunately they lend themselves readily to parallel operation.

The Tungar Rectifier.—"Tungar" is the trade name applied to the hot-electrode, gas-filled rectifier of the General Electric Company. This rectifier is being used to an increasing extent for battery charging in smaller central offices.

The tungar bulb operates essentially on the principles of the two-element vacuum tube, the valve action occurring between a hot filament and a cold electrode. Instead of a vacuum, however, the tube contains argon, an inert gas, at low pressure. This is ionized by the electrons emitted from the incandescent filament and acts as the principal current carrier. The current flow through the tube is, of course, in one direction only, from the

cold electrode, which is of graphite, to the hot filament, which is of coiled tungsten wire.

Half-wave rectification is obtained with one bulb only; for the smoother current required in telephone work full-wave rectification with two bulbs, or one double-anode bulb, is employed. Full-wave rectification with two bulbs is shown in principle in Fig. 203. In this, the filament current is derived from sections of the secondary winding of the line transformer. Figure 204 shows one of the circuits of a full-wave rectifier unit as used to charge batteries in telephone offices. Here the filament current is derived from a third winding on the transformer.

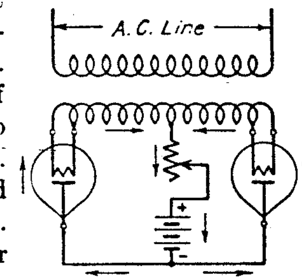


FIG. 203.—Principle of tungar full-wave rectifier.

Full-wave, noiseless tungar rectifier sets are available for operation on 25-, 50-, and 60-cycle alternating current at 115 or 230 volts, and with direct-current outputs ranging from 0.3 to 0.5 ampere at 30 volts up to 12 amperes at 6 to 90 volts. Tungar bulbs have an average life of about 4,000 hours of actual operation. The efficiencies at full

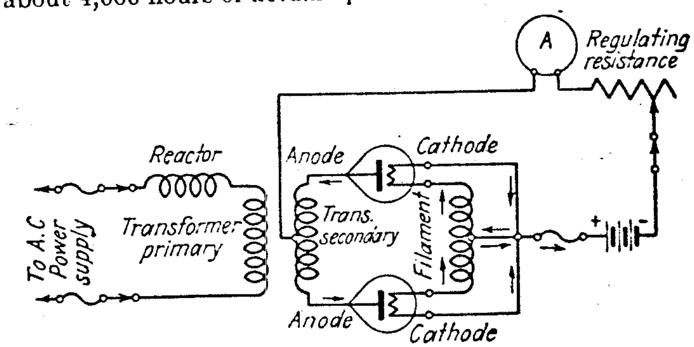


FIG. 204.—Tungar rectifier circuit.

load of the full-wave "noiseless" sets are: 28 per cent for the 30-volt, 0.3- to 0.5-ampere set, 48 per cent for the 19- to 52-volt, 1- to 3-ampere set, and 76 per cent for the 6- to 90-volt, 12-ampere set. At less than full load the efficiencies are smaller. For instance, the efficiency of the 12-ampere noiseless set drops to 68 per cent when operating at half load.

As they require practically no attention, save for occasional bulb replacement, they are finding increasing favor for battery charging in small telephone installations which receive only occasional maintenance attention, such as private branch exchanges, unattended automatic offices, or other offices where it may be desired to float the battery over Sundays and holidays in order to maintain their reserve capacity.

The Copper Oxide Rectifier.—Probably the simplest form of rectifier is that which depends on the fact that a disk of copper coated with a layer of copper oxide will allow current to flow from the oxide to the copper but not in the reverse direction. Whatever property it is that brings about this unidirectional action resides entirely at the surface contact between the copper and the oxide. Apparently, the action is wholly electronic with no

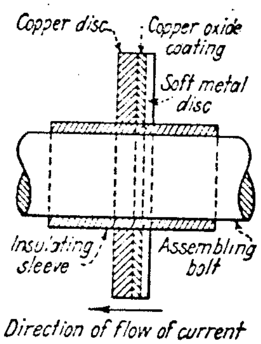


FIG. 205.—Copper-oxide rectifying element.

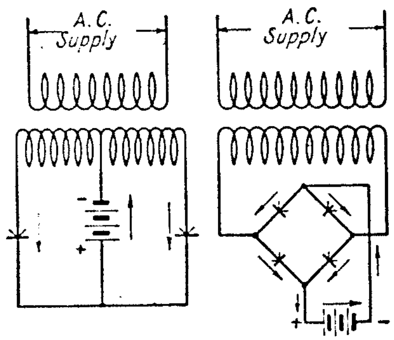


FIG. 206.—Two circuits for full-wave copper-oxide rectifier.

accompanying chemical reaction. Unless damaged by too heavy currents, these devices seem to have an indefinite life. Rectifiers depending on this principle are made in this country by the General Electric and Westinghouse companies under the names of "Copper Oxide" and "Rectox," respectively.

A single element of a copper oxide rectifier with its method of mounting is shown in Fig. 205. Such an element constitutes in itself a half-wave rectifier of limited capacity in voltage and current. The voltage may be increased indefinitely by connecting such elements in series, while the current range may be increased by multiple connection.

As regularly made by the General Electric Company, the elements are in two sizes, in which the washers are respectively $1\frac{1}{8}$ and $1\frac{1}{2}$ inches in diameter. The smaller element has a nominal rating of 65 milliamperes and 0.05 watt, and the larger of 125 milliamperes and 0.10 watt. These ratings are for continuous operation and are subject to rather wide variation with changes in temperature and methods of mounting as affecting ventilation and radiation. For momentary or instantaneous operation, currents as high as fifty times the continuous ratings may be obtained.

Figure 206 shows in principle two methods of connecting copper oxide elements for full-wave rectification. When properly filtered, the current from either of these methods of connection is sufficiently smooth for telephone charging purposes.

The General Electric Company in comparing its merits with those of the tungar rectifier gives the following information:

While the copper oxide rectifier could be used for large currents, its real field in telephone work, as so far developed, is in small-battery installations where small continuously applied charging current (trickle charge) will suffice to keep the battery properly charged.

For very low outputs, such as trickle charging at a fraction of an ampere, the copper oxide will generally work out to better advantage than the tungar. For low outputs, the tungar operates at low efficiency, whereas the efficiency of the copper oxide will range from 30 to 50 per cent which is good for a unit of such low power. On higher outputs, where the tungar bulb can be operated at its full-load rating, its efficiency may run as high as 75 per cent, making it superior to the copper oxide unit.

The cost of a copper oxide rectifier is inherently higher than that of a tungar of equivalent capacity. However, for low-current work, the higher efficiency with consequent reduction in operating cost may more than offset the higher initial cost.

The average life of the tungar bulb, as stated, is about 4,000 working hours, while that of the copper oxide element is, as far as known, indefinitely long. The absence of bulb-replacement expense is, of course, an advantage in favor of the copper oxide rectifier that must be considered in the comparison. It becomes of somewhat greater weight when the rectifier is installed at remote points receiving infrequent maintenance attention, since it cannot be known in advance just when the tungar bulb will fail.

Ringing-current Sources.—In furtherance of the policy of maintaining continuous service under all circumstances, duplicate sources of ringing current are provided at the central office, one being held in reserve in case of failure of the other. Such provision of emergency ringing equipment is an important feature of telephone power plants, because all calls for subscribers in an office will fail with the failure of the ringing current.

Ringing current, either alternating or pulsating, is commonly furnished at frequencies approximating 20 cycles per second. A principal exception to this statement is in the case of the harmonic system of selective ringing, where several frequencies ranging from 16⅔ to 66⅔ cycles per second are used selectively to operate the tuned ringers on party lines. Other standard frequencies, chosen well outside the ringer-operating range, are 135 cycles in signaling over long-distance lines, "composited" for simultaneous telephony and telegraphy, and a 1,000-cycle current interrupted twenty times a second that is used on long-distance "repeatered" circuits. The discussion of ringing-current sources in this chapter will be restricted to those for ordinary ringing purposes, that is, for actuating subscribers' bells.

As a rule 20-cycle ringing current is generated at about 80 volts. For the harmonic selective-signaling system, different voltages are used for the different frequencies, a typical range being: 16⅔ cycles, 75 volts; 33⅓ cycles, 100 volts; 50 cycles, 135 volts; and 66⅔ cycles, 175 volts. The rising scale of voltage with higher frequencies is due of course to the increasing impedance offered by the line circuit to the higher frequencies.

Sources of central-office ringing current are of two general kinds: the rotary, or motor-generator, type and the vibrating, or pole-changer, type. As a general rule, the vibrator types are used in the smaller offices and the rotary types in the larger, many medium-sized offices containing both types.

In very small magneto offices with little traffic, ringing current is furnished by the hand generator at the operator's switchboard position. Where the traffic is such as to make this burdensome to the operator, a pole changer or a small motor-driven magneto may serve as the regular ringing-current supply, in which case the hand generator serves as an emergency reserve. For larger magneto offices, the ringing-current equipment may comprise two pole changers or, if commercial electric power is available, small motor-generator sets.

For the smallest common-battery offices, two pole changers are commonly employed. In somewhat larger offices, it is not uncommon to find one pole changer and one motor-generator set, while in still larger offices two or more motor-generator sets may be found.

Motor-generator Ringing Sets.—The simplest type of rotary ringing set sometimes used in small magneto offices is a motor-driven magneto generator of the type shown in Fig. 148 of the preceding volume.[1] Such a generator, having two poles, delivers 1 cycle per revolution, making a frequency of 19 cycles per second at its normal speed of 1,150 revolutions per minute. At this speed its output is about 15 watts at 80 volts.

Only the generators of these very small capacity ringing machines derive their magnetic fields from permanent magnets, those of greater output following the usual dynamo-electric machine practice of using the more powerful electromagnetic fields. In its essential elements, therefore, the rotary ringing set consists of an electrically excited alternator of the desired frequency and voltage and an electric motor of the required speed and power adapted to run on the current supply available. In practice, however, the ringing set usually includes more than this. The main shaft usually carries a commutator which interrupts the current from the battery to give the "busy," "trouble," "howler," and other tones required by the service. A slow-speed shaft driven from the main shaft by a worm gear carries other commutators to furnish the slower current impulses required, such as those for intermittent ringing and flashing recall. In case harmonic selection on party lines is used, the set may have four generators each for a different frequency, the armatures of these all being on a common motor-driven shaft. The set may also have a voltage regulator for the ringing-current output and a speed governor for the motor. The latter is particularly important in the multi-frequency sets used for party-line selection where close regulation of the ringing frequencies is required.

In the larger offices employing two motor-generator ringing sets, the one for normal operation is driven from the outside power service which may be direct or single or multi-phase alternating. The reserve set is driven by a direct-current motor taking its current from the central-office battery. This requires that the ringing machine motor current be taken into account as a part of the load to be carried by the battery and charging machines.

In some of the largest offices of the Bell System the two ringing sets are alike and each is adapted to run from either the outside line or the battery current. Moreover, if the commercial power fails, the "throwover" is accomplished automatically

[1] "Manual Switching and Substation Equipment," p. 171.

a relay device operating on failure of the outside current to switch from the line motor to the battery motor.

One of these two-motor ringing sets is shown in Fig. 207. The generator at the left is a double-current machine, delivering 20-cycle 80-volt alternating current for ringing purposes from the collector rings at the left-hand end of the armature and direct

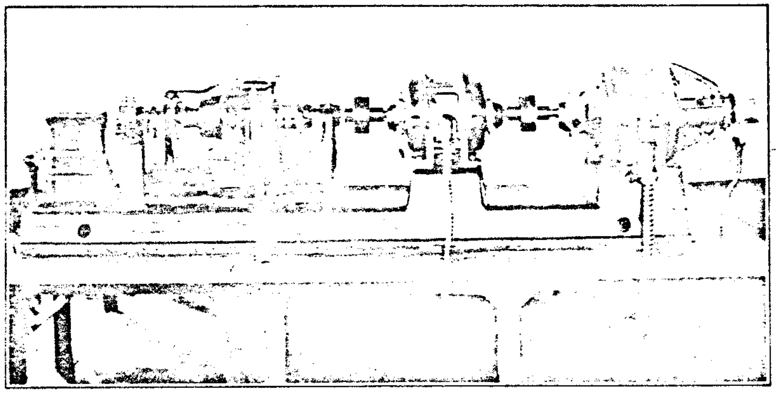


FIG. 207.—Two-motor ringing set for large Bell offices. (*Courtesy of Bell Telephone Laboratories.*)

current at + or −110 volts from the commutator at the other end of the armature. This direct current is for energizing the field magnets, the generator thus being self-exciting, and for controlling the coin boxes at telephone stations in exchanges where that kind of service is given. The motor in the center is single phase alternating and is the one normally in operation. The motor at the right-hand end is 48-volt direct current. If the alternating-current supply is interrupted, the 48-volt motor is automatically cut in by means of contactors on the power board. Upon the outside service being restored, the direct-current motor is disconnected and the set continues to operate on the alternating current. These changes, which are entirely automatic, are accomplished with no appreciable changes in speed or voltage of the set.

On the right-hand end of the shaft of the 48-volt motor is a speed governor which, by centrifugal action, cuts a resistance into or out of the shunt-field circuit and thus holds the speed of the motor practically constant, in spite of fluctuations of the storage-battery voltage. The busy and other tone signal commutators are shown at the left-hand end of the set.

In manual offices, the high-speed interrupter on the main shaft produces two different tone signaling currents by interrupting the 24-volt battery current. Of these, a low tone of 153 interruptions per second is for the audible "busy-back" and other purposes, such as the "line out of order" signal on the multiple and the "group-busy" indication in straightforward trunking. The other is a high tone of 460 interruptions per second of the 24-volt battery current. This is used for the "howler" circuit used in notifying subscribers that their receivers are off their hooks and also, in straightforward trunking, as a signal to the "A" operator that the "B" operator is ready to receive the call.

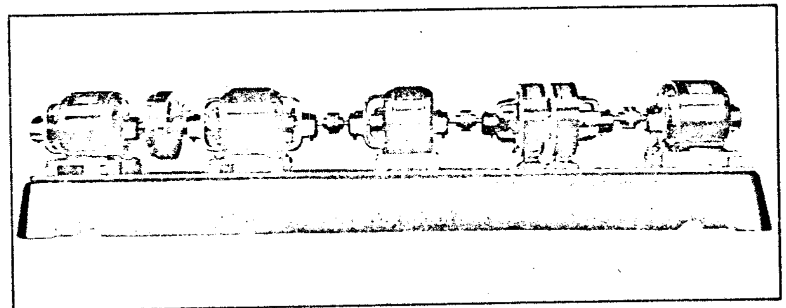


FIG. 208.—Four-frequency ringing set. (*Courtesy of Holtzer-Cabot Electric Company.*)

The interruptions of the low-speed commutator can best be expressed at their rate per *minute*. They may occur in the direct battery current, the tone currents, and the ringing current. A few of these are 60 per minute in the low tone current for the subscribers' busy signal, 60 per minute in the direct battery current for the flashing recall, and 2 seconds on and 4 off of the ringing current for machine ringing.

One of the "multi-cycle" motor-generator sets for furnishing the four frequencies of current required in harmonic selective ringing on party lines is shown in Fig. 208. The central unit is the motor and the four other units are alternating-current generators having 2, 4, 6, and 8 poles respectively. At a speed of 1,000 revolutions per minute they generate 16⅔, 33⅓, 50, and 66⅔ cycles per second respectively, these being the frequencies employed in harmonic selection on party lines when motor-generator sets are used. The direct-current motor-generator sets of this type are equipped with a governor to hold the speed constant. The alternating-current sets require no speed governor but are geared to and equipped with a direct-current exciter.

The Vibrating Pole Changer.—This consists of a heavy tuned vibrating reed actuated by an electromagnet as in the ordinary battery bell, the reed serving as a switching device to reverse the polarity of a battery at each vibration. It thus becomes a source of alternating electromotive force of frequency corresponding to the rate of vibration. One is shown in bare principle in Fig. 209. The low-voltage battery is the source of motive power. The higher-voltage battery is the source of ringing energy, its current flowing through the primary of the transformer, being reversed at each vibration, and its voltage stepped up to that required for ringing purposes. In magneto exchanges, the motor battery may consist of two Edison primary cells and the ringing battery of two series strings of eighteen dry cells connected in multiple. Reactance coils and condensers properly associated with the device may serve to suppress the sparks at the contacts and to round off the peaks of the ringing current.

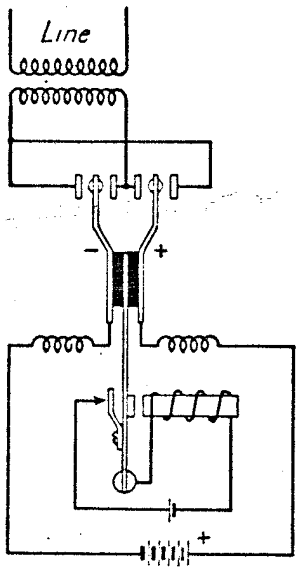


Fig. 209.—Principle of vibrating pole changer.

Figure 210 shows the complete circuits of the Western Electric Company's No. 84 F. ringing pole changer, together with an

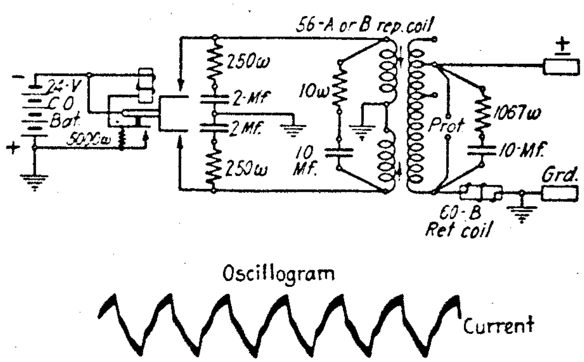


Fig. 210.—Circuits and oscillogram of vibrating pole changer.

oscillogram of its ringing current. This takes both operating and ringing current from the main battery. As the reed is tuned

to twenty complete vibrations per second, it subjects the primary of the transformer to alternating potential at that frequency and this is stepped up by the transformer to 83 volts at the ringing bus-bars. The retardation coils, condensers, and resistances are arranged to suppress sparking at the contacts, to prevent noise in the battery circuit, and to round off the peaks of the ringing current. This set delivers alternating current only. Superposed ringing current for two- or four-party selective ringing may be had, however, by associating with it two 30- to 40-volt auxiliary batteries as discussed in Chap. V of the preceding volume.[1]

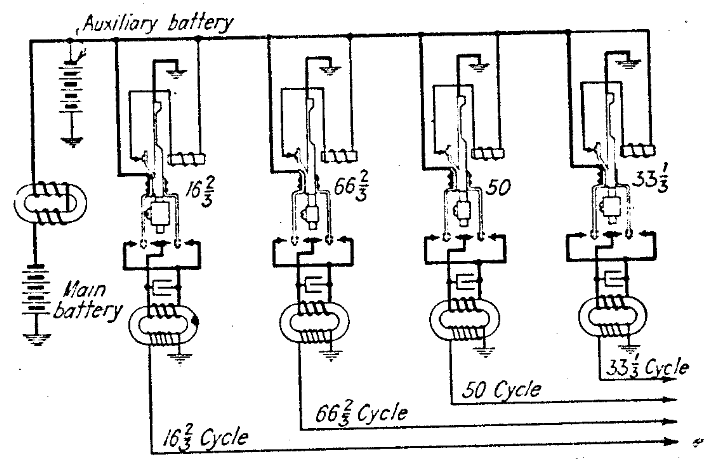


Fig. 211.—Four-frequency harmonic converter.

Figure 211 shows how the harmonic-vibrator principle is applied to harmonic selective ringing on party lines. A separate vibrator is used for each of the frequencies of ringing current desired. The method by which current from the main battery is made to operate the motor magnets of the vibrators, and by which the currents through the transformer primaries are made to alternate at the respective frequencies of these vibrators, is obvious. It is also clear how the secondary currents developed in these transformers are stepped up in voltage and led to the switchboard terminals, so as to be available for connection with the subscribers' lines. The condensers are for the purpose of spark reduction and for aiding in smoothing out the current waves. The auxiliary battery and the retardation coil in the

[1] "Manual Switching and Substation Equipment," p. 150.

main supply lead are for the purpose of preventing the pulsating currents drawn from the main battery from making it "noisy." These two batteries have like poles connected to the supply lead, the auxiliary battery furnishing no current to the system except when the electromotive force of the impulse flowing from the main battery is choked down by the impedance coil, when the deficiency is momentarily supplied for each wave by the auxiliary battery.

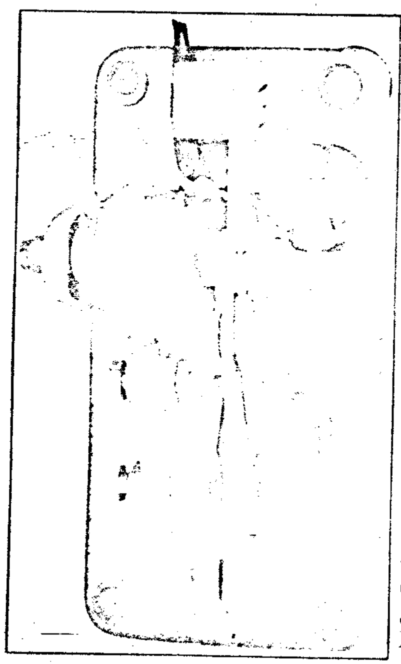


FIG. 212.—Pole-changing vibrator. (*Courtesy of Automatic Electric Company.*)

Where vibrating pole changers are used to supplement multi-frequency motor-generator ringing sets in offices using the harmonic-ringing system, the frequencies used are, of course, the same as those of the rotary set—$16\frac{2}{3}$, $33\frac{1}{3}$, 50, and $66\frac{2}{3}$ cycles. These frequencies must necessarily bear to each other the same ratios as the numbers, 2, 4, 6, and 8, respectively, of poles on the ringing generators of the rotary set. Since all the generators of the rotary set are connected to the same shaft, this exact multiple relation cannot well be avoided, although, in some cases, it has been thought to be objectionable on account of the higher-frequency ringers showing a tendency to respond to harmonics of the lower-frequency currents.

This restriction does not exist where vibrating pole changers alone are used in supplying the ringing current, since each individual pole-changer unit may be tuned to any frequency independent of the others. Some companies on this account have adopted a so-called "non-multiple" or "synchronomic" set of frequencies wherein such even multiple relation does not exist. The non-multiple frequencies most commonly used are 20, 30, 42, 54, and 66. When all these frequencies are used, it makes possible the selection among five stations on a line by

ringing over the metallic circuit or among ten if ringing over the two sides of the line and ground.

Figure 212 shows one of the harmonic-ringing vibrator units as manufactured by the Automatic Electric Company for the Strowger system. The vibrating reed is slotted at its lower end to permit accurate tuning by altering the point of attachment of the weight. This is for the finer adjustment to a desired frequency. The coarser adjustments, as from one desired frequency to another, are obtained by changing weights and reeds. All working parts are mounted on heavy lugs, cast integral with the base. The contact points for maintaining the vibration of the reed are shown just below the motor magnet, the ringing contacts being located on opposite sides of the lower end of the reed. Heavy tungsten contact points are used, all being adjustable as shown. Vibrating pole changers, properly designed and maintained, have been found capable of producing ringing currents of stable frequency over long periods with infrequent adjustment.

Storage-battery Charging Methods.—The two general methods of handling the storage batteries in telephone power plants with respect to supplying current to them and withdrawing it from them may be referred to respectively as the "charge-and-discharge" method and the "continuous-floating" method. Until comparatively recently, the former of these was commonly practiced, the battery being subjected to definite alternate periods of charge and discharge with an occasional overcharge to bring all cells up to uniform full charge. It is now generally recognized, however, that better results are obtained by subjecting the battery to as small amount of charge and discharge as possible, and this is leading telephone operating companies to adopt, as nearly as their operating conditions will permit, the continuous-floating method, wherein the switchboard load is continuously carried by the charging machines with the batteries "floating" across the line. The battery is thus kept continuously at a fully charged state, or nearly so.

Under this plan, the generators really carry the exchange load, except as the battery may help it to meet overdrafts of short duration. The battery, on the other hand, serves the two all-important functions of acting as a power reservoir, in case of failure of the primary source, and of "ironing out" the irregularities of the generator output to make the current smooth enough for telephone talking circuits.

The continuous-floating method has been found to give longer life to the battery and in addition has other important advantages, of which the chief ones may be briefly summarized as follows: The reserve or "stand-by" capacity of the battery is always maintained at its maximum, since the battery is always fully charged. The cost of primary power supply is reduced, because the current is delivered directly to the switchboard, largely eliminating the losses involved in the chemical reactions during charge and discharge of the battery. The voltage is more easily kept within the desired operating range, because the wide variations of the battery while alternately charging and discharging are largely eliminated. Lastly, for a given output and a given requirement as to voltage regulation, the first cost of equipment is reduced because of the increased efficiency of operation and the simpler voltage-regulation equipment required.

Under the continuous-floating plan, the charging rate is adjusted so that the voltage at the battery terminals will average 2.15 volts per cell with a range from about 2.10 to 2.20.

Complete Power Plants.—In manual common-battery offices, the power plant usually has a single 24-volt battery for feeding the local talking and most of the other switchboard circuits, with an auxiliary battery of smaller cells to give a pressure of 48 volts principally for use on long-distance connections. Some manual switchboards, however, have been designed for 48-volt operation throughout, in which case a single battery of that voltage suffices. It has been common practice in manual offices to select a battery of such capacity as to enable it, when fully charged, to carry the entire load of the office for a period of at least 24 hours in case of failure of the charging sources. As the voltage-regulation requirements in manual systems are not so exacting as in automatic, it has not usually been found necessary in manual offices to employ counter electromotive force or end cells to equalize the voltage of charge and discharge periods.

Automatic or machine-switching offices generally operate on a main battery of 48 volts. Some systems, like the Strowger, supply talking current at this voltage, while others, like the panel type, use 24 volts for talking and 48 for most other switchboard purposes. Partly because of the great reliability of present-day commercial power sources, partly because of the much greater amount of current required in machine-switching offices, particularly those of the power-driven type, and partly because of the increased battery reserve afforded by the now prevalent continuous-floating method of charging, it is not feasible nor is it considered necessary to provide battery reserve capacity for such long periods as was formerly done in manual power-plant design. Of course, the emergency period over which the battery should be required to carry the load, without assistance from the generators, varies with local conditions, particularly as concerns the reliability of the available sources of primary power. In the very large power plants of the Bell System, sometimes supplying current for as many as five complete 10,000-line switchboard units, the battery when fully charged has a reserve capacity that will carry a load equivalent to 3 busy hours (switchboard drain plus that of all battery-driven motors). For the Strowger system a 5-hour battery reserve capacity is considered good practice under most conditions.

Other features of the power plant than the battery also vary considerably according to the size of the exchange, the type of its equipment, and the character of the service to be rendered. It is, therefore, difficult to generalize, but, as examples of modern American practice, a typical power plant for a medium-sized Strowger office and one of the very large multi-office plants of the Bell System may be considered.

A typical power plant of the Automatic Electric Company for one of its automatic central offices comprises: one storage battery; one, two, or three battery-charging sets; two sets of ringing and tone equipment; and one power switchboard with its charging and ringing controls, battery switching controls, distributing fuse, and supervisory equipment.

The Strowger system is designed to operate on battery voltages of from 45 to 52 volts and two methods have been used by its manufacturers to keep within these limits. One was to use a battery of twenty-five regular cells and seven counter electromotive force cells, the latter being used to prevent the voltage from rising above the desired limit during charging. The other method, and the one now used in new installations, is to employ a single battery of twenty-six cells, of which the three on the negative end are used as end cells. Normally, while the battery is floating on the line, only twenty-three of the cells are connected, with a resulting voltage of from about 48 to 51. If, however, for any reason, the charging current is cut off, the three end cells are cut in to prevent the voltage dropping below 45 as the battery becomes discharged. It is thus possible to use practically the entire storage capacity of the twenty-six cells, since, even when discharged down to 1.75 volts per cell, the voltage remains above the lower working limit of the equipment.

Figure 213 shows a schematic diagram of the Strowger power circuit using this end-cell feature, all fuses, circuit breakers, and motors being omitted for greater clearness. The two charging machines shown may, of course, be either motor or

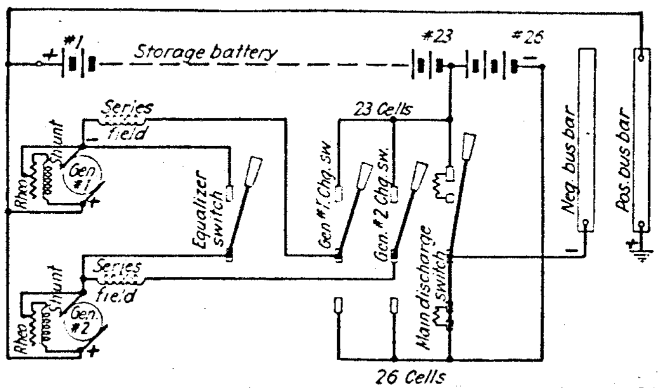


FIG. 213.—Schematic diagram of power circuit.

engine driven. By means of their respective single-pole double-throw switches, either of them may be connected to charge either the twenty-three cells or the entire twenty-six cells. The equalizer switch at the left is for connecting the two generators in parallel, so that their combined capacity may be used if desired. The main discharge switch at the right serves to connect either the entire twenty-six cells or only the twenty-three cells to the central-office bus-bars, from which all battery current for the operation of the entire system is drawn. This is a "make-before-break" type of switch with current-limiting resistances to prevent a short circuit on the three end cells while they are being switched into or out of the circuit. The make-before-break feature of this switch also prevents opening the main discharge circuit while making the change.

The typical Strowger power plant for offices equipped for from 2,000 to 10,000 lines has this twenty-six-cell battery arrangement. Compound-wound instead of the usual shunt generators are used, because their flatter voltage characteristic is considered better adapted for the continuous-floating method of charging. One motor-generator set is preferably given about twice the capacity of the other, in order that the charging current may be more efficiently adapted to the load.

The normal operating routine of such a battery and charging machine arrangement is to keep one machine running continuously, the smaller one being used whenever the load is within its capacity, and the larger one, or both in multiple, when required. Only twenty-three cells would ordinarily be connected, the voltage being maintained at about 50.

In cases where the night load is so small as not to justify the running of even the smallest machine, or if for any other reason continuous charging is not possible or desirable, the end cells are cut in to the discharge circuit as soon, after stopping the charging, as the voltage drops to about 46, the entire twenty-six cells then carrying the load until the charging is again started. On again starting the charge, the end cells may be left in the charging circuit, even though cut out of the discharge circuit, and so remain until fully charged.

In small-community step-by-step systems, a partial-float method of charging, without end cells, has been devised. In this, the charging is stopped and started automatically in accordance with the requirements of the battery. Whenever a call originates, the power supervisory equipment closes a circuit from the commercial power line to the charging equipment. The charge then continues until the high-voltage limit is reached, when the power circuit is automatically disconnected.

The type of ringing equipment employed in Strowger offices depends, as in other types of systems, on the size of the office and the kinds of service rendered. In larger offices, single-frequency rotary ringing machines are usually provided for ringing on individual lines, while either rotary or vibrating multi-frequency machines are used for party-line ringing. The rotary charging and ringing sets of a typical 5,000-line Strowger office are shown in Fig. 214. In the smaller offices, vibrating types are more commonly used for both individual and party line ringing. Since the ringing of subscribers' bells is automatic, usually with a period of 1 second on and 4 off, the ringing interrupters are so arranged that the 1-second ringing periods will come successively on different groups of connectors, thus approximating an even distribution of the ringing load on these machines throughout the entire cycle.

The power switchboard consists of panels of slate, mounted on an angle-iron framework. Upon the panels are mounted all of the apparatus required for controlling the charging and ringing machines and for switching the end cells of the battery.

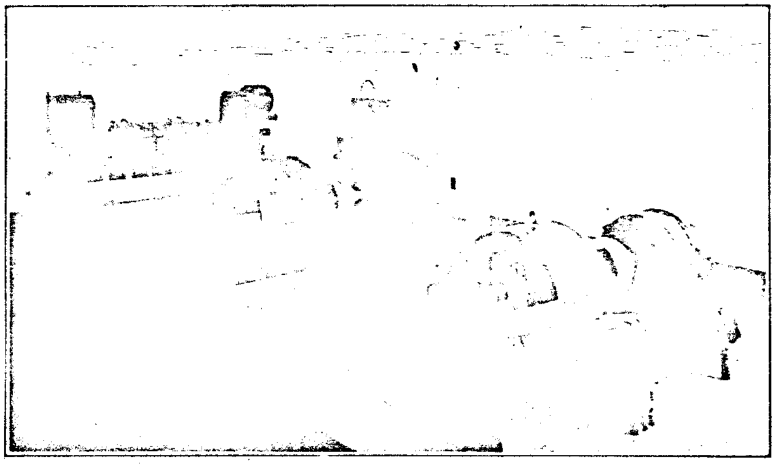


FIG. 214.—Charging and ringing sets of typical 5,000-line Strowger office. (*Courtesy of Automatic Electric Company.*)

The fuses required for battery current distribution to each large unit of the exchange, and the relays and other apparatus required to supervise the central-office equipment, are mounted on switchboard panels which may be included in the main power line-up or located at some central point in the equipment room. A complete power board for a Strowger office is shown in Fig. 215. From left to right the three panels are respectively: the "ringing panel" the "battery-charging panel," and the "distributing fuse and supervisory panel."

At the top right and left corners of the ringing panel are the relay-type ringing distributors or "ringing interrupters" as they are called. Between these is the frequency meter for measuring the frequency of the ringing currents used in harmonic selection on party lines. The various switches on this portion of the panel are associated with the ringing vibrators below.

Above them are a fuse alarm supervisory lamp and an interrupter supervisory lamp. The main portion of this panel carries the harmonic-ringing vibrators and their associated switches. The vibrators, like the ringing interrupters, are enclosed by glass-front cases. The upper three at the left and upper two at the right are the duplicate sets for the five ringing frequencies. The lower sets on each side are the busy interrupters and vibrators, also in duplicate. The various transformers, impedance

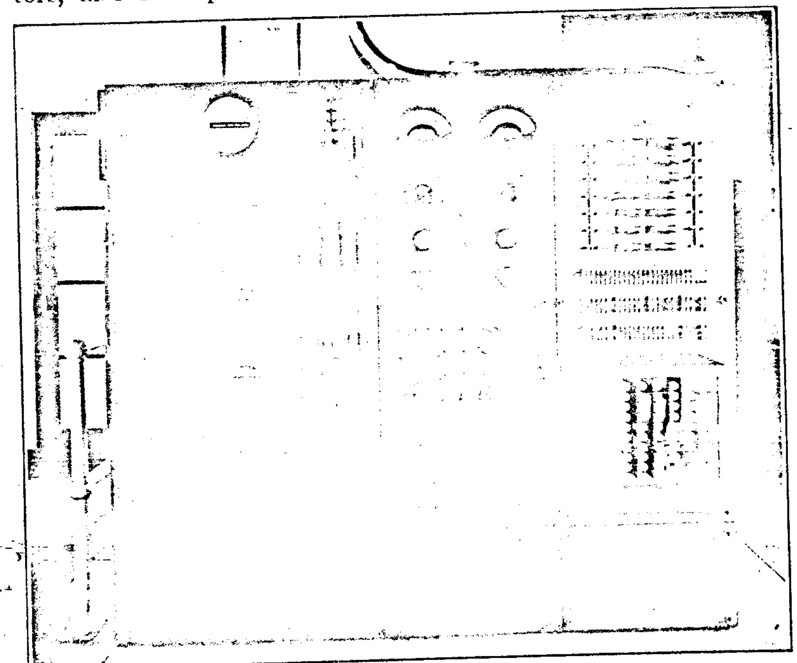


FIG. 215.—Typical Strowger power switchboard. (*Courtesy of Automatic Electric Company.*)

coils, condensers, and resistances associated with the vibrator sets are mounted on the rear of the panel.

The center panel carries the switches, instruments, and associated equipment of the generator-control and battery-charging circuits, which are essentially like those of Fig. 213. At the top are the voltmeter and ammeter with their associated switches. Between these two meter switches is the generator equalizer switch. Near the middle of the panel are the field rheostats for the two charging generators. Below these, mounted horizontally, are the main discharge switch and the two generator switches in the main charging circuits. At the bottom of the panel are two circuit breakers, connected in the positive leads from the two charging units. The main battery fuse is seen between these two circuit breakers.

The right-hand panel has the various distributing fuses on its upper portion and the relays of the supervisory alarm system on the lower half. The horizontally mounted enclosed fuses above are connected in the battery leads to the groups of line switches, selectors, connectors, etc. At the right and left of these fuses are alarm fuses of the various vibrator sets. The three horizontal rows of alarm fuses in the center of the panel are associated with the supervisory alarm, desk, miscellaneous battery, fused ground, and generator supply leads.

The group of relays at the bottom of this panel belong to the supervisory alarm system and control the various audible and visible signals already described in Chap. III on the Step-by-step System.

Principally on account of the drain of the motors required to drive the panel-type switches, which of course must be borne by the batteries when other sources of power fail, the batteries in panel-type offices assume relatively large proportions. This is particularly true when a common power plant serves two, three, four, or five central-office units of 8,000 or 10,000 lines each, as is sometimes the case in congested districts of large metropolitan areas.

In the panel-type as in manual systems, talking current is furnished at both 24 and 48 volts, the heavier local talking-circuit drain being at the lower voltage. Battery current for the switch-driving motors and most of the switching circuits is at 48 volts. The operating voltage limits are considerably closer than in manual systems. On account of the size of the cells involved and the need for close voltage regulation, the batteries are divided into two complete sets, that is, two No. 1 or 24-volt and two No. 2 or 48-volt, with provision for operating the sets singly or in parallel. Three end cells are provided for each 48-volt battery, and one for each 24-volt. Switches provide for cutting the end cells into the discharge circuits one at a time, enabling practically constant voltage to be maintained on these circuits.

Before discussing the more recent developments in the engineering of these large power plants, brief reference to earlier

practices may be made. The earlier power plants for machine-switching offices of the Bell System followed the general plan of layout that had long been practiced in manual offices.[1] Under this, all control of the power machinery and of the battery charge and discharge circuits was exerted from the power switchboard, and this of course required that all mains, as well as the various controls and measuring and indicating circuits, be run from the battery and the various machines to switches and instruments on

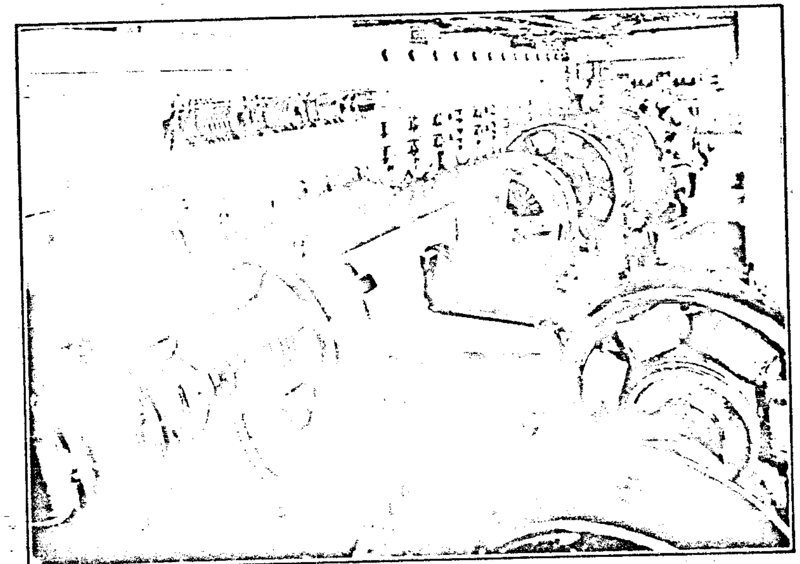


FIG. 216.—Large old-style Bell power plant.

this board. The conductors between the power board and the different motor-generator sets were disposed in conduits usually in the floor.

A partial general view of one of these older power plants, with special telephone charging machines, a switchboard over 50 feet long, and all motor and generator leads in floor conduit, is shown in Fig. 216. A view of the floor conduit of such a plant, before pouring the floor, is given in Fig. 217. The conduit openings for the motor generators and power switchboard, projecting up just above the level of the future floor, are to be noted. Figure 218, a rear view of a battery control board in one of these older plants,

[1] MAETZEL, R., Recent Developments in Power Plant Design, *The Telephone Review*, New York, October, 1924.

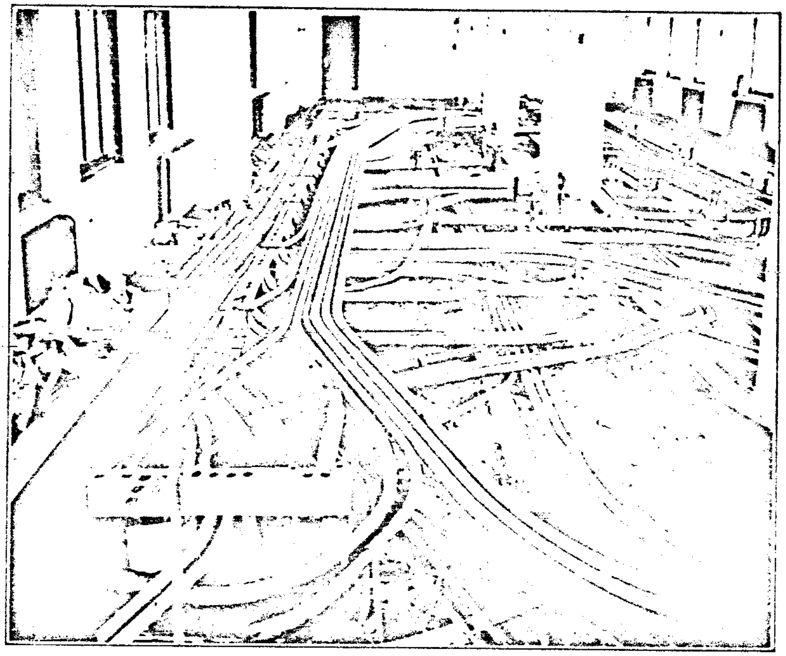


FIG. 217.—Under-floor conduit in old-style power room.

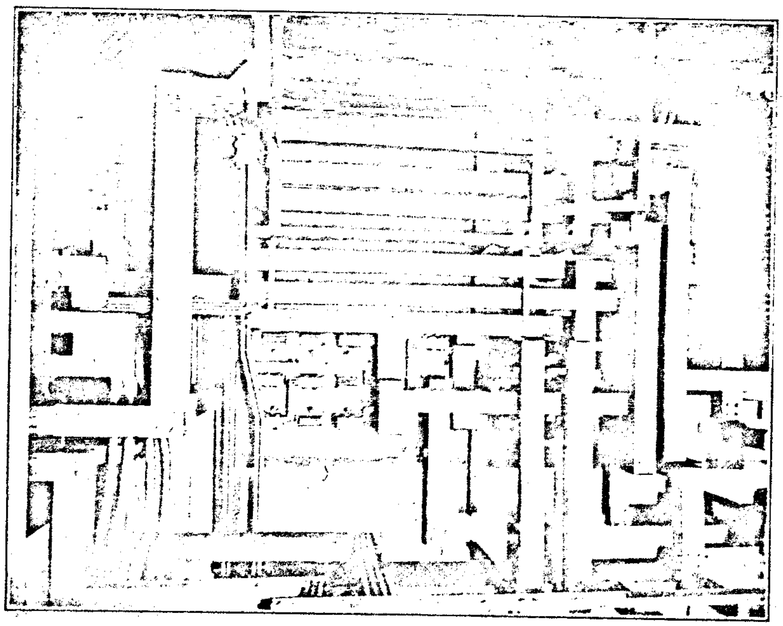


FIG. 218.—Rear view of battery control panel.

gives some idea of the sizes and complex arrangements of some of the conductors involved. In some cases, the bus-bars are made up of eight 4- by ½-inch copper bars.

Under this general plan, the power boards become inconveniently long, requiring considerable running back and forth by the attendant when operating a number of charging sets. The floor conduit required for the power circuits, however, was perhaps the greatest disadvantage of this plan of layout. It usually resulted in confusion in building operations, delaying the pouring of the power-plant floor until the details of the machine and

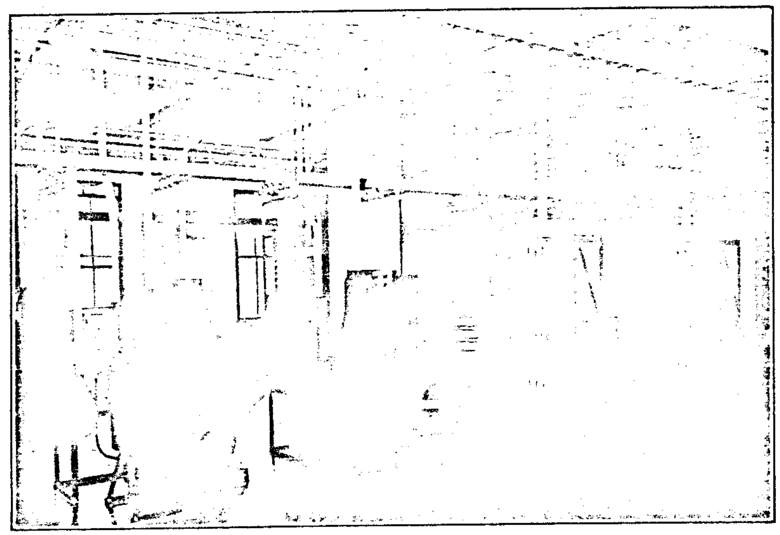


FIG. 219.—Semi-remote control system for charging motor-generator sets.

switchboard layout were completed. Moreover, the conduit system was inflexible when laid, particularly with reference to future additions to the plant as required for growth.

In order to overcome these difficulties and to facilitate the starting, stopping, and regulating of the charging sets, Mr. Richard Maetzel, power-plant engineer of the New York Telephone Company, developed what is now called the "semi-remote-control" type of telephone power plant which, for large new offices, has generally superseded the older type. This system is characterized principally: First, by the placing of most of the apparatus involved in starting and switching each of the charging motor-generator sets *at the set;* second, by the connecting of generator leads to exposed overhead "collector bus-bars," supported from the ceiling, and the placing of all motor leads in overhead conduit, thus eliminating all floor conduit; and, third, by the placing at a convenient point in the machine room of a remote-control panel from which the operation of each generator

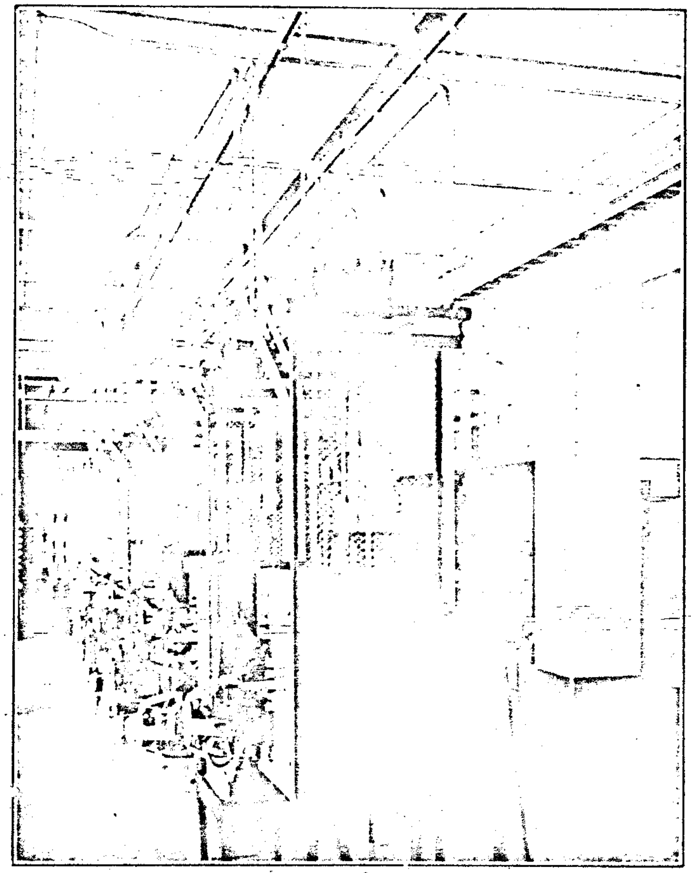


FIG. 220.—Semi-remote-control system for charging motor-generator sets.

may be regulated and the current and voltage of the various circuits measured.

Figures 219 and 220 are partial views of the machine room of a power plant embodying these features. This is the Barclay-Vesey central-office installation of the New York Telephone Company, located at 140 West Street, New York City. It is common to four central offices with capacity for supplying that

many 10,000-line units of panel-type equipment. Its remote-control panel, which is seen at the right of Fig. 220, is shown in front view in Fig. 221.

Described in somewhat more details:

The starting and stopping equipment of each motor is located at the motor. The leads to the motor are extended through conduits installed on the superstructure overhead and are fused at the control panel.

Each generator is provided with a panel on which are located:

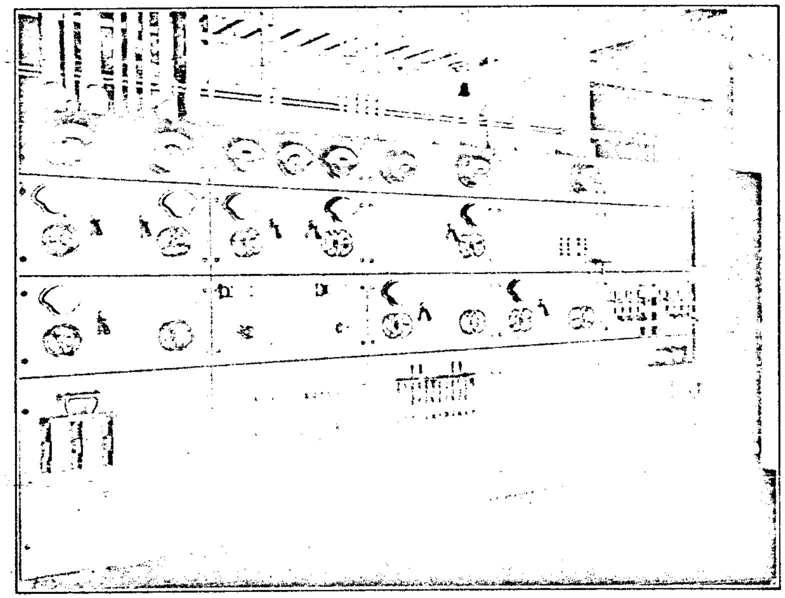


FIG. 221.—Remote-control panel.

a. Switches so arranged that the generator can be connected to any set of batteries.

b. A remote-control circuit breaker.

c. An ammeter shunt.

On the remote control panel are located:

a. Push buttons for each generator by means of which the circuit breaker can be opened or closed.

b. The field rheostat for each generator.

c. The ammeter for each generator.

d. Voltmeters and ammeters for the battery discharge, with switches so arranged that the current and voltage values can be read for each of the various circuits.

e. Small pilot lights, indicating the battery to which each generator is, at the time, connected.

Commercial-type generators are used, designed either for 33-volt or for 33- and 65-volt operation. There may be several of each of these, and typical connections for them with the overhead collector bus-bars and the batteries are shown in Fig. 222. This figure also shows the general method of disposal of the motor leads, control and meter circuits in overhead conduits extending from the motor-generator charging sets to the control

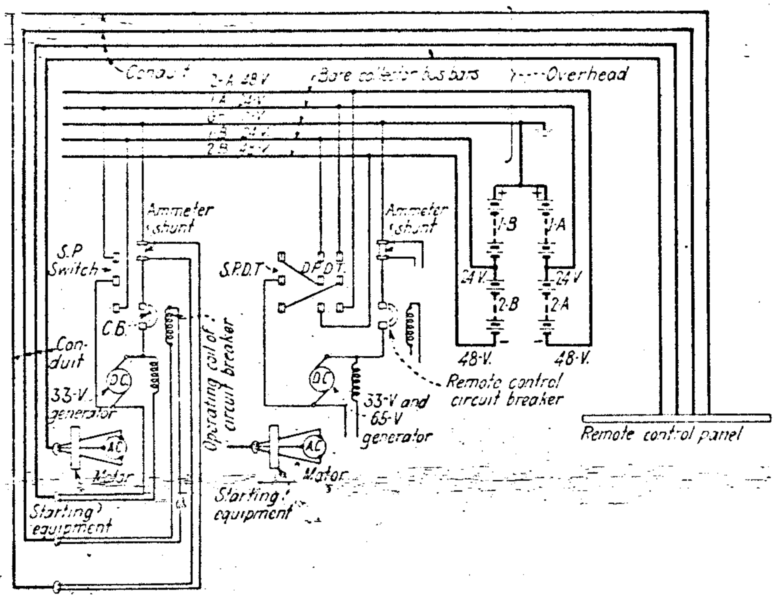


FIG. 222.—Typical connections of motor-generator charging sets.

panel. As is clear from this diagram, the 33-volt generator may be connected with either of the 24-volt batteries by means of a double-throw single-pole switch on its generator panel, while the 33- to 65-volt machine may be connected to either the 24- or the 48-volt section of either battery by means of the double-throw single-pole and double-pole knife switches on its panel.

The battery discharge circuits are shown in Fig. 223, from which the end cells, fuses, and all except the main discharge switches have been omitted. The battery control panel is mounted as close to the battery terminals as possible and carries on its face the main battery switches and the switches and fuses

for the principal branches of the battery supply to different parts of the system. The battery supply circuits are protected by means of duplicate fuses in series. These are mounted on the face of the battery control panel and each pair is provided with a single-pole double-throw switch so arranged that it can be made to short-circuit either fuse of the pair. When one of them blows, the fact is indicated by an alarm and the attendant, by throwing the switch into its alternate position, may short-circuit the blown fuse and restore service through the remaining good one. Two

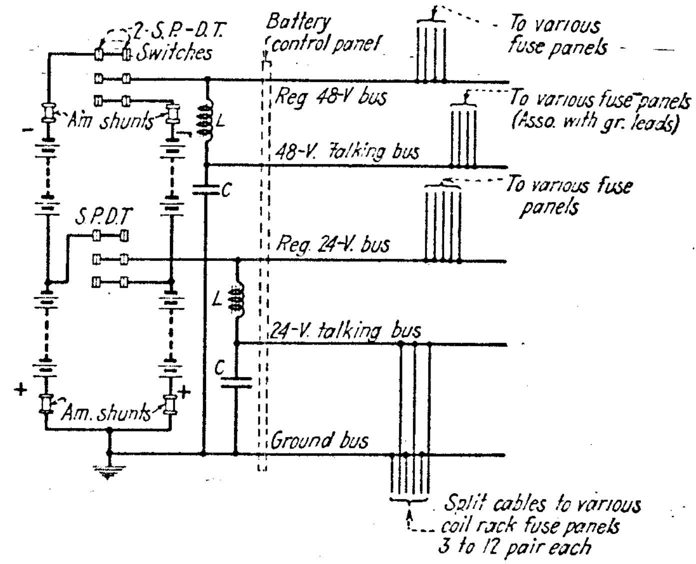


FIG. 223.—Typical discharge circuits.

electric filters for the talking currents, consisting in each case of a heavy choke coil L and an electrolytic condenser C, are connected, close to the battery, with the 24-volt and the 48-volt talking-supply mains as shown. Either set of batteries or both in multiple may be connected with the distribution bus-bars by the single-pole double-throw switches. The split cable, consisting of from three to twelve pairs, extends from the ground and 24-volt talking bus-bars to the coil-rack fuse panels, which, under this provision, may be conveniently located in a remote part of the building as described in Chap. VIII of the preceding volume.[1]

[1] "Manual Switching and Substation Equipment," p. 259.

Figure 224 shows a partial view of the battery room in the Barclay-Vesey plant, and Fig. 225 a front view of the battery

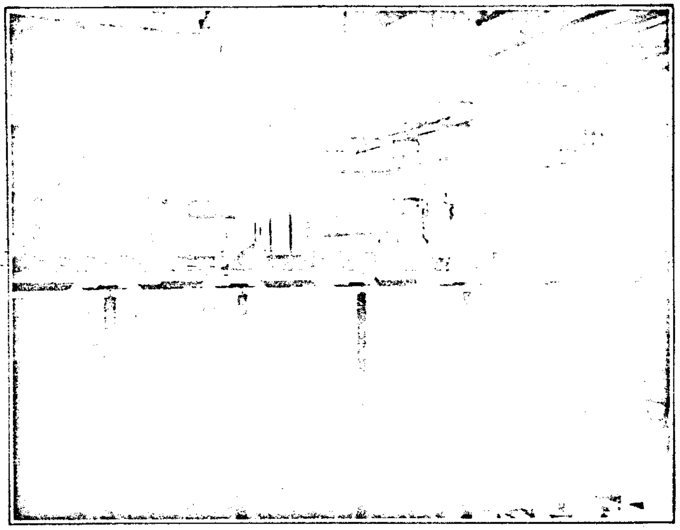


FIG. 224.—Partial view of battery room.

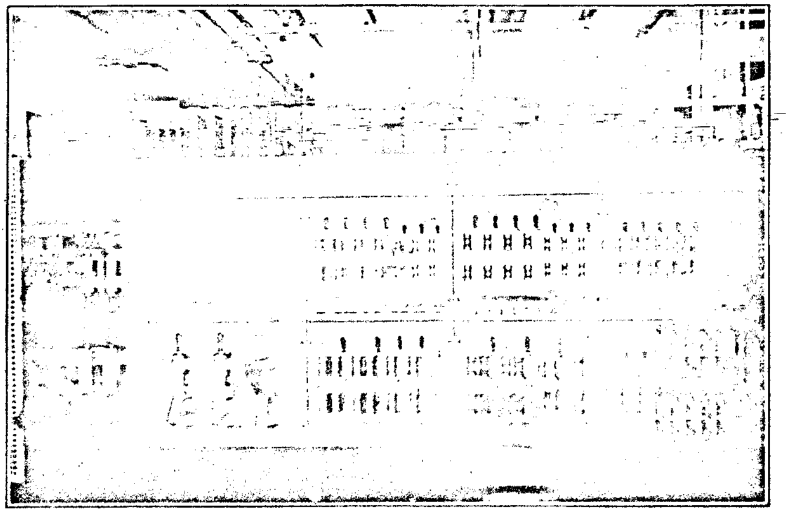


FIG. 225.—Battery control panel.

control panel in the same installation. The former figure is principally interesting in showing the very heavy copper bus-bars connecting with the battery terminals and the method of their

support from the ceiling. The battery control panel end of these bars may be seen in Fig. 225 just above the left-hand panel. The collector bus-bars, leading from the several generator panels, are seen in this view above the second panel. The relative positions in the machine room of the battery control panel and the remote-control panel may be seen in Fig. 220.

Under the continuous-floating routine of operation employed in these large plants, the two sets of batteries are left connected in multiple except at such times as it becomes necessary to subject either set to an overcharge for conditioning purposes. Then one set is floated while the other is relieved of the central-office load and connected only with the generators. The end cells are supposed to be used in case of prolonged interruption in the charging facilities, at which times they are added, one at a time, to compensate for the drop in voltage due to the drain without charge.

CHAPTER VIII

PROTECTIVE APPARATUS

Up to this point we have considered only the types of telephone equipment that are concerned in the transmission of speech and in the establishment of the paths over which the transmission occurs. There is another class, however, which, although it plays no part in the carrying out of either of these functions and remains passive in all normal workings of the telephone system, is, nevertheless, of vital importance. This is the apparatus designed to safeguard property and life from electrical hazards, to which, in varying degree, telephone systems are necessarily subjected. This safeguarding function is more far-reaching than at first appears, extending far beyond the premises and the personnel of the telephone company itself. It reaches over the area covered by the telephone system and to the subscribers' stations, where it has a possible effect on property of both the telephone company and the subscribers and on the persons of all who render or use the service.

In the early days of telephony, lightning constituted the only electrical hazard. Some trouble was experienced from telegraph currents but these, while annoying, were scarcely dangerous because of their low voltage. Electric railways, electric lighting, and power-transmission systems did not yet exist. With their coming, there appeared a menace which at first threatened the very existence of the telephone industry. The general abandonment of the grounded line in favor of the metallic circuit went far to overcome the most serious threat from these "foreign" sources in so far as they interfered with the transmission of speech, but it did not remove the dangers to life and property that were involved in the proximity of the railway, light, and power wires.

The electrical hazards, which under modern conditions may endanger telephone property and the lives of those operating and using it, are principally lightning and high-tension currents. In addition, currents from low potential sources, either in the telephone system itself or outside it, and not ordinarily con-

sidered harmful to life, may do damage to telephone property by the accumulation of heat or by the corrosive effects of electrolytic action.

We may dismiss electrolytic corrosion from this chapter dealing with protective apparatus, because ordinarily no specific apparatus is employed to guard against it. The safeguards that are employed against damage by electrolysis are to be found either in the proper insulation of conductors or in such design of the plant as will avoid the conditions favorable to electrolytic action.

Lightning, by generating excessive heat, may burn out apparatus or conductors and cause fires in adjacent property or, by excessive voltage, may break down the insulation of apparatus and conductors. Lightning damage may occur from a direct lightning stroke or from induced effects from near-by strokes. It is usually instantaneous, the heat generated being due to the flow of very heavy currents for minute periods of time. It should be borne in mind that currents arising from lightning are of an oscillatory nature, with high frequency, so that the path followed by them depends more on the absence of inductance than of resistance.

High-tension power lines may cause practically the same kinds of damage to either life or property as lightning. Dangerous shocks may be given, insulation may be broken down, or conductors destructively heated. These hazards may be introduced into the telephone system by direct contact between the power and telephone wires or by induction between them. They differ from lightning hazards principally in that they usually involve lower potentials and lower frequencies and are likely to be of much longer duration.

But currents large enough to do damage to telephone apparatus may come from the low-potential sources within the telephone system itself. Ordinarily, the currents flowing from the battery, charging generators, ringing machines, or other sources within the central office are prevented from rising to dangerous values by the resistances of the telephone apparatus and circuits themselves. In this sense, it is the aim of telephone-equipment design to make the apparatus and circuits "self-protecting." When, however, owing to some accidental derangement of conductors, the current from these low-potential sources is allowed to flow in other than their intended channels, the required amount of resistance may not be present and the currents may become large enough to do damage by overheating conductors. In fact, very large currents may flow from the storage battery if the discharge path is of low enough resistance.

In contradistinction to the hazards arising from excessive potentials or currents, there is another class due to small currents which, if allowed to persist, may store up enough heat in the conductors of telephone equipment to generate dangerous temperatures. These, called "sneak currents" because of their insidious nature, may be brought into the telephone system in various ways, as from a high-resistance cross with foreign wires. An important function of the central-office protective system is to guard against them.

To summarize: electrical hazards which must be guarded against by protective apparatus in telephone systems may arise from either natural or artificial causes. Of the natural hazards, that of lightning alone need be considered as of importance. Of the artificial hazards, the sources may be external to the telephone system or within it. The external ones are those communicated to the telephone system by conduction or induction from power, lighting, street-railway, or other foreign systems. Internal hazards are those of currents from the normal sources within the telephone system itself, when, owing to some mishap, they are allowed to flow in other than intended channels.

It is the function of telephone protective equipment to safeguard persons and property against all these hazards, whether arising from internal or external, natural or artificial causes. Obviously, the protective devices should be sufficiently sensitive to operate before the class of plant it is protecting is damaged, but, on the other hand, it is important that it shall not be so sensitive as to cause an undue number of useless service interruptions.

Telephone protective apparatus is of three different classes according to the type of hazard it is intended to guard against:

a. Those which guard against excessive currents. Of these, there are overload circuit breakers and fuses.

b. Those which guard against excessive voltages. The air-gap arrester or "open-space cut-out" is the principal one of these to be considered in telephony.

c. Those which guard against small currents which become dangerous only when persisting for a considerable time. Small-capacity fuses are sometimes used for this purpose but the real

protector against sneak currents is the heat coil or thermal cut-out, which, in marked degree, recognizes time as well as current strength in its operation.

Protection against Heavy Currents.—The overload circuit breaker is an electromagnetic switch designed to open a circuit automatically when the amount of current flowing in it approaches the danger point. It usually opens the circuit more promptly for a large excess of current than for a smaller one. It is not to be classed specifically as a telephone protective device, for its principal use is in power systems. As such, it finds use in telephone central-office power plants.

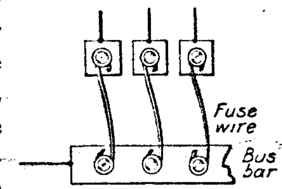


Fig. 226.—Open fuses.

Fuses.—A fuse is a link of easily melting metal placed in series in the circuit it is designed to protect. Conductively, it should form the weakest part of the circuit, so that it will be destroyed by a current somewhat smaller than will endanger other parts of the circuit.

The fuse links for telephone apparatus are often in the form of a thin ribbon or fine wire of lead or of a lead alloy, although sometimes a smaller wire of copper or phosphor bronze has been used. For power circuits, the link is often made of a thin strip of zinc. It is important that the fuse shall be chemically stable under atmospheric conditions, so that it may not gradually change its characteristics with the lapse of time.

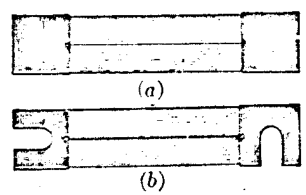


Fig. 227.—Mica fuses (*a*) Western Union type, (*b*) Postal type.

There are *open* and *enclosed* fuses. A form of open fuse, now little used in telephone work, consists merely of a short piece of fuse wire, cut from a longer piece and clamped between two fixed binding posts forming terminals of the circuit to be protected. Three such fuses, for protecting three individual circuits leading from a common bus, are shown in Fig. 226. This type has little to recommend it. One main objection to it is the ease with which a blown fuse may be replaced by a piece of copper wire or other conductor of too large carrying capacity, a practice which, while saving subsequent annoyance in the matter of fuse replacements, is likely to lead to serious trouble in other directions. Another objection is the likelihood of damaging the soft fuse wire, with consequent alteration of its carrying capacity, by the act of clamping it in its binding posts.

Forms of open fuses have been developed, however, which largely avoid these two difficulties by permanently associating frail fuse wire with some sort of support of insulating material which carries terminals of its own, between which the fuse link is permanently connected. These terminals on the fuse support are adapted, without danger of injuring the fuse wire itself, to cooperate with "slip-in" or screw terminals in the circuit to be protected. The well-known "mica fuse," originating in telegraph work, is an example.

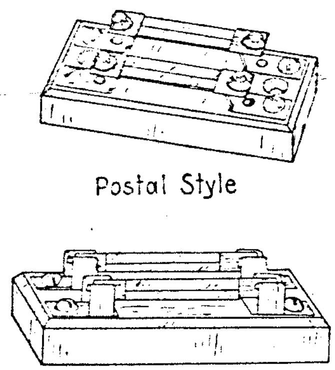


FIG. 228.—Mica fuse blocks.

Two types of mica fuses, known respectively as the "Western Union" and the "Postal," are shown in Fig. 227. In these, the fuse wire is mounted on a mica base or enclosed between two strips of mica. The terminals are of either copper or tinfoil wrapped about the ends of the mica. These fuses may be inserted in the circuit by clamping the terminals under screws or by sliding them between spring clips. Fuse blocks for either of these types of mounting are shown in the two views of Fig. 228. Mica fuses are compact, cheap, clearly visible for inspection, and easily replaced, but they are not held in very high esteem in any comprehensive scheme of telephone protection work. Among their disadvantages: they are too short, have no means of "blowing out" arcs that may be formed across their terminals, and often give no audible or visible indication that they have operated. Even where they may be mounted on a fireproof panel and used only in circuits carrying low potentials, their extensive use in telephone work is prevented by the fact that they usually give no indication of their operation. They are usually designed to blow on small currents, $\frac{1}{8}$ or $\frac{1}{4}$ ampere, and are generally quite inaccurate in their rating.

For protecting low-potential circuits, such as those supplying current from the common battery to the various parts of switchboard systems, the open fuse shown in Figs. 229 and 230 has been standardized for the Bell System. It is known as the "No. 35 type alarm fuse." One of them is to be found in the supply circuit to each individual cord or trunk repeating coil in common-battery manual systems. Also, one of them is placed in the battery feed for each small group of subscribers' line circuits, ringing circuits, and tone circuits.

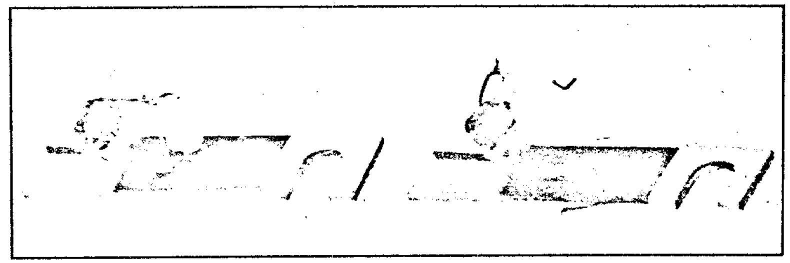


FIG. 229.—Western Electric No. 35 type alarm fuse. (*Courtesy of Bell Telephone Laboratories.*)

The body of this fuse is of black fiber about $1\frac{3}{4}$ inches long and $\frac{7}{16}$ inch wide, carrying a notched sheet-copper terminal at each end. The terminal at one end has an extension, projecting at right angles from the strip, to which is soldered a coiled spring of brass wire, carrying a glass bead at its free end. Attached to the other terminal, and on the other side of the fiber strip, is a flat spring with a normal tension tending to hold its free end at a considerable distance from the strip. The fuse wire itself passes through a hole in the fiber strip, its ends being connected to the free ends of the two springs in such manner as to be held in tension by them, drawing each of them toward the strip, as shown in the left-hand view of Fig. 230.

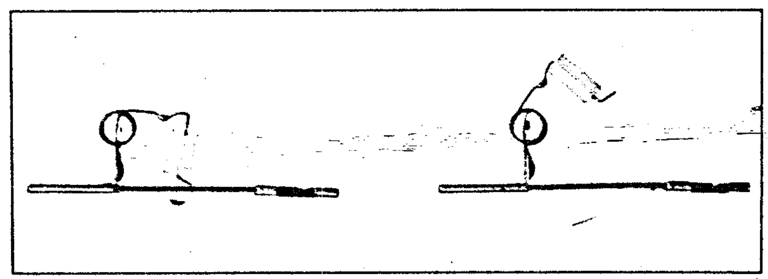


FIG. 230.—Two side views of No. 35 type alarm fuse. (*Courtesy of Bell Telephone Laboratories.*)

These fuses are mounted in rows side by side, $1\frac{1}{4}$ inches between centers, on the slate fuse panel. The side-notched end is, in each case, attached to the battery bus-bar, so that the flat spring carries battery potential even when the fuse is blown. The other end is attached to the terminal of the individual circuit which the fuse protects. Immediately behind such a row of fuses lies a conducting strip common to the row, this being connected to ground through a lamp and a relay controlling an alarm bell. The tension of the fuse wires normally holds all of the flat springs out of contact with this alarm strip but, when any fuse blows, the flat spring is released and engages the alarm strip, causing the lamp to glow and the alarm to sound. Also, the released tension of the fuse wire permits the coiled spring on the front of the strip to rise and bring the glass bead into a prominent position out of alignment with the others. Thus the blowing of a fuse sounds a general alarm to indicate that somewhere a fuse has blown, lights a lamp to indicate the group in which the fuse is to be found, and raises the glass bead prominently to identify the particular fuse.

These fuses are made in different sizes, ranging from $\frac{1}{2}$ ampere to 5 amperes. To aid in the proper identification of the fuses and particularly to prevent a fuse of the wrong rating being used in a given place, the glass beads are variously colored. The operating characteristics and the corresponding color of bead are shown in the following table:

RATING CHARACTERISTICS OF NO. 35 TYPE ALARM FUSES

Rated, amperes	Operation		Color of bead
	Amperes	In less than	
$1\frac{1}{3}$	2	$1\frac{1}{2}$ minutes	White
2	3	3 minutes	Yellow
$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$ minutes	Red
3	$4\frac{1}{2}$	5 minutes	Blue
5	$6\frac{1}{2}$	5 minutes	Green

Usually, in the design of central-office equipments, an effort is made to keep the current values in the different battery discharge leads down to $1\frac{1}{3}$ amperes and for that reason the $1\frac{1}{3}$-ampere size is by far the most common of the No. 35 type fuses. It is usually economical to place them near the first piece of apparatus in the battery lead. In manual offices, therefore, they are placed on a coil-rack fuse panel adjacent to the repeating-coil rack—that is, on the rack carrying the cord and trunk circuit repeating coil. In machine-switching offices, separate fuse panels are provided for each frame or for each group of apparatus.

The fuses so far considered are for low-potential circuits within the central office and never for outside circuits that require protection against lightning or high-potential power currents, in spite of the fact that mica fuses have often been used in telephone lines as a supposed protection against lightning. The principal reasons why these open fuses are not suitable for other than low-potential circuits are that they are too short, are not fireproof, and have no means for extinguishing arcs that may be formed across their terminals when the disturbing potential persists.

Fuses for the protection of circuits exposed to high-tension currents are usually of the enclosed or tubular type. The object of enclosing the fuse link is threefold: to prevent the melting or exploding fuse from scattering molten metal or hot gases which might start fires; to provide a means for automatically extinguishing arcs that tend to form across the gap left by the destroyed fuse; and to afford mechanical protection to the fuse link itself. The "cartridge fuse," used extensively in power work generally and in the power plants of telephone exchanges, is a familiar example of the enclosed fuse. It consists of a tube of strong insulating material with a metal terminal in the form of a ferrule or blade at each end. The fuse link, often a thin strip of zinc, extends within the tube from one terminal to the other.

A word may be said about the rating of commercial cartridge fuses. Their rated capacity is usually expressed in amperes and is intended to indicate the nominal safe value of current that the fuse will carry. The National Board of Fire Underwriters specify that, for acceptance, at least 50 per cent of the fuses chosen at random from stock shall meet the following requirements:

1. Fuse must carry 110 per cent normal current indefinitely.
2. Fuse temperature must not rise more than 70°C., when carrying 110 per cent normal current.
3. Fuse must blow within a specified time, according to size, when carrying 150 per cent normal current (1 minute for 1- to 30-ampere sizes, 2 minutes for 31- to 60-ampere sizes).

Coming now to enclosed fuses specifically intended for telephone use, the Western Electric No. 11-C tubular fuse, shown in

Fig. 231, has long formed an important element of the protection equipment of the Bell operating companies. The enclosing member is a tube of red fiber with a number of cross slots on one side as shown. The terminal at each end is provided with a screw and lock nut for attaching it to the circuit terminals. The fuse link itself is a thin ribbon of lead, covered throughout its length

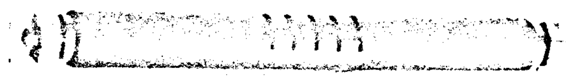


Fig. 231.—Western Electric No. 11-C tubular fuse.

by soft asbestos yarn and soldered to the terminal at each end. The link is made of lead in order to fuse at a low temperature and thus not develop dangerous heat. It is made in the form of a ribbon rather than a round wire to give it more surface radiating capacity and thus to minimize its tendency to blow upon the passage of instantaneous lightning currents. The slots provide an exit for the hot gases generated when the fuse is suddenly vaporized, and the rushing out of these gases, lengthwise through the tube, tends to blow out any arc that may be formed.

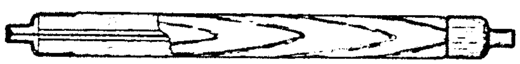


Fig. 232.—Cook tubular fuse.

Another tubular telephone fuse, made by the Cook Electric Company, of Chicago, and largely used by independent operating companies in this and foreign countries, is shown in Fig. 232. Here the fuse casing is variously made of porcelain, wood, or fiber. It carries at each end a terminal ferrule of brass, to which the ends of the fuse wire within the tube are soldered. These terminals on the fuse are so conformed at their ends as to slip between, and be firmly held under tension, by spring metal clips of the protector devices to be referred to later.

There has been a wide diversity of practice regarding the carrying capacity of tubular telephone fuses, and before discussing this it is well to point out that the Bell and independent telephone companies have quite different methods of rating their fuses. The Western Electric Company and the other companies of the

Bell System, like the power companies, rate their fuses according to the *current they will safely carry*. The manufacturing and operating companies in the independent field, on the other hand, rate their fuses according to their *blowing point*. Thus the No. 11-C tubular fuse of the Western Electric Company (Fig. 231) rated at "7 amperes" will carry 7 amperes indefinitely and will blow at 10½ amperes, which is 150 per cent of the rated value. On the other hand, the standard tubular fuse of the Cook Electric Company (Fig. 232) rated at "5 amperes" will blow at 5 amperes. Thus the difference in actual carrying capacity of the two fuses is much greater than their respective ratings would indicate.

In telephone-line wires that are exposed to possible crosses with power lines, the Bell companies have consistently used a tubular fuse rated at 7 amperes. Many of the older independent companies, however, have insisted on line fuses of much smaller capacities. Thus the standards of the Cook Electric Company, made to comply with this demand, are a 5-ampere rating for protectors at cable terminals and a 3-ampere rating for protectors at substations. The difference in practice as to fuse capacity has grown out of somewhat different ideas in the Bell and independent fields regarding the *manner* of protecting telephone lines. This point will be referred to at greater length when the use of the fuse in combination with protective devices of other types is considered.

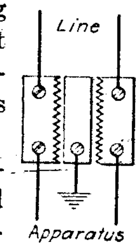


Fig. 233.—Early air-gap arrester or open-space cut-out.

Protection against High Potentials.—The open-space cut-out or air-gap arrester is primarily relied upon to protect against lightning and, in combination with the fuse, to protect against crosses from high-potential power wires. Its action is based on the principle that a charge of electricity, if of high enough potential, can jump across an air gap in seeking ground. A pressure of 70,000 volts, for instance, will cause a current to pass between electrodes separated by about 1 inch of dry air and smaller voltages will, of course, discharge across shorter air gaps. The potential required to jump across an air gap depends somewhat on the character of the surface of the opposed conductors, a discharge taking place more easily between points or between roughened surfaces than between flat or smooth ones. Figure 233 shows how these principles were applied in the early air-gap arresters of telegraphy and telephony. When the line wires become charged to a sufficiently high potential, the air gap between the two line plates and the ground would break down, allowing the charge to pass harmlessly to earth. Later, in telephony, carbon blocks were substituted for the metallic plates, these blocks being normally held apart by thin insulating separators usually of mica. The air-gap arrester or open-space cut-out then became essentially what is shown in Fig. 234, which, except for variations in detail, is representative of present-day practice.

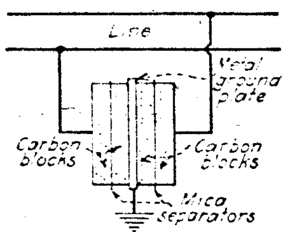


FIG. 234.—Principle of carbon-block arrester.

Carbon presented two principal advantages over the sawtooth metal plates of earlier practice: it did not melt under the heat of arcing across the gap and its granular structure presented, in effect, a multitude of points for facilitating the discharge.

Figure 235 shows the general form of a set of carbon blocks with their intervening insulating separator, such as, with certain

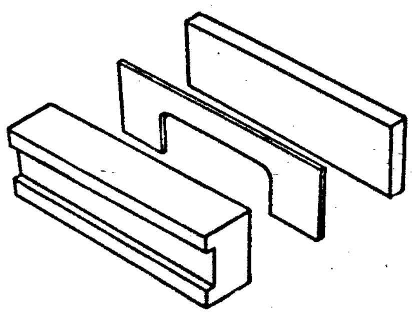


FIG. 235.—Carbon blocks and dielectric.

variations, have long been used in open-space cut-outs. The grooved carbon is the one engaged by the line spring of the protector mounting, the spring resting in the groove which serves in guiding the carbon into its proper position. The flat carbon rests against the ground plate of the protector mounting, the two blocks and the intervening separator or dielectric being clamped together by the pressure of the line spring. In mounting, such a protector should always be so placed that the U-shaped dielectric will lie in a vertical plane with its open side pointed downward, so as to

allow any carbon dust, torn off by a lightning discharge, to fall out and thus be less likely to leave a permanent ground on the line.

This matter of whether the open-space cut-out is to leave a ground on the line after operation or not has received much attention. For lightning discharges, which are usually of momentary duration, it is desirable that the line be left clear after the discharge. Otherwise, after a lightning storm much time, labor, and expense are required in cleaning the carbons to restore the service. In the case of crosses with power and lighting lines, however, the discharge is likely to persist and develop dangerous heat by the continued arcing at the arrester. The Bell companies meet this condition by designing their carbon blocks so that, with continued heat, they will definitely provide a permanent low-resistance path to ground across the gap. The independent practice, on the other hand, has tended toward an open-space cut-out with no provision for permanently grounding the line. The independent telephone man has generally been quite willing to accept an arrester of this kind because of the trouble saved in clearing grounds after electric storms and has been quite ready to overlook the fact that a power ground on his line may not be taken care of. In comparison with the Bell practice, his tendency has been toward the use of less sensitive open-space cut-outs, that are less likely to ground, coupled with line fuses of lower rating that, of course, are subject to more frequent renewals.

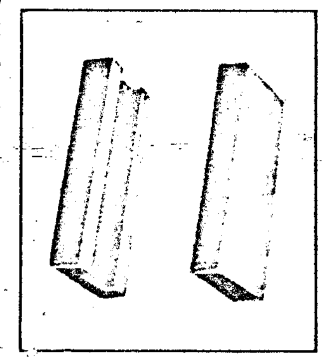


FIG. 236.—Western Electric Nos. 1 and 2 protector blocks.

Figure 236 shows the No. 1 and No. 2 carbon blocks of the Western Electric Company protector, which for many years were used by the Bell Companies for substation and central-office protection. These employed a U-shaped mica dielectric which held the blocks at such a distance apart that they would operate in case of lightning or crosses with light or power wires that caused potentials of more than about 500 volts. The provision for the permanent grounding of the line in case of a power-wire cross consists in the small plug of a low-fusing lead alloy imbedded in the center of the No. 1 block. When the arc persists, this plug melts and flows between the plates, thus shunting the arc by a resistance so low that it is extinguished. In this case, were not a fuse provided between the arrester ground and the power cross, as hereafter described, current would continue to flow to ground without injury to the apparatus beyond the arrester but with danger of overheating the conductor between the cross and the ground.

Recently the Nos. 1 and 2 protector blocks have been superseded in the Bell System by the Nos. 26 and 27 blocks shown in

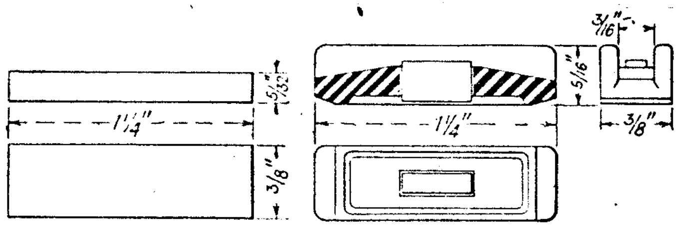


FIG. 237.—Western Electric Nos. 26 and 27 protector blocks.

Fig. 237. These are adapted to fit in the same protector mountings as the old blocks. Figure 238 gives a perspective view of each of these same blocks and also shows how two pairs of them are assembled in the protector mountings, which, in the Bell System,

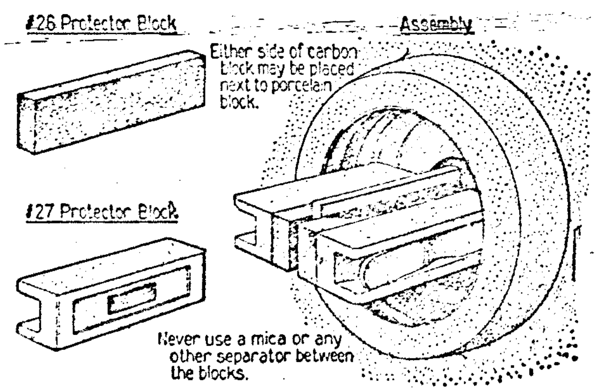


FIG. 238.—Western Electric substation arrester.

are used at all subscribers' stations requiring protection. This mounting has a base of porcelain, from the center of which projects, at right angles, a ground plate. Secured to the base on

each side of the ground plate are the two line springs, each so disposed as to clamp its pair of blocks firmly between itself and the ground plate. A cylindrical metal cup, not shown, serves as a cover to guard against sparks' being thrown off by the protector and also to prevent the accumulation of dust from the atmosphere. The No. 26 block is a rectangular piece of hard non-dusting carbon which forms the ground electrode. The No. 27 block consists of a porcelain body, carrying in its center a small rectangular carbon insert forming the line electrode. The insert is fastened in place by glass cement which softens when heated. The face of the porcelain block bears directly against the No. 26 block when assembled in the mounting, no intervening separator being used. The face of the carbon insert is set back slightly from the plane of the porcelain face, just far enough to assure the proper thickness of air gap. The opposite side of the carbon insert projects far enough into the groove of the porcelain block so that it will be engaged by the line spring and pressed toward the No. 26 block, this pressure of course being normally resisted by the cement joint between the insert and the porcelain. Ordinarily, lightning potentials will discharge across the air gap but will not permanently ground the line. A discharge from a power line will, if it persists long enough, generate enough heat to melt the glass cement and allow the mounting spring to push the carbon insert into direct contact with the ground block, thus permanently grounding the line. This is of comparatively rare occurrence. In the majority of protector operations that occur in practice, the blocks do not become permanently grounded.

Arresters equipped with this pair of blocks are used at subscribers' stations and at central offices. Because of their smaller air gap, they will operate at lower potentials than those equipped with the older form of block. Notwithstanding this increased sensitivity, the new type of block gives less trouble from grounding by the accumulation of dust than the older form. This is mainly due to the fact that the space across the air gap is open at all four edges of the carbon insert, thus affording an easy path for the escape of carbon dust into the chamber within the porcelain block.

This cut-out formed of the No. 26 and No. 27 blocks has an air gap of approximately 3 mils (0.003 inch). On the average, it will break down at a peak of 350 volts, and practically all of them will break down at voltages of 550 or less. There is another type of porcelain block, the No. 30, of the same external dimensions as the No. 27 but with the carbon insert slightly more depressed to give an air gap of about 6 mils (0.006 inch). This, when used with the No. 26 block, has an average breakdown of about 710 peak volts, practically all of them discharging at voltages of 1,080 or less. This combination is used at the junction of cable and open wire, as will be described later.

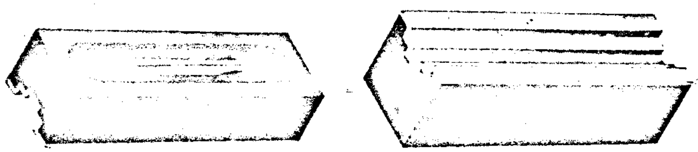


FIG. 239.—Cook "non-grounding" discharger.

To meet the demand of the independent companies for an open-space cut-out with a minimum liability of grounding the line, the Cook Electric Company, of Chicago, supplies the type of cut-out or discharger shown in Fig. 239. In this, the grounded electrode, the lower one of the assembled pair at the right, is an ordinary rectangular block of hard non-dusting carbon. The other member of the pair is a Bakelite block, having on one side a grooved cap of bronze adapted to fit the springs of the ordinary arrester mounting. Molded within this block and extending through it from the cap on one side to a chamber on the other is a heavy bronze blade, the exposed edge of which is ground to a

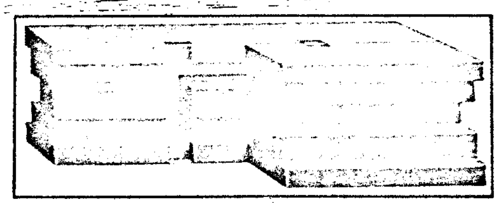


FIG. 240.—Cook "unit" discharger.

surface whose plane lies slightly below the plane of the face which rests against the carbon block. No separator is used between the two blocks, the desired air gap being secured by merely bringing the faces of the two blocks together in the protector mounting. Unlike the Bell open-space cut-out, which is specifically intended to ground the line permanently under certain circumstances, this one is employed by the independent companies because it is intended never to leave a permanent ground on the line. Its value, of course, is principally in lightning

protection, for which purpose it is used in pole cable terminals, substation protectors, and rural-line arresters. In fact, it is used at points outside the central office, where the carbons are less readily accessible for cleaning after storms.

Another arrangement of open-space cut-out blocks made by the same company is shown in Fig. 240. In this, two very hard carbons are cemented together with an interposed celluloid dielectric, forming together a unitary structure adapted to be slipped into place in an ordinary protector mounting. As illustrated, the carbons have two grooves cut across the length and width of the discharge surface. The dielectric, a form of celluloid called "Kodaloid," has a rectangular opening in its center to afford an air gap between the two central carbon rectangles. Cementing the two carbons and the celluloid dielectric together tends to assure accuracy of air gap with resulting uniformity of action, since there is practically no variation in the thickness of the celluloid and no liability that the installer will alter the air gap by substituting dielectrics of other thicknesses. These units are intended to break down at 500 volts and are said to act reliably within a few volts of this potential. Unlike the discharger of Fig. 239, this one is intended to put a ground on the line after continuous arcing, the heat generated serving to melt or burn the celluloid and allow the springs to force the carbons together.

Obviously, the sensitiveness of open-space cut-outs can be varied by using separators of different thicknesses. The choice of this thickness is affected by two opposing considerations. The arrester must not operate at the potentials employed in the normal operation of the telephone system but must operate at such higher potentials as would injure the telephone equipment. If too thin a separator is used, the arrester is likely to respond to some of the higher potentials regularly employed in telephone operation, such, for instance, as the peak voltages of ringing current. On the other hand, if too thick a separater is used, the arrester will be less sensitive and will not be so effective in protecting against external high potentials.

The tendency during recent years has been away from the mica separator. The principal objection to it has been the difficulty and resulting cost of producing it accurately to the desired thickness. Another objection to the mica separator, or in fact any other detached separator, is the facility with which a workman may increase the air gap by using two or more separators.

Another type of open-space cut-out has found limited use in telephone protection. This is the vacuum-tube arrester, in which the line and the ground electrodes are enclosed in an exhausted glass bulb, instead of being open to atmospheric conditions. This permits a wider discharge gap for a given breakdown voltage and consequently less likelihood of permanent grounding after a discharge. It has not found general application in commercial telephony, however, because of its bulk and cost, coupled with the difficulty of building it to have a definite and constant breakdown potential.

Protection against Sneak Currents.—Sneak currents are too small and of too low voltage to affect either the fuses or the open-space cut-outs ordinarily used in the protection of telephone lines, and yet, if allowed to flow for undue periods, they may store up enough heat in telephone equipment to generate dangerous temperatures.

The amount of heat generated in a conductor is equal to I^2Rt, where I is the current, R the resistance of the conductor, and t the time of flow. Hence it is clear that, in order to deal effectively with these small currents, our protection device should recognize the element of time. This the heat coil, which is the sensitive element in the sneak-current protector, does.

Essentially, a sneak-current protector consists of a line-grounding switch and a heat coil. The movable element of the switch is normally held in its ungrounding position by a small mass of low-fusing solder within the heat coil. The resistance or heating element of the heat coil is connected in series in the circuit which it protects and, when traversed by a sneak current for a sufficient period, it stores up enough heat to melt the solder and allow the switch element, under spring action, to assume its alternate or grounding position. In some protectors, the switch not only *grounds* the line but opens it as well.

The resistance of the heat coil is so proportioned to its heat-radiating capacity that the normal talking or signaling currents traversing the line will not cause the temperature within the coil to rise enough to melt the solder. A sneak current, however, because of either its greater volume or its longer duration or both, builds up heat faster than it can be disposed of by the coil and, as a result, the temperature gradually rises until the solder

is melted, releasing the switching spring and allowing it to assume its alternate or grounding position.

The heat coil used by the Bell System at the central-office end of all lines requiring protection is shown, somewhat magnified, in Fig. 241. This consists of a coil of fine wire wound around a small copper tube, in which a small rod or pin is soldered. The coil and soldered joint are enclosed in a fiber shell for mechanical protection and heat insulation. The pin and copper tube projecting from one end of the shell form one terminal of the coil. The pin is fixed in the fiber shell but is insulated from the metal cap at the other end, which forms the other terminal of the coil.

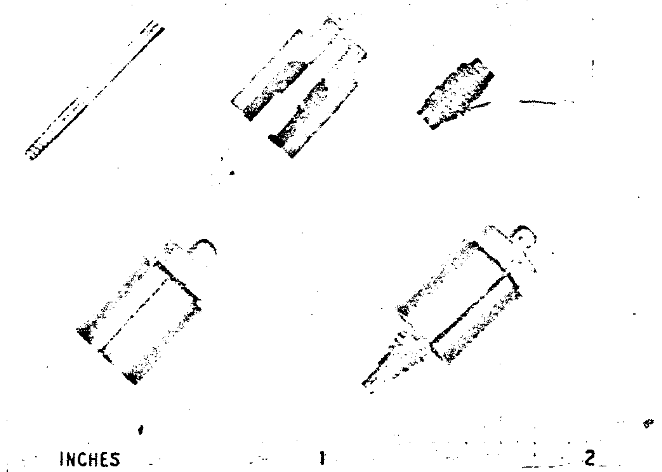


FIG. 241.—Western Electric No. 76-A heat coil. *(Courtesy of Bell Telephone Laboratories.)*

The central-office protector mounting for heat coils and air-gap arresters is shown in Fig. 242, which indicates also the circuit connections and the principal dimensions. The sectional view shows a pair of protectors, one for each of the conductors of a metallic circuit entering the central office. The ground plate shown in the center forms a common mounting for many protectors arranged side by side and, in this case, on ½-inch centers. In the larger offices of the Bell System, in order to conserve terminal room space, similar protectors are mounted on ⅜-inch centers along the mounting strip, thus affording room for 400 pairs on a vertical strip extending from floor to ceiling.

The two inner springs, next to the ground plate, form the terminals of the two conductors of the "outside line," that is, the line extending through the outside cable system to subscribers' stations or to other central offices. Each of these outside-line springs has three branches. Of these the longest one engages the porcelain or line block of the air-gap arrester. The two shorter ones are engaged by the exposed ends of the pin and copper tube respectively of the heat coil.

The two springs lying at the outside of the group of each pair of protectors form the terminals of the pair of line wires leading from the protector to the switchboard equipment, these constituting what is called the "inside line." When the heat coils are slipped in place in the protector mounting, as shown, the con-

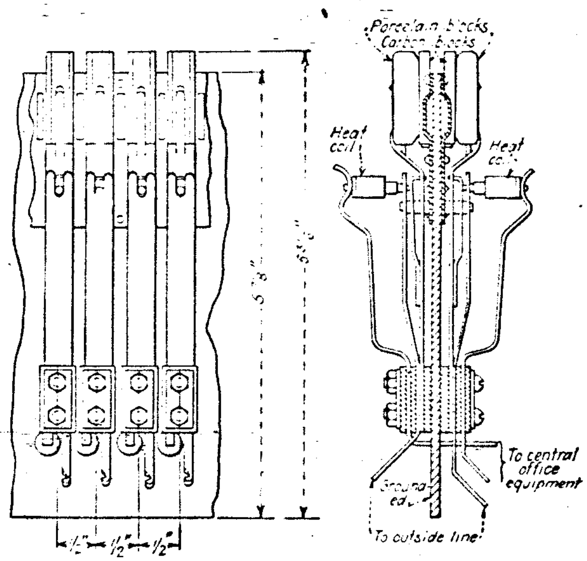


Fig. 242.—Western Electric central-office protector.

nections between the outside- and the inside-line wires are completed through their windings. Normally, the pin is prevented by the solder from sliding within the copper sleeve, the end of which forms a fixed shoulder preventing the heavy outer spring from forcing the pin toward the central ground plate. When, however, a sneak current develops enough heat to soften the solder, the pin is allowed to slide through the copper sleeve toward the ground plate. This movement, without breaking the circuit through the heat coil, presses the short ground branch of the outside-spring against the ground plate, thus putting a dead ground on the line.

By virtue of the open-space cut-out of this protector, any potential on the line exceeding approximately 350 volts will be shunted to ground by the breakdown of the air gap. Likewise, any sneak current which persists long enough to endanger the central-office apparatus is diverted by the grounding of the line, owing to the action of the heat coil.

The heat coil now in general use in the Bell System (No. 76-A, with black shell for identification) has a resistance of approximately 3.45 ohms. It will carry 0.35 ampere for 3 hours and will operate on a current of 0.54 ampere within 210 seconds.

In practice, those telephone lines which, throughout their length, are not considered to be exposed to electrical hazards are not provided with protection. The question of the classes of lines falling within the "exposed" and the "unexposed" categories will be considered later in this chapter. It may be said here, however, that it is the practice of the Bell System to provide all lines at the central office with the complete protector *mounting* as shown in Fig. 242, whether requiring protection or not. In the case of unexposed lines, the heat coils and the carbon blocks are omitted, "dummy" heat coils and wooden protector blocks being substituted in their places. In this way, the facilities for terminating the conductors of the inside and outside lines afforded by the protector springs are available on all lines, with the additional advantage that the status of any line, whether with respect to its requiring protection or not, may be changed by merely changing its heat-coil and protector-block equipment.

A type of heat coil known as "self-soldering" has come into wide use in the independent telephone field. It derives this name from the fact that upon cooling after operation, it resolders itself so as to be again usable by a mere change of position in the protector mounting.

The most widely used heat coil of this type is one made by the Cook Electric Company, shown in Fig. 243. The coil is provided with a ratchet on its outer edge, one of the teeth of which serves as a detent for the movable arrester spring as long as the coil is prevented from rotating by the solder. When, however, the solder is melted, the ratchet is permitted to turn, thus releasing the spring. These protectors are re-set by merely placing the controlling spring in engagement with another tooth of the coil after the solder has again congealed.

The resistance element of this coil is wound on a small copper spool, as shown in the sectional view of Fig. 243. One end of the resistor winding terminates in this spool, and the other end

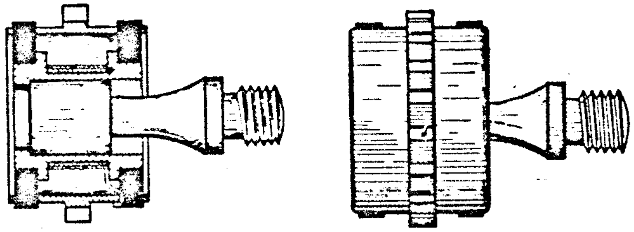


FIG. 243.—Cook self-soldering heat coil.

in an outer metal shell, which carries ratchet teeth as indicated. This copper spool is soldered to a central metallic pin, which screws into the line spring of the protector mounting as shown in Fig. 244.

The movable spring of the arrester mounting is provided with a detent adapted to engage one of the ratchet teeth, so as to be held in its restricted position as long as the soldered joint prevents the ratchet from turning.

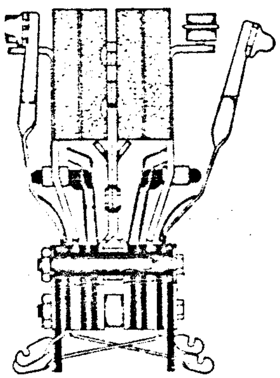


FIG. 244.—Cook central-office protector.

As shown in Fig. 244, the two soldering terminals at the lower right corner are for the attachment of the outside-line conductors, those at the lower left corner being for the inside line. The protector at the left is shown in its normal position, the ratchet on the heat coil holding the long movable spring in its flexed position. When so held, the circuit from the outside- to the inside-line wire is completed through the heat coil. Also, by means of the insulating plunger engaged by the mid portion of the movable spring, the two short inner springs are held out of engagement with the line spring.

The parts of the protector at the right of Fig. 244 are shown in the position they assume after the heat coil has operated. Upon the melting of the solder, the ratchet releases the long outer spring, thus opening the line circuit. Also, by releasing the pressure on the insulating plunger, the two shorter springs are

allowed to engage the spring forming the terminal of the outside line. The inner one of these short springs is seen to be in permanent connection with the ground plate and it thus serves to ground the outside line. The other one of the short springs also becomes grounded by engaging the now grounded line spring. It forms the terminal of an alarm circuit, which is thus energized to sound an alarm whenever any heat coil operates.

This sneak-current protector, which has a non-inductively wound coil not exceeding 4 ohms in resistance, will operate in

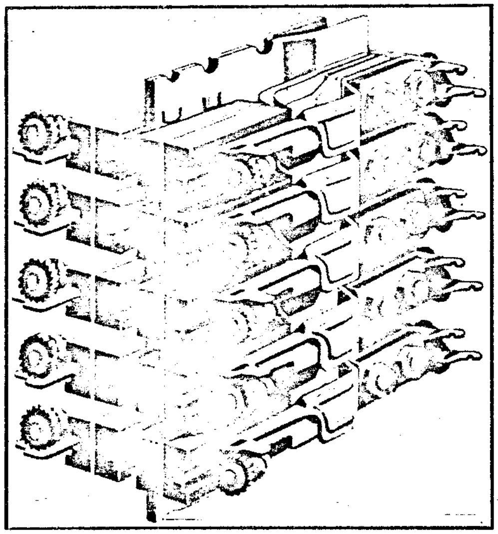


FIG. 245.—Strip of Cook central-office protectors.

less than 210 seconds on 0.5 ampere and will carry 0.35 ampere for 3 hours with a room temperature of 68°F.

The arrangement of the open-space cut-out of this protector and its mode of operation when subjected to dangerous potentials will be clear from this cut in view of what has been said before. The carbon blocks and separators may be of either of the types shown in Figs. 235 and 240.

Five pairs of these central-office protectors, for five metallic circuits, are shown in Fig. 245. These are ordinarily mounted on $1\frac{1}{2}$-inch centers but, for use in very large central offices, the same company makes a somewhat different arrangement mounted on $\frac{3}{8}$-inch centers.

General Plan of Protection.—The foregoing discussion has dealt mainly with the individual pieces of protective apparatus, the fuse, the open-space cut-out, and the heat coil. No one of these alone suffices, and it remains to be seen how, in combination, they are made to afford the degree of protection desired.

Of first importance in the matter of protection, and ranking ahead of any protective apparatus *per se*, is the initial design and construction, and subsequent upkeep, of the telephone plant itself, with regard to maintaining proper clearances from the wires of other companies and the avoidance of dangerous voltages and currents from outside sources. These are the "first-line defenses" against electrical dangers to life and property. In practice, however, these defenses cannot be invulnerable. Many of the wires must, of necessity, be run in exposed places and, even with the greatest care, the proper clearances cannot always be maintained, so that occasional accidental contacts cannot be wholly prevented. This makes necessary the "second-line defenses," consisting of the various protective devices that have been described.

The voltages normally employed within the telephone system are as a rule not dangerous to either persons or property. The most commonly used voltage is that of the 24- or 48-volt battery used for talking and signaling purposes. This, of course, is a direct-current voltage to which most of the circuits of the telephone system are subjected practically all the time. The highest normal voltage within the telephone system is that of the ringing current, which, with a proper ringing machine, does not rise above 160 volts at the peak of the wave. Other voltages, sometimes used, are: 40 volts direct current for the operation of message registers and 135 volts, plus or minus, for telegraph operation. All parts of the telephone system are designed to withstand these normal voltages with a reasonable margin of safety. For the most part, the telephone apparatus itself has such impedance that the currents in it from these normal voltages will not reach dangerous values. In that respect, it is the intent in the design of the system that the apparatus shall be self-protecting. But when something goes wrong within the exchange, as in the case of short circuits, the currents from these normal sources are prevented from rising above safe values by fuses, such as the No. 35 type alarm fuse of Fig. 229, placed in the various leads over which current is supplied to individual circuits

or to small groups of circuits. Further than this, no protecting devices are required with respect to the sources of current normally employed in the telephone system.

With respect to hazards from foreign wires, telephone circuits are classified as "exposed" and "unexposed." Comprehensive definitions of these terms would be rather voluminous but, for the present discussion, it may be stated that an unexposed circuit is considered to be one so located that there is no possibility of having pressures from foreign wires in excess of 250 volts

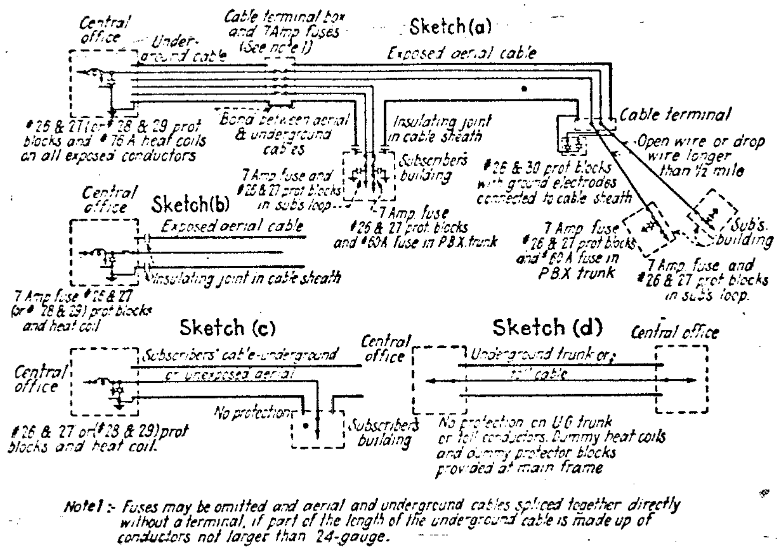


FIG. 246.—Application of protective devices.

impressed on any part of it. A circuit not meeting this requirement is considered to be exposed.

Regarding telephone wires in cables, it may be said that the wires in underground cables are, in themselves, generally considered unexposed, except as they may be connected with exposed wires beyond the underground section. The wires in aerial cables are considered exposed or unexposed according to the environment of the cable. If there is possibility of a cross with foreign wires carrying pressures of 250 volts or higher, then the wires in the cable are exposed. Although the wires within the cables are insulated from the cable sheath, it has been found that a cross between a foreign wire and the cable sheath may easily burn through the cable sheath and affect the wires within.

Figure 246 shows, in schematic form, the manner in which protection is usually provided in the Bell System under some of the more common plant conditions. For convenience in interpreting this figure, the characteristics of the different protective devices shown on it by code numbers are given below, mostly in repetition:

Fuses.—With exception of the No. 60-A fuse, all fuses have a 7-ampere rating and are of the general type shown in Fig. 231.

The 60-A fuse has the same operating characteristics as the heat coil, except that it opens rather than grounds the conductor. It consists of two short heating wires joined by a small ball of solder and within a short fiber tube. The wires are held under spring tension, so that when the solder softens they are pulled apart to open the circuit. This fuse is used where sneak current protection is required at places other than central offices.

Protector Blocks.—The Nos. 26 and 27 blocks (Figs. 237 and 238) have a rated breakdown voltage of 350.

The Nos. 28 and 29 blocks have the same breakdown rating. They differ from the Nos. 26 and 27 blocks only in size and are used only at those central offices that are provided with the ⅜-inch protector mountings.

The No. 30 block differs from the No. 27 only in its thickness of air gap. It is used only at junctions of aerial cable and open wire and, in combination with the No. 26 block, has a rated breakdown voltage of 710.

Heat Coils.—These are used only at central offices. The No. 76-A coil (Fig. 241) has a resistance of 3.45 ohms. It is rated to carry 0.35 ampere for 3 hours and to operate within 210 seconds on a current of 0.54 ampere.

We may conveniently discuss the application of these various protective elements in connection with Fig. 246 under three separate headings, according to the classes of property affected: central-office protection, substation protection, and cable protection.

Central-office Protection.—The protection required at the central-office end of each line under the different plant conditions covered by Fig. 246 is indicated at the left-hand end of each of four sketches of that figure. For exposed lines (Sketches *a* and *b*) it always consists of an open-space cut-out, a heat coil, and a fuse element.

The location and character of this fuse element deserve attention. It is to be remembered that the line fuse, rated at 7 amperes, will carry currents large enough to injure the central-office equipment and that this fuse is for the purpose of interrupting the heavier currents that flow in the line from a high-potential source after the open-space cut-out or the heat-coil protector has operated to put a dead ground on the line. This grounding of the line by the open-space cut-out or the sneak-current protector serves to protect the apparatus and wiring beyond these protectors inside the central office, but it is likely to produce currents that would endanger the protector mounting itself and the line wire between the protector and the source of trouble were it not for the intervening fuse.

This fuse element need not be and usually is not at the central office. In the Bell System of protection, it is located at the juncture between the exposed and unexposed portions of the line. Thus, in Sketch *a*, the fuses are placed at the point where the exposed aerial cable ends and the underground cable begins. In Sketch *b*, it is placed in the central office, ahead of the other protective devices, for at this point the juncture of the unexposed wires within and the exposed wires outside occurs.

The fuse between the underground and aerial cable (Sketch *a*) may be omitted entirely in cases where a considerable length of the underground cable entering the central office is composed of 24-gage wires or smaller. Its omission, in this case, is on the theory that cable conductors of these small sizes will fuse on current values not high enough to overheat the central-office protectors dangerously. With these small-gage cables, therefore, the cable conductor suffices as the fuse element.

In cases where the cable throughout its length is unexposed, as where it is all underground, or is unexposed aerial cable (Sketches *c* and *d*), then the fuse is omitted entirely.

One may ask, in view of this latter statement, why the heat-coil and air-gap protector are used at the central-office end of an unexposed subscriber's loop (Sketch *c*). This is explained in the *Bulletin*[1] from which the information of Fig. 246 was taken as follows: "Subscribers' loops, even though classified as unexposed, are nevertheless subject to the possibility of having lighting voltages (110 to 220 volts) impressed on them as a

[1] "Principles of Protection," American Telephone and Telegraph Company, 1929.

result of contacts at the subscribers' premises and heat-coil protection at the central office is therefore advisable. Although open-space cut-outs are not needed electrically on unexposed subscribers' loops they are generally provided for the reason that it is cheaper to do this than it is to keep account of the relatively frequent changes in the exposure status of such circuits and insure that open-space cut-outs are installed in all cases where the exposure conditions require them."

Sketch *c*, it will be noted, relates to cables containing the wires of subscribers' lines. The case is somewhat different where inter-office trunk wires or toll wires are contained within a cable that is wholly underground (Sketch *d*). Here there is considered to be no exposure to the conductors themselves throughout their length and none in the buildings in which they terminate. Changes in the exposure classification of trunk and toll circuits are, in general, rare and are not difficult to keep account of. It is the practice, therefore, to omit open-space cut-outs and heat-coil protection on unexposed circuits of this kind.

All lines entering a central office, whether requiring protection or not, are terminated on protector mountings such as those shown in Fig. 242, but, where protection is not required, dummy heat coils and wooden blocks are substituted for the regular heat coils and carbon blocks. The dummy heat coils are in the form of metal cylinders adapted to fit in the protector mounting, and they serve to maintain the continuity of the line through the protector. The wooden blocks prevent the grounding of the line that would otherwise occur on the removal of the carbon blocks. The combined heat-coil and air-gap arresters (Fig. 242) in central offices are always mounted in long vertical strips on the "protector side" of the main distributing frame, as will be shown more clearly in the next chapter. Where the line cables enter the central office directly from underground conduits, as is practically always the case in large offices, the line fuses, which must be regarded as a part of the central-office protection, are placed at the outer ends of the underground cables as indicated in Sketch *a*. Only in the case of relatively small exchanges do aerial cables enter the central office directly. Where this is the case, the line fuses are mounted either on a separate fuse rack just inside the office or in a boxed enclosure on the pole just outside the office. Thus, in either case, the

rule of placing the fuse between the exposed and unexposed portions of the line is followed.

In Fig. 246, the heavy lines on each side of the cable conductors represent the sheath of the cable. Some confusion in understanding will be avoided if it is remembered that these two lines represent in reality a single conducting cylinder, so that the indication of a ground on one of the heavy lines, as at the central office in Sketch *a*, is in reality a ground on both of them. The sheaths of underground cables entering a central office are bonded to the central-office ground, except where electrolysis conditions make it undesirable. Where this is done, the cable sheath becomes a part of the central-office ground network. Where the cable entrance to the central office is through exposed aerial cable, the continuity of the cable sheaths entering the building is interrupted by means of insulating joints as shown in Sketch *b*. These are employed primarily to prevent a transfer of electricity into the building by way of the sheath, in the event of a cross between the sheath and a power conductor.

Station Protection.—Protection consisting of an open-space cut-out and a 7-ampere fuse is provided for all subscribers' stations served by exposed lines. This is shown at the subscribers' stations at the center and right-hand end of Sketch *a*. As at the central-office end, the fuse is always placed between the air-gap arrester and the exposed part of the line, so as to interrupt the flow of the heavy current that is likely to follow the grounding of the line due to the discharge through the air gap.

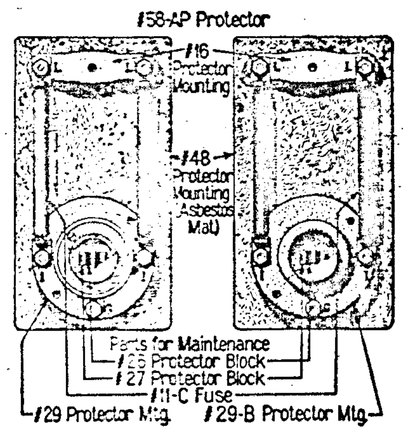


Fig. 247.—Western Electric station protector.

In the case of private branch-exchange trunks (Sketch *a*), where the apparatus is of such a nature that sneak currents are likely to do damage, No. 60-A fuses are also included in the trunk. These are placed inside the other protective equipment, that is, between it and the P.B.X. equipment. At stations where the telephone circuit terminates in a subscribers' set, sneak-current protection is not employed, since the impedances involved are such that the amount of current which can flow from pressures not high enough to operate the air-gap arrester are considered insufficient to constitute a fire hazard.

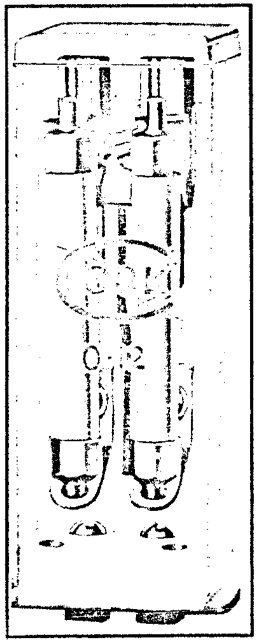


FIG. 248.—Cook station protector.

As indicated in Sketch *c*, no protection is used at substations served by lines that are unexposed throughout their length.

The Western Electric standard station protector, of which two slightly different forms are shown in Fig. 247, is used at all subscribers' stations of the Bell System requiring protection. This applies to manual and machine-switching common-battery stations and to magneto stations. The lower portions of these comprise essentially the same carbon protector blocks and mountings as are shown in Fig. 238. The upper porcelain mountings carry the line ends of the pair of tubular fuses of the type shown separately in Fig. 231.

These station protectors are mounted on either the inside or outside of the building in which the station is located, and as close to the point of entrance of the outside line wires as possible. Where mounted outside the building, they are placed in weather-tight iron boxes. The outside mounting, where permissible, offers advantages in point of accessibility, being available to the maintenance man at times when the subscribers' premises are closed.

A substation protector manufactured by the Cook Electric Company for those telephone companies in the independent field employing substation protection is shown in Fig. 248. Like the Western Electric protector, it consists of a pair of tubular fuses and two pairs of arrester blocks, and it may be mounted either inside or outside the building. The fuses ordinarily employed in this protector are rated to blow at either 3 or 5 amperes, and the arrester blocks may be of carbon with celluloid dielectrics, as shown in Fig. 235, or of the type shown in Fig. 239, in case blocks not so likely to ground the line permanently are desired. The line, instrument, and ground wires pass up through holes in the porcelain base to the arrester terminals, the line terminals being on the back face of the porcelain standard near the bottom and the instrument and ground wire terminals near the top.

Cable Protection.—As indicated at the right-hand end of Sketch *a*, (Fig. 246) open-space cut-outs are employed where open wires of considerable length pass into cables. In such cases, each protector is connected between a line conductor and the cable sheath. Here they are intended to prevent the building up of high potentials, due to lightning, between the conductors and the sheath. Ordinarily, the potential of cable conductors follows closely the potential of the sheath. But where, as in the present case, the cable conductors extend considerably beyond the end of the sheath, lightning may cause differences of potential between the cable conductor and the sheath sufficient to break down the insulation. The open-space cut-out, connected as shown, tends to limit such potential differences to values which the cable insulation is capable of withstanding.

Unless the region is particularly subject to lightning storms, it is customary, in Bell practice, to provide this protection at cable terminals only in cases where some of the open wires extend more than half a mile beyond the cable end. Where any of the lines are so equipped, the same treatment is applied to all in the cable, even though some of the open-wire extensions may be shorter. For such use, the No. 30 protector block, with a breakdown voltage of approximately 750 volts, is used, instead of the No. 27 which is used in all other cases. Concerning protection at such points the bulletin above referred to says: "Although the protectors installed at junctions of cable and open wire are effective against lightning, they cannot, in general, be expected to prevent damage to cables from contacts between power wires and the open-wire telephone circuits. The only practicable way of preventing such damage lies in avoiding contacts with power wires." As will be seen, quite a different idea of cable protection has existed among the independent telephone companies.

Protection Practices of Early Independent Companies.—It has been mentioned that the early independent telephone companies in the United States developed their protective systems along somewhat different lines from those of the Bell companies. Within the past five years the tendency has been for many of these companies to follow more closely the Bell practices as just outlined. However, as there is still a good deal of argument in some quarters about proper methods, a brief discussion of some of the divergent plans may be of interest.

In matters of degree, the independent companies have always inclined to fuses of lower carrying capacity and to air-gap arresters less likely to leave permanent grounds on the line. Besides these, there were more fundamental differences of method, such as: the omission of fuses at the junction of underground and exposed aerial cable; the use of fuse and air-gap protection in cable terminals at points where open wires join aerial cables in city distribution; and the omission of all protection at subscribers' stations in common-battery systems.

The first of these main differences—the omission of fuses between the underground and exposed aerial cable—seems to have been the result either of a misconception as to the function of the line fuse or else of a tendency to regard the wires in aerial cable as unexposed because they were enclosed in a lead sheath from which they were supposedly insulated. It has already been stated that the proper function of the line fuse is to protect against the excessive currents that would flow from a power cross upon the grounding of the line by the open-space cut-out. If the aerial cable be in an area where contacts with power wires are possible, its wires must be regarded as exposed. The contact may be brought about by such causes as a power wire falling across the cable, the cable falling across the power wire, or a third conductor falling across the two. In the case of any such contact, whether it be with a 450-volt trolley or feeder, with the wires of a constant-current lighting system,[1] or with power-transmission wires of various voltages, a hole is likely to be burned in the soft-lead sheath, through which arcs may strike to the wires within, causing dangerous currents to flow to the central office or to the subscribers' premises or to both. As far as the central-office switchboard equipment itself is concerned,

[1] Most constant-current series street-lighting circuits are automatically regulated to maintain their currents at 6.6 amperes. When a break occurs in such a circuit, the regulation causes the voltage to rise to high values in an attempt to maintain the current at this constant value. One of the reasons for the choice of 7 amperes as the carrying capacity of the line tubular fuse of the Bell System was that it would not blow when traversed by the 6.6 amperes current of these systems. When a fuse attempts to break a circuit in which such a current is flowing, the automatic regulation is likely to cause the voltage to rise so high as to maintain an arc across the gap and a continuance of the flow.

it will be safeguarded primarily by the distributing-frame protection, but the heavy current that will flow to ground as a result of the operation of this protection may be disastrous to the protective apparatus itself or to the cable conductors between it and the cross.

It is obviously wise, therefore, always to place a fuse, rated to blow on a current dangerous to the intervening conductors or the protector mountings, between the central office and any exposed portion of the line circuit. As to the best place for this fuse's being at the point where the exposed wires join the unexposed, there can be little argument, for only at this point can all of the unexposed equipment be protected from all of the exposed equipment.

The independent practice of using protected cable terminals, that is, of placing low-capacity fuses and air-gap arresters in all terminals where the wires in aerial cables are connected with open wires for distribution to subscribers' stations, is intended to protect the aerial cable itself and the things beyond it from the hazards on the exposed open wires. The advocates of the protected terminal argue that it saves a large amount of aerial cable that would otherwise be damaged by lightning or high-tension crosses. In addition to this, of course, where there are no other intervening line fuses, it helps to protect the central-office equipment from hazards arising on the open wires. Against this argument for protected terminals must be weighed the increased cost of cable terminals themselves, the increased expense involved in their maintenance, and the increased number of service interruptions due to the action of the protectors in opening or grounding the line. The fuses at the aerial cable terminals cannot in any event be said to take the place of the fuses between the aerial and underground cable, because they afford no protection to the central-office equipment from dangerous contacts with the aerial cable.

The practice of omitting all protection at the subscribers' station, of course, leaves the station unguarded against dangerous currents, whether from lightning or power, which may enter it over the line wires. If an open-space cut-out alone is provided at the subscribers' stations, as has been the practice of some independent companies, it violates a fundamental rule of protection that a fuse must always be placed between the open-space cut-out and the exposed portion of the line.

CHAPTER IX

DISTRIBUTING FRAMES

Distributing frames have been briefly considered in Chap. XI of the preceding volume[1] in connection with manual-switchboard systems and will now be dealt with somewhat more comprehensively. Broadly speaking, the primary function of the distributing frame is to afford convenient facilities for variously interconnecting the terminals of permanently wired circuits by means of "cross-connecting" or "jumper" wires run in less permanent fashion. To illustrate: in the main distributing frame, M.D.F., all "outside lines" entering a central office from the street cables are permanently wired to their respective terminals on the "line side" of the frame, and all "switchboard lines" extending to the switchboard equipment in the office are permanently wired to their terminals on the "switchboard side" of the frame. By means of jumper wires, the terminals of any outside line may be connected to those of any switchboard line in a manner which, without disturbing any of the permanent wiring, permits subsequent changes in the distribution as occasion may arise from time to time. This, among other advantages, makes it possible for a subscriber to move to another location within the same area without having to change his telephone number. He retains his old switchboard line, which determines his directory number and, by a change in jumper, is connected to his new outside line.

There are distributing frames for other purposes than that of changing the connections between outside lines and switchboard lines. The intermediate distributing frame, I.D.F., as another principal example, permits similar changes to be made in the distribution of individual lines of the multiple in a manual switchboard with respect to the answering jacks and lamps on different switchboard positions, so that changes in the distribution of the traffic among the operators may be effected. In automatic or machine-switching systems, the I.D.F. performs a

[1] "Manual Switching and Substation Equipment," pp. 319 *et seq.*

similar function in enabling changes in the distribution of load among various groups of switches to be made.

The fact that the distributing frame, regardless of the nature of its distributing function, provides means for terminating the various line and switchboard circuits in permanent and orderly manner enables it to serve another important purpose. It affords convenient and easily identified points of access to the circuits for testing purposes.

The Main Distributing Frame.—The M.D.F. marks a natural dividing point between the outside plant and the inside plant or between the outside lines and the inside, or switchboard, lines. From this, it logically follows that the central-office protectors discussed in the last chapter, which guard the inside plant from hazards arising in the outside plant, should be mounted on it. The fact that all inside and outside lines terminate on it, in such manner as to be readily identified and easily accessible without disturbing any of the permanent wiring, makes the main frame the most convenient point from which to conduct many of the tests that are required to determine the electrical condition of the lines. For this reason, the protector mountings are designed with particular reference to this testing function,

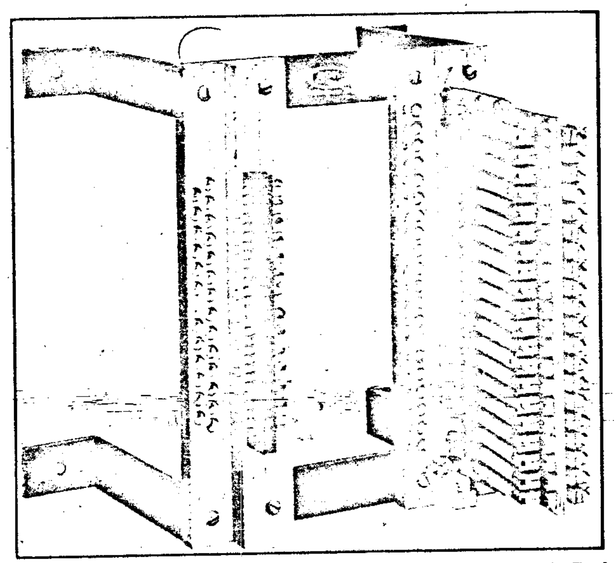


FIG. 249.—Small wall-type distributing frame. (*Courtesy of Cook Electric Company.*)

so as to afford means for conveniently associating the testing or observing apparatus with either the outside or the inside portions of the line or merely to bridge it across the two.

To illustrate first by a very simple case, Figs. 249 and 250 show a main frame for use in a very small office. It is adapted for wall mounting inside the central office near the point where the line cable enters. As shown in the diagram of Fig. 250, the individual wires of the line cable pass through the left-hand set of holes in the left-hand fanning strip and are soldered

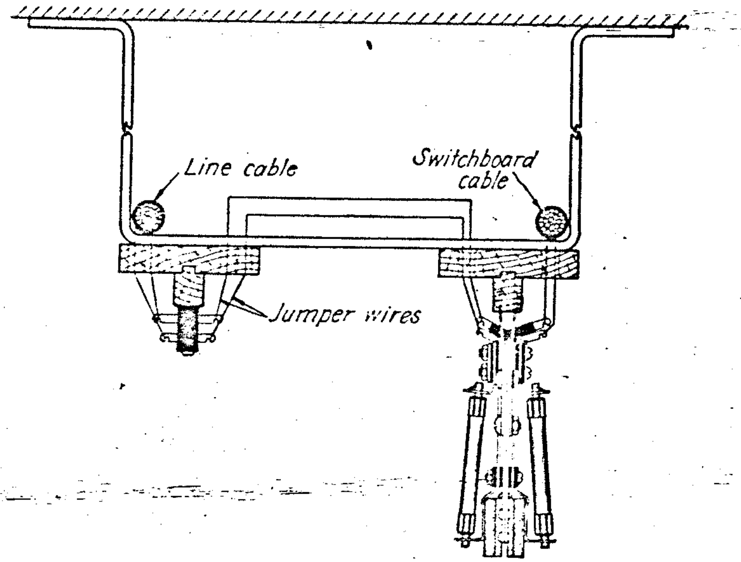


FIG. 250.—Diagram of small wall-type distributing frame. (*Courtesy of Cook Electric Company.*)

to the terminal punchings on that strip. Likewise, the switchboard cable is fanned out, its wires passing through the holes in a similar fanning strip and attached to the right-hand terminals of the protectors carried on the right-hand strip. These connections of the line and switchboard cable wires are intended to be permanent, and, without disturbing them, it is possible to connect any outside line with any inside line through the protectors by means of jumper wires extending between the corresponding pair of free terminals on the two strips.

The protectors employed in this case consist merely of a pair of low-capacity tubular fuses and a pair of carbon blocks for each line, a practice sometimes employed in small exchanges

in lieu of the more common heat-coil and carbon-block protectors. In this particular case, the protectors are carried on the switchboard side of the frame. In larger offices, it is now more common practice to place the protectors on the line side, as will be referred to later.

A considerably more elaborate framework for supporting the two sets of terminals for the line and switchboard wires and for facilitating the running of the jumper wires between them is required for larger offices. The prototype of the modern

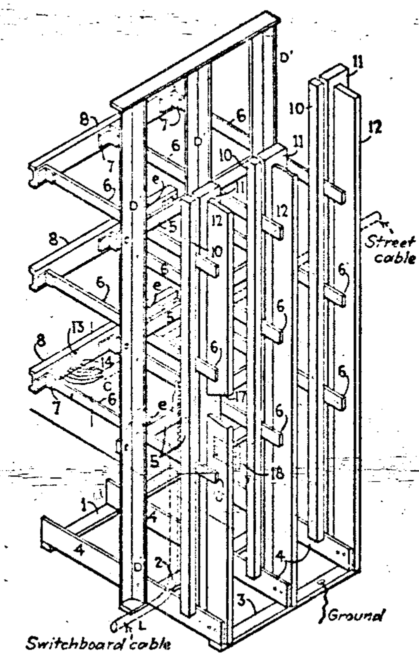


FIG. 251.—Ford and Lenfest distributing frame.

M.D.F. was designed by Mr. Angus S. Hibbard, of the Chicago Telephone Company, in the early nineties. The Hibbard frame was an open structure of iron pipe extending at right angles in three directions, its vertical, longitudinal, and lateral members forming between them vertical and horizontal runways for the jumper wires. The line and switchboard terminals respectively were carried on vertical strips mounted on the ends of the cross members on opposite sides of the frame. The use of iron pipe made the structure itself fireproof and afforded rounded surfaces not likely to abrade the jumper wires.

The next important step in the development of the distributing frame was made by Messrs. Ford and Lenfest, of the Western Electric Company, shortly afterward. This, as shown in Fig. 251, carried vertical strips on one side for the central-office protectors, in which switchboard cables terminated, and long horizontal strips on the other side, in which the wires of the street cables terminated. With minor variations, practically all main

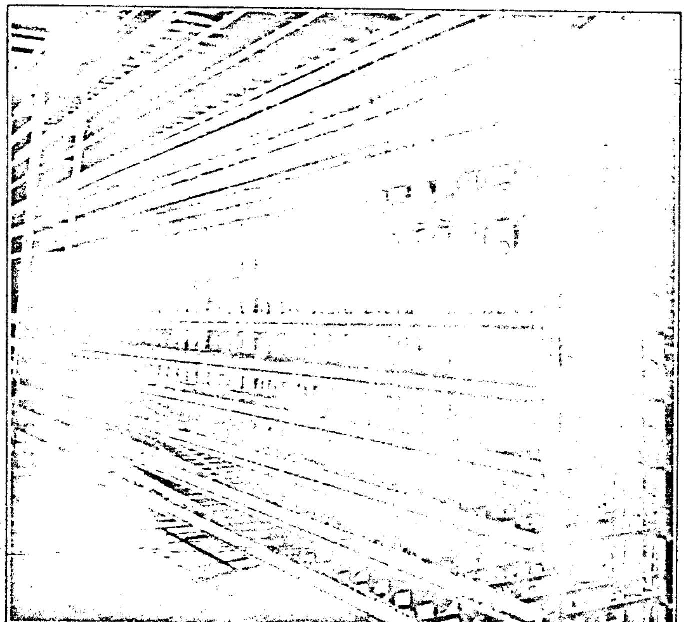


FIG. 252.—Horizontal side of large main distributing frame. *(Courtesy of The American Telephone and Telegraph Company.)*

distributing frames, except those in very small offices, are now constructed after this general design.

The earlier practice with main frames of this type was, as shown in Fig. 251, to terminate the outside lines on the "horizontal side" of the frame, that is, with the terminals arranged in long horizontal rows, and to terminate the switchboard lines on the "vertical side," that is, on the protector terminals arranged in vertical rows. The reason for this arrangement was economy in protectors, since there are usually more outside lines than switchboard lines. Later, it became the more common practice to terminate the outside lines on the vertical side carrying the

protectors and the inside lines on the horizontal side opposite the protectors. To distinguish between these two practices, frames are now designated as A type or B type, according to whether the inside or the outside lines are connected to the protector side. The difference lies in the manner of connecting rather than in any essential structural features of the frame. In the A-type frame, the older practice of terminating the outside cables on the horizontal side is followed, while the B-type frames employ the later plan of connecting the outside cables to the protectors on the vertical side.

Figure 252 shows a main frame in a large Bell office. The jumper wires are seen lying on the shelves formed by the horizontal members of the framework. The guide rings lying nearly in the plane of the vertical members are of iron heavily insulated. Their function is to guide the jumper wires where they make sharp changes in direction and to prevent injury to its insulating covering by chafing against sharp corners of the framework.

This is a B-type frame and the switchboard cables connecting with the horizontal rows of terminals are not seen in this view because they lie in each case just back of the horizontal wooden fanning strip. These cables are fanned out so that their individual wires may pass through holes adjacent to the individual terminals in the lower side of the strip. The jumper wires pass from the upper ends of these terminals through corresponding holes in the upper side of the fanning strip, whence they are led through the runways and rings to the protector terminals on the other side of the frame.

By means of ladders mounted on rollers so as to travel freely along the length of the frame (Fig. 252), wiremen are given convenient access to the upper portions of the frame. Another practice, contributing to greater accessibility and the avoidance of accidents, is to adopt a mezzanine construction, as illustrated in Fig. 253.

In such offices, the incoming line cables are brought up through the floor and fanned out to the protector strips. The vertical bars carrying the protectors are spaced on 8-inch centers, along the length of the frame. Each strip carries protectors for 101 lines and four of them with capacity of 404 lines are mounted one above the other, two above and two below the mezzanine balcony. It is customary for convenience in maintenance to terminate the wires of a single cable either all below or all above the balcony. On the switchboard side, these large frames carry 15 horizontal rows of terminals. The terminals are mounted in 20-line units, each 8 inches long. It is seen from the foregoing that each 8-inch length of frame provides capacity for 400 outside lines and 300 inside lines. This ratio of outside to

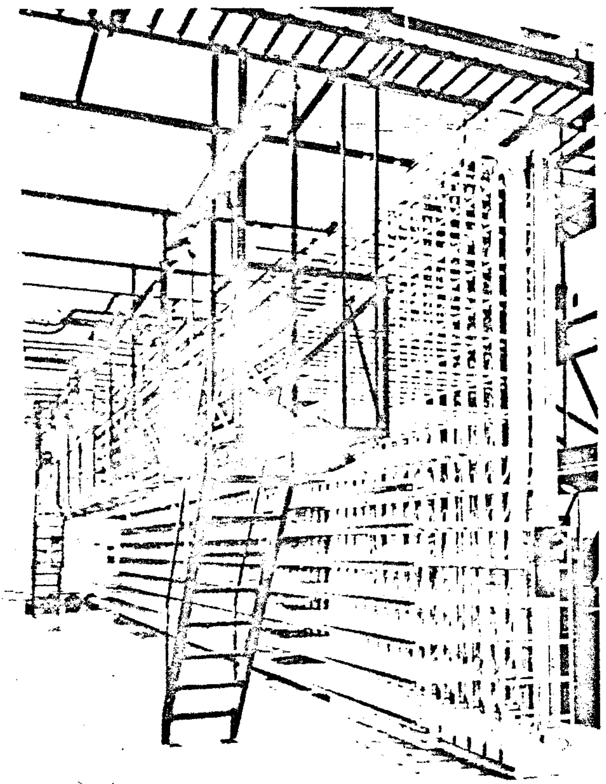


FIG. 253.—Main distributing frame with mezzanine galleries. (*Courtesy of Bell Telephone Laboratories.*)

inside lines provides for an excess of cable pairs entering the office over those passing to the switchboard equipment, and it is evident that, unless it is maintained on about a 4 to 3 basis, one side of the frame will grow faster than the other, resulting in unnecessary length of frame and in unduly long jumpers.

Figure 254 shows a detail of the apparatus and wiring on the vertical side of the frame. Here the protectors of the type

shown in Fig. 242 (Chap. VIII) are arranged in long vertical rows, in large offices usually 400 pairs high. Portions of two such rows are visible at the right of this figure. The hand-formed cable carrying the outside line wires is lashed to the frame, so as to be just back of the vertical fanning strip. It is seen to taper from bottom to top as its individual wires are taken out and led through holes in the fanning strip to the line-terminal springs of the protectors. The jumper wires are

FIG. 254.—Detail of vertical side of main distributing frame. (*Courtesy of The American Telephone and Telegraph Company.*)

connected to the switchboard terminals of the protectors and pass back through another row of holes in the fanning strip, after which they may be seen at the extreme left in their devious courses to the other side of the frame.

Figure 255 shows another view of the vertical or protector side of the frame, this including parts of four vertical protector strips. The row of double jacks in the center of this figure are the terminals for test trunks leading from the main frame to the test desk and for service-observing lines leading to the service-observing desk. Any one of the "plug-up" or "test" lines terminating in these jacks may be connected to any subscriber's line on the frame by a long flexible cord, terminating on one end in a plug adapted to register with these jacks, and at its other end in a test plug or test connectors adapted to make connection with any line at its protector mounting. Two of these cords are shown in Fig. 255. One of them ends in a single plug which is seen inserted into the third right-hand jack from the top. The other end of this cord terminates in two single test connectors that are seen applied to a pair of protector springs just to the right and a little below the plug. The other

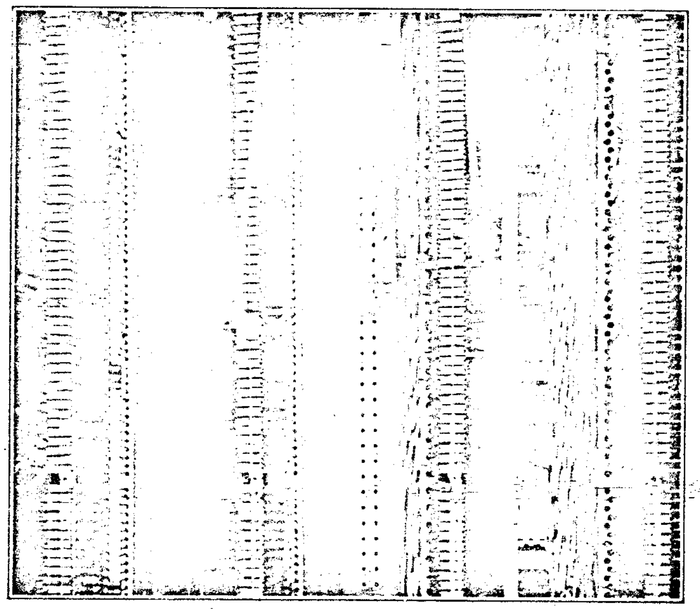


FIG. 255.—Vertical side of frame showing protectors and plug-up lines. *(Courtesy of The American Telephone and Telegraph Company.)*

cord ends in a double plug seen in one of the double jacks. The other end terminates in a test plug that is shown applied to a protector just at the left of the plug. Thus, any line on which tests or service observations are to be made may be temporarily connected by one of these plug-up lines to a desk where such functions are carried out.

In Fig. 256 are shown side and end elevations of a type of frame made by the Cook Electric Company of Chicago and largely used by independent operating companies. The dimensions given in this figure are for a frame using 200 pairs of protectors per vertical strip, the protectors being of the type shown

in Figs. 244 and 245 (Chap. VIII) and mounted on $\frac{1}{2}$-inch centers. Its total length would, of course, vary with the number of vertical bars required, $7\frac{1}{2}$ inches being added for each increase of 200 lines capacity. For comparatively small offices,

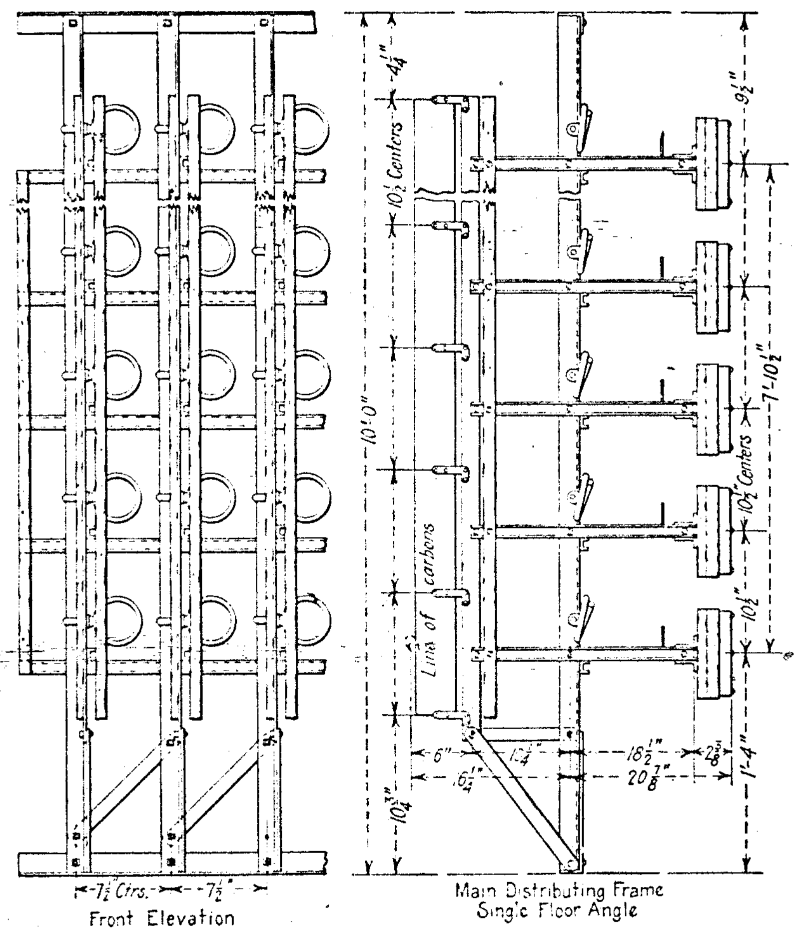


FIG. 256.—Cook distributing frame.

lower frames with a smaller number of protectors per vertical may be conveniently used, the over-all height being but 6 feet where 100-pair verticals are used. For large offices, it is this company's practice to employ a slightly different type of protector mounted on $\frac{3}{8}$-inch centers, and 200, 300, or 400 pairs high as head-room and floor-space conditions may require.

The terminals on the line side of this frame, opposite the protector side, are usually arranged in short vertical strips as

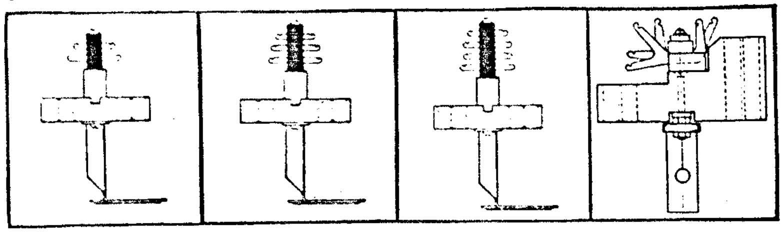


FIG. 257.—Arrangement of distributing-frame terminals. (*Courtesy of Cook Electric Company.*)

shown in Fig. 256. In this case, the strips each carry twenty or twenty-six sets of terminals. They are short enough to allow sufficient space between them to facilitate laying the jumper wires in the horizontal channels of the frame. In some cases, however, the line terminals are mounted in continuous rows on long horizontal fanning strips as in Bell practice.

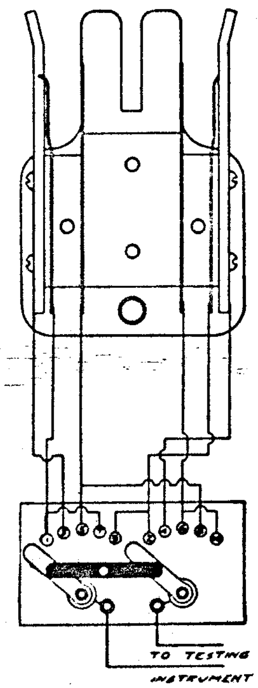


FIG. 258.—Distributing-frame test plug.

Figure 257 shows several typical arrangements of terminals and fanning strips on the unprotected side of distributing frames. The soldering terminals are tinned metal punchings set in hard-rubber strips which are mounted on the maple fanning strips. The arrangement shown in the three blocks at the left of this figure are more common in independent practice, while that in the block at the right is representative of Bell practice.

The test-plug arrangement for the Cook protector of Fig. 244 (Chap. VIII), used in testing lines at the main frame, is shown in Fig. 258. By slipping the test plug over the protector of the line in question, connection is made for permitting tests either through or around the heat coils. When the plug is withdrawn, the protector is set. The switch associated with the plug permits the following tests: contacts 1 and 2, outside line through heat coils; contacts 3 and 4, inside line; contacts 5 and 6, outside line direct; contacts 7 and 8, one heat coil; contacts 9 and 10, other heat coil.

Intermediate Distributing Frames.—The I.D.F. is structurally very similar to the M.D.F., the principal difference being that it carries no protectors. Its function in connection with manual multiple switchboards, as already explained, is to permit changes in the distribution of traffic loads among the operators' positions. By it, any answering jack with its permanently associated line-lamp and relay equipment may be cross-connected to any line in the multiple. In machine-switching offices, the I.D.F. performs a similar function, permitting redistribution of traffic to different groups of switches.

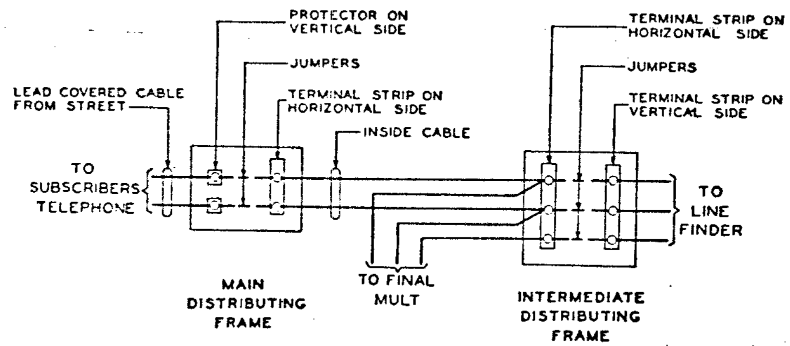


FIG. 259.—Main and intermediate distributing-frame relations in machine-switching office.

The relationship between the main and intermediate distributing frames in a manual office has already been dealt with in connection with Figs. 278 and 279 of the preceding volume.[1] The same relationship in a machine-switching office is shown in Fig. 259, this having particular reference to a panel-type office. As in the manual office, the terminals on the horizontal side of the I.D.F. are permanently cabled to those on the horizontal side of the M.D.F. and to multiple terminals through which connections are finally completed. The terminals on the vertical side are permanently cabled to the line-finder equipment, which corresponds to the answering-jack equipment of a manual office. By means of jumper wires on the I.D.F., any line in the line-finder equipment may be cross-connected to any line in the final multiple.

Frames for Multi-office Buildings.—The tremendous telephone development in congested metropolitan areas often makes it economical to establish several central-office units in a single

[1] "Manual Switching and Substation Equipment," pp. 319 and 321.

building. Where this is done, it is advantageous for a number of reasons to make one large main distributing frame serve all the offices. One reason is that it permits a wider range of cross-connections between inside and outside lines, so that a subscriber may move to any location within the area served by the

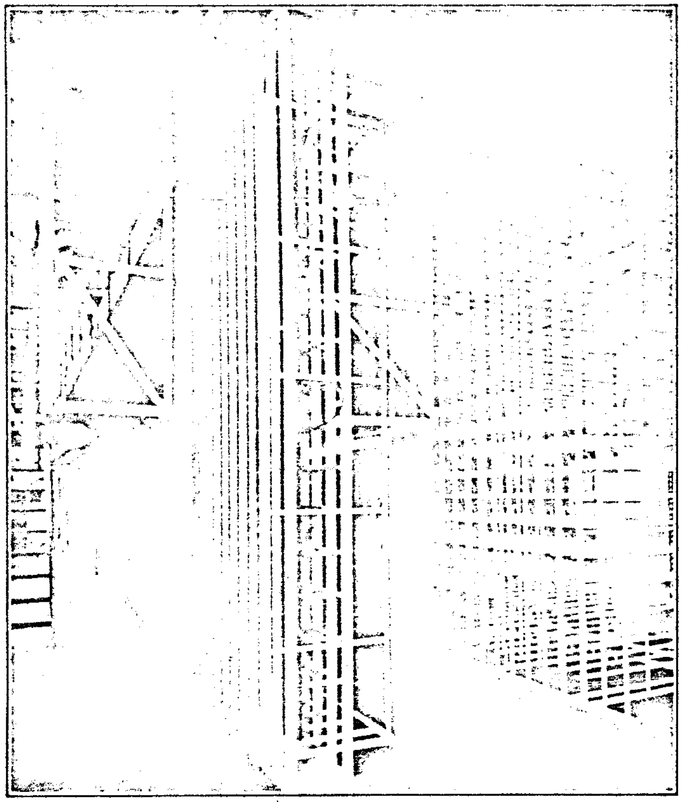


FIG. 260.—Protector frame (center) and separate main distributing frame (right). (*Courtesy of Bell Telephone Laboratories.*)

group of offices in the building and still retain his former telephone number.

Sometimes, as in the telephone building at 140 West Street, New York City, as many as five 10,000-line central-office switchboard units are thus served by a single main distributing frame. Frames of such large capacities are sometimes too long to permit their being laid out in a straight line in the floor space available. Sometimes it has been necessary for them to be bent at right

angles along two sides of the building in L shape or to be doubled back on themselves in U shape. In other cases, they have been in two separate lines with tie cables between. Obviously, a single straight-line frame is desirable.

In order to retain the advantages of the straight-line distributing frame even where very large capacities are required

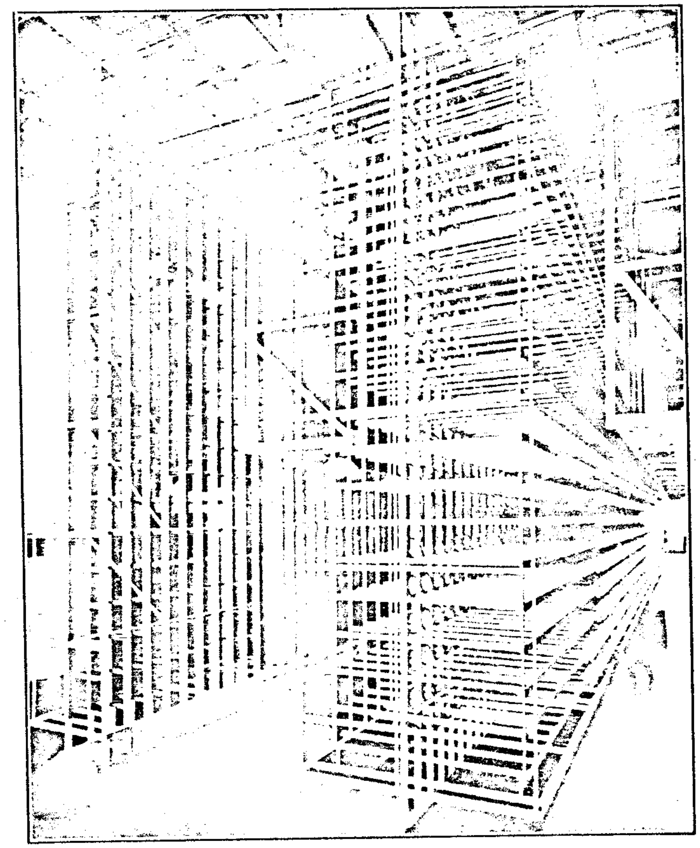


FIG. 261.—Main distributing frame (center) with separate protector frames (left). (*Courtesy of Bell Telephone Laboratories.*)

and also to shorten the length of jumpers and economize in floor space, a new type of main frame has recently been developed for the Bell System.[1] The salient feature of this involves a return to the very early practice of carrying the protectors on a

[1] NOBLE, R. E., A New Main Distributing Frame for Large Offices, *Bell Laboratories Record*, p. 430, May, 1930.

separate structure of their own rather than on the distributing frame. There are thus a protector frame and a distributing frame proper. The rigid limitation as to size imposed by the protector mountings is thus not imposed on the distributing frame proper, which, as will be seen, may effect great economy in its size by a greater concentration of its comparatively simple terminal slips.

The protector frame (Fig. 260) carries vertical strips of protectors, 404 high, spaced on 8-inch centers on both sides. The total length of this frame is thus just half what it would be under the older arrangement. The use of comparatively light structural members of the frame with diagonal braces is to be noted at the front where the protection bars are not yet mounted.

In order to effect a similar saving in the length of the distributing frame proper (Fig. 261), the terminal strips (Fig. 262)

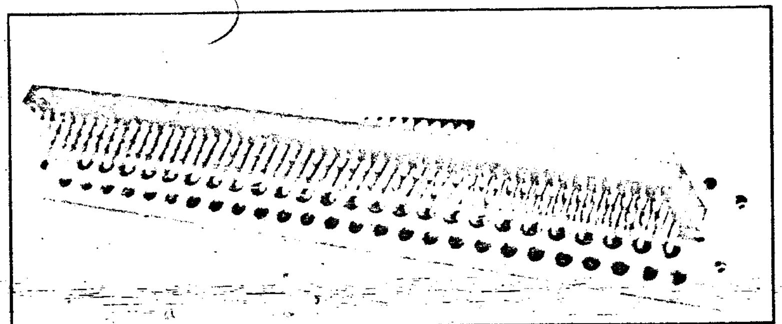


FIG. 262.—Line-terminal strip for 100 pairs. (*Courtesy of Bell Telephone Laboratories.*)

on its vertical side are made to carry terminals for just twice as many lines per unit of height as the protector strips. Thus each vertical on the line side of the distributing frame carries 808 lines which, so far as that side of the frame is concerned, just halves the total length of the frame for a given required capacity. This permits the terminals of each 8-inch length of the protector frame to be wired directly over to a corresponding 8-inch length on the line side of the distributing frame proper.

An increase in the terminal capacity of the horizontal side of this new frame has been achieved by making it carry 19 shelves and horizontal strips, instead of 15 as in the older frames, and by mounting the terminals closer together horizontally, so that 100 lines occupy a 32-inch horizontal length of strip instead of 40 inches as before. The horizontal side is thus

given a terminal capacity of about 60 per cent of that of the vertical side, it having been found that this is more nearly in accordance with the requirements of these frames than the 75 per cent ratio of the older types of frames.

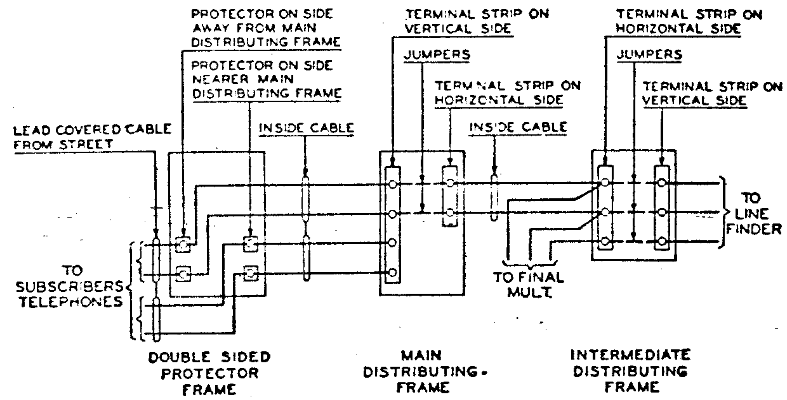


FIG. 263.—Relation of protector frame and distributing frames in multi-office terminal rooms.

Figure 263 is a diagram showing the connections from outside lines to switchboard apparatus through the several frames where this new type of terminal-room equipment is employed. This, in view of its legends, needs no further description.

CHAPTER X

PRIVATE BRANCH EXCHANGES

A "private branch exchange" is a private telephone system operating in conjunction with a city exchange. It comprises a switchboard, associated telephone stations, and, in some instances, a local power plant. It is generally installed on the premises of a subscriber and for this reason is a "private" exchange. It is connected with a public central office by trunk lines and for this reason is a "branch" exchange. Its purpose is to afford facilities for intercommunication among its own local stations and also between these and the stations of the public exchange. Frequently one or more private branch exchanges are interconnected by tie lines, thus constituting a private system of branch exchanges. In referring to private branch exchanges, the abbreviation "P.B.X." or merely "PBX" is commonly used.

Private branch exchanges may be operated in conjunction with either manual or machine-switching public exchanges, but, whether manual or machine switching, in all except certain small systems, it utilizes the services of an operator or attendant, at least for the proper distribution of incoming calls from the public exchange. Private branch-exchange systems are most commonly of the manual type, although many are in use which employ dial-controlled switches for local and exchange connections. When used in connection with dial public-exchange systems, it is customary to publish in the telephone directory certain numbers for night calls, so that the services of operators or attendants may be dispensed with during other than the regular business hours. The importance of the private branch-exchange method of giving telephone service will be apparent when it is stated that in the United States one-sixth of all telephone stations are so served.

Manual Systems.—Manual private branch-exchange equipment employs the same kinds of telephone sets and, with minor differences, the same kinds of switchboards as have already

been dealt with in considering manual public-exchange equipment. The telephone sets, therefore, require no special attention, being either magneto or common battery, usually according to the type of central-office equipment with which they work. The switchboards may be of the cordless or cord types and, if the latter, may be either non-multiple or multiple, depending on the number of lines and amount of traffic.

Cordless Switchboards.—The general type of switchboard briefly discussed in Chap. VII of the preceding volume,[1] which operates without cords or plugs, finds its greatest use in small

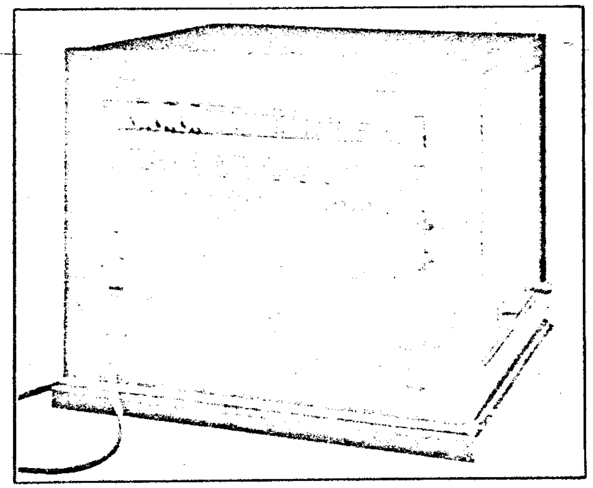


FIG. 264.—Cordless-type P.B.X. switchboard. (*Courtesy of Bell Telephone Laboratories.*)

P.B.X. installations having but few station lines and few trunks to the central office. Figures 264 and 265 show one of these as recently standardized for the Bell System. The one illustrated is for seven station lines, three trunk lines, and five connecting circuits (equivalent of cord circuits). A regular desk-stand telephone is usually provided for the attendant's telephone set. This is provided with a dial if the cooperating central office is for dial service.

In the top row of the face equipment are three drops for the trunk lines and seven visual signals for the station lines. At the left in a vertical row are five visual supervisory signals, one associated with each of the connecting circuits. In some

[1] "Manual Switching and Substation Equipment," p. 242.

cases, these mechanical signals are replaced by switchboard lamps.

Below each of the trunk and station signals is a vertical strip of three two-way lever keys. Each of these is associated with the trunk or station line, the signal of which is above it. The two upper keys and the upward position of the lower key of

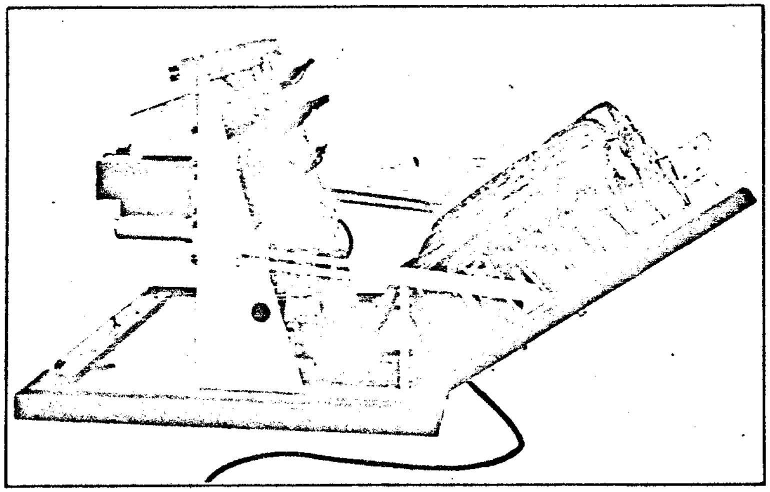


Fig. 265.—Cordless-type P.B.X. switchboard—enclosing cabinet removed. (*Courtesy of Bell Telephone Laboratories.*)

each strip are also associated with the connecting circuits, so that, when any two of these keys are thrown in corresponding position, the two corresponding lines will be connected together through one of the connecting circuits. The downward positions of the first three lower keys serve as holding keys for the trunk lines and of the next seven as ringing keys for the respective station lines. The eleventh group of three two-way lever keys at the right end are talking or listening keys for associating the attendant's telephone circuit with the corresponding connecting circuits, except that the downward position of the lower key is for night service. The two turn keys at the extreme right are respectively for switching the ringing circuit from the central-office ringing leads to the hand generator and for cutting off the buzzer located in the cabinet.

In answering an incoming call from a trunk line, the attendant throws one of the trunk keys and the talking key in the same level. The connection is then extended to the desired station

by means of a station key in the same horizontal row. The station is rung by the ringing key associated with the station line wanted.

An outgoing call may be made in one of two ways: The attendant may operate one of the trunk keys and the corresponding talking key and pass the call to the "A" operator, if it be a manual exchange, or dial the subscriber wanted, if it be a machine-switching office. Or, after having connected the station line with the trunk as before, the operator may allow the subscriber to pass the call or dial it, as the case may be.

A connection between local-station lines is made by operating the two respective station keys to connect with the same connecting circuit. For night service, trunk lines may be left connected through to certain of the station lines, by moving the trunk and station keys as just described and also operating the night service and the buzzer keys; then exchange calls to and from these stations may be made without the assistance of an attendant, but local station-to-station calls cannot be made.

The ringing current usually is supplied over conductors from the central-office power plant, but a hand generator is provided for use in case of a failure of the central-office supply. The talking battery is supplied over conductors (battery feeders) from the central office for local connections and over the respective trunk conductors for the trunk connections.

The cordless type of P.B.X. board is sometimes built for as many as twelve station lines, five trunk lines, and five connecting circuits. For larger numbers of lines or for heavier traffic than can be handled with five connecting circuits, the cord type of board is usually resorted to.

The so-called "intercommunicating" system is sometimes used in small P.B.X. installations. In the intercommunicating system, every line runs to every station and each station has, in effect, its own switchboard by which it may connect its telephone to any one of the lines. A cordless system of this type has been designed for use in residence and small business establishments requiring not over twenty-four station and trunk lines. In this, each station has a key set with a push-button key for each station and trunk line. The keys usually have three positions known as "normal," "talking," and "ringing." When a key is partially depressed, it is in the talking position and remains locked until another key is pressed. When fully depressed, it is in the ringing position but restores to the talking position when finger pressure is removed. All other keys except the one depressed are in the normal position. Connections for local-to-local station and local-station to central-office calls are made by depressing the correspondingly designated keys. Incoming calls may be answered at any station as required and

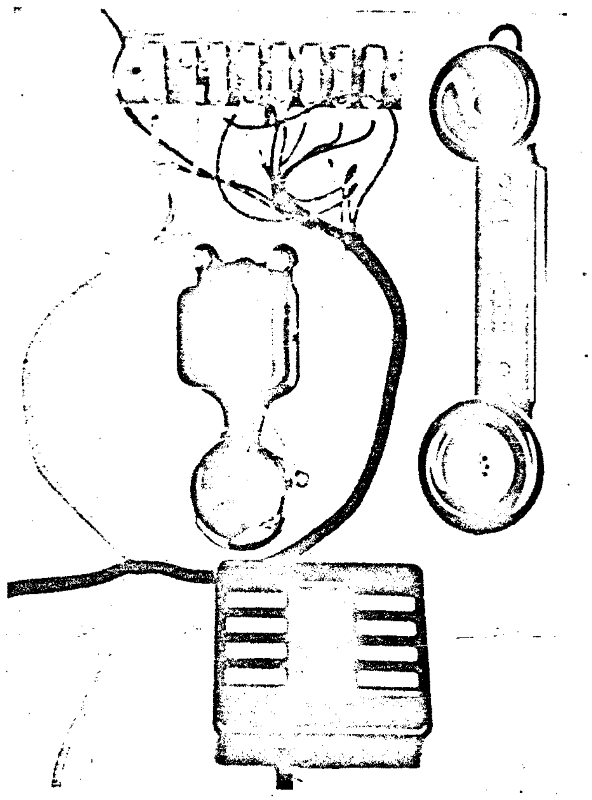


FIG. 266.—Key-type intercommunicating set.

then transferred to the particular station wanted. Figure 266 illustrates one of the sets of this system.

Cord-type Non-multiple Switchboards.—Where the number of lines or the amount of traffic of a P.B.X. is greater than can economically be handled by a cordless type of switchboard, but not so great as to require the services of more than two operators, the non-multiple cord type of switchboard is employed. These are similar in general appearance and function to the non-multiple

manual switchboards discussed in the preceding volume, the differences residing in the provision for central-office trunking. The cord circuits are usually of the bridged-impedance-condenser type. The station lines, and usually the trunk lines, terminate in jacks with associated lamp signals. Sometimes, however, plug-ended trunks are used, in which case the trunk lamp signals are mounted on the key board.

A front view of one of these non-multiple common-battery P.B.X. switchboards, as standardized for use in the Bell System, is shown in Fig. 267. This has jack-ended trunks, the trunk jacks with lamps and designation strips being mounted in the lower part of the face-equipment space. Above these are the station line jacks with their lamps and designation strips. The plugs, keys, and supervisory lamps of the cord circuits are arranged on the plug and key shelves in the usual manner, a pair of plugs being used for each connection, whether between two station lines or between a station line and a trunk to the main exchange.

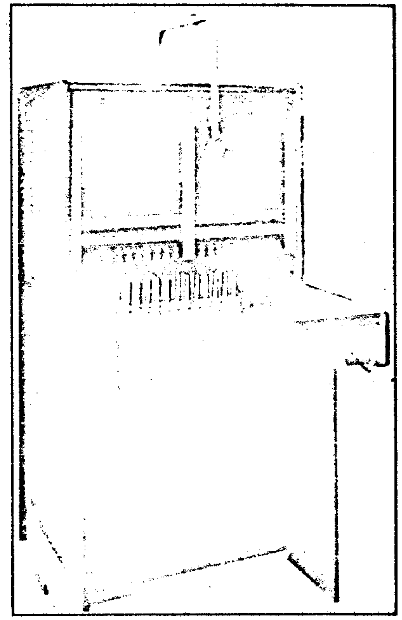


FIG. 267.—Non-multiple-type P.B.X. switchboard. (*Courtesy of Bell Telephone Laboratories.*)

An incoming call over a trunk line is answered by the attendant and extended to the desired station by means of one of the connecting cord circuits. On an outgoing call, the attendant extends the calling local line over a trunk to the city exchange, after which she may pass the call to an "A" operator (or dial it if the main office is automatic). Or, after extending the connection over the trunk, she may allow the calling subscriber to pass or dial the call if he desires to do so. Station lines are connected together for local connections by means of the cord circuits. These operations resemble so closely those for manual central-office boards already described that further explanation is unnecessary. For night service, some of the trunk lines may be left connected through to certain of the station lines, so that calls to and from these stations may be made without the assistance of an attendant.

This type of board is standardized in several different sizes, all of similar general appearance, to meet the requirements of different establishments for which the non-multiple board is suitable. The smallest has a capacity for 40 station lines and the largest about 300. The number of trunk lines and cord circuits is made to suit the different traffic conditions. When a greater station-line capacity is needed or the traffic is too heavy for one operator, and this type of board is otherwise suitable, two sections are placed side by side. Since this arrangement produces a reach for either operator that is about the maximum practical, not more than two sections are used together.

The ringing current usually is obtained from the central-office power plant over cable conductors and a hand generator is provided for emergency use. The talking battery for local connections is obtained over separate cable conductors (battery feeders) from the central office, but on trunk connections the talking battery for the local station is usually furnished over the trunk. In certain cases where local conditions require it, a small and simple form of power plant is installed with the P.B.X. switchboard.

Figure 268 shows the circuits of another make of non-multiple cord-type P.B.X. switchboard—in this case the standards of the Stromberg-Carlson Company for use in connection with different types of main exchanges. Here the trunks are plug ended, so that an incoming call is completed by merely inserting the trunk plug into the jack of the local-station line. A call from a local station is always answered by the answering plug of a P.B.X. cord circuit. Then, if the calling station desires a city-exchange connection, the answering plug is withdrawn and a trunk plug inserted in its place.

The operation of the local line circuit *a* and the cord circuit *b* is obvious. In order to understand the operation of the trunk circuits *c*, *d*, or *e*, however, the mechanical interaction between the armatures of relays 1 and 2 must be noted. It must be remembered also that the trunk lines terminate in the switchboard of the "main" office in the same manner as an ordinary subscriber line and that the operators at that office follow the same routine in answering or ringing on a P.B.X. trunk as on an ordinary subscriber line.

Thus in the case of the common-battery manual-office trunk (circuit *c*), the city-exchange operator calls the P.B.X. by ringing over the trunk line as she would over any other subscriber line.

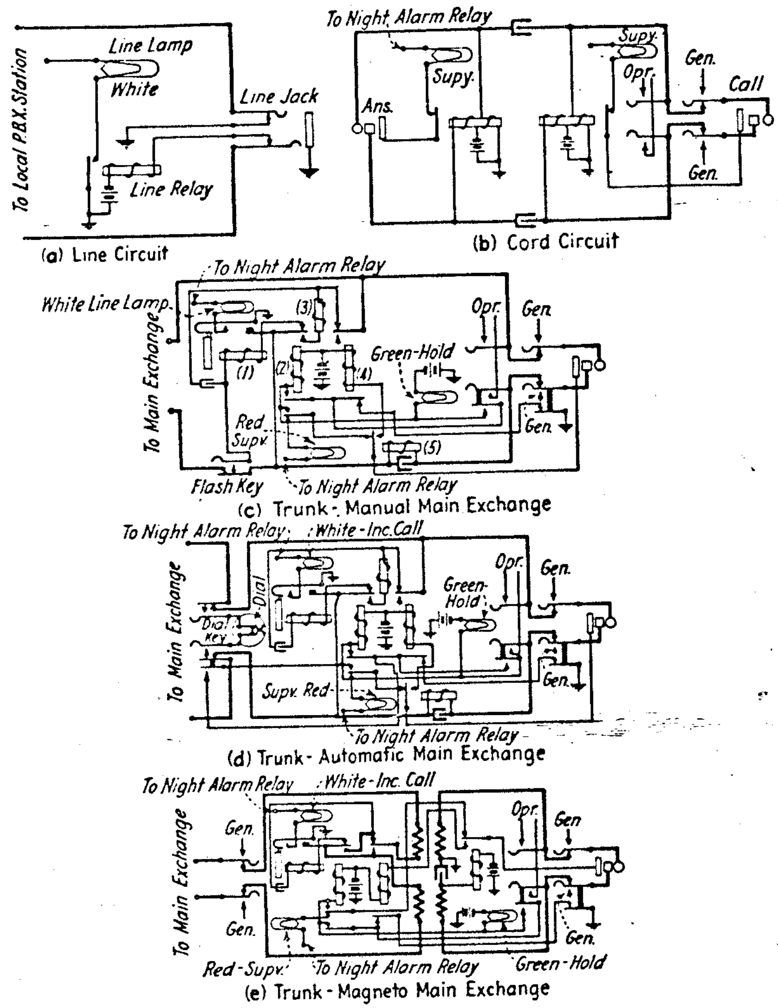


FIG. 268.—Circuits of manual non-multiple P.B.X. switchboard.

Relay 1 at the P.B.X. responds to the ringing current through the condenser, its armature latching in its attracted position: The white lamp is thus lighted to indicate the call. When the P.B.X. attendant responds by throwing her listening key, relay 2 is energized in parallel with the green holding lamp. The operation of relay 2 unlatches relay 1, extinguishing the white line lamp, and also connects the holding retardation coil 3 across the trunk circuit to prevent the cord supervisory lamps at the main office from giving a premature signal for disconnection. The attendant may now release her listening key, since the relay 2 remains locked over a circuit to ground at the ringing key. After the attendant inserts the trunk plug into the line jack, another locking circuit for maintaining the holding condition is established to ground over the sleeve strand of the cord. When the called local subscriber has been rung by the P.B.X. attendant, his response, by closing his line circuit, energizes the supervisory relay 5. This, in operating, releases the relay 2, energizes the relay 4, breaking the holding circuit through coil 3 and extinguishing the green holding lamp. The circuit through the called subscriber's telephone has now been substituted as a holding circuit to prevent the lighting of the main-office supervisory lamps.

The called P.B.X. subscriber receives his talking current from the main office over the trunk, this current maintaining the supervisory relay 5 energized. When he hangs up, the trunk-line circuit is broken and the main-office supervisory signals are lighted. Also, the relay 5 releases, lighting the red supervisory lamp as a signal to the P.B.X. attendant.

A detailed description of the other functions of this circuit (*c*) or of the operation of the other circuits (*d* and *e*) to automatic and magneto offices respectively need not be given, as they may be understood by a study of the diagram in view of what has been said.

Multiple P.B.X. Switchboards.—Private branch exchanges sometimes have more lines and traffic than can be handled by a non-multiple board. Multiple boards then become necessary for the reasons stated in earlier chapters. The earlier multiple P.B.X. switchboards were mainly adaptations of the multiple boards developed for regular central-office service, although it may be mentioned that the use of multiple line lamps became general in P.B.X. multiple boards at an earlier date than in city-exchange boards. The later types, while following the same principles, have been designed especially for P.B.X. service. The methods of operating these are similar to those for the central-office multiple boards previously described and need no further explanation here.

A feature of the larger boards, not so frequently encountered in the smaller ones, is that of tie lines between different private branch exchanges. It is not uncommon for large establishments to have several P.B.X. boards located at points widely separated, and the tie lines are to expedite communication between them. Sometimes, in order to permit satisfactory conversation over these, higher voltages are required than for local or exchange connections. Furthermore, it is sometimes desirable to connect tie lines together tandem fashion, establishing connections between two distant private branch exchanges through an intermediate one. The voltage ordinarily used on the local cord circuits is 24, and that required on the long-distance tie-line connections is 48.

It is desirable to have universal cord circuits (one type for all kinds of connections), and this was made possible by placing in the tie-line circuits that equipment which was necessary only for tie-line calls and leaving in the cord circuit only that which was common to all types of calls. The voltage control for the tie lines was thus placed in the line circuits. The tie lines were divided at each end, each branch extending through the board in two multiples instead of one as is the ordinary practice. One of the branch multiples is used when a call, originating at a distant P.B.X., is for a station at the local P.B.X., and the other when the call is for a station at another P.B.X., thus requiring extension through another tie line. By this arrangement, 48 volts are supplied to the tie line for a terminating call and a simple through connection made when two tie lines are connected together. The operator at the local P.B.X. simply has to select the proper branch multiple to suit the class of call being handled. An alternative to this arrangement, which was formerly used, was to provide special tie-line positions with equipment suitable for use with the long-distance tie lines.

Figure 269 is a front view of the No. 605 multiple P.B.X. board of the Bell System, which has a capacity up to 1,500 lines. In the main portion of the face-equipment space is located the station line multiple, consisting of jacks and lamps, the designation strips being omitted and the regular jack numbers used for identification. The lines are multipled every fourth panel. At the bottom of the space are the multiple jacks of the central-office trunk lines and tie lines. On the keyboard are the keys, lamps, and plugs of the cord circuits, which are of the universal bridged-impedance-condenser type. A dial is provided for each position when the associated central office is of the dial type.

At the left, or head, end of the switchboard is a casing or cabinet, enclosing the framework for two distributing frames. This casing is made to match the rest of the board but is without keyboards. Next in order is the "head" section. The face of this section has in the first panel the battery cut-off, night-alarm, fuse-alarm, and power-alarm switches and also the signal lamps required with the different alarms; and the second panel is provided with a portion of the multiple, to enable the first operator

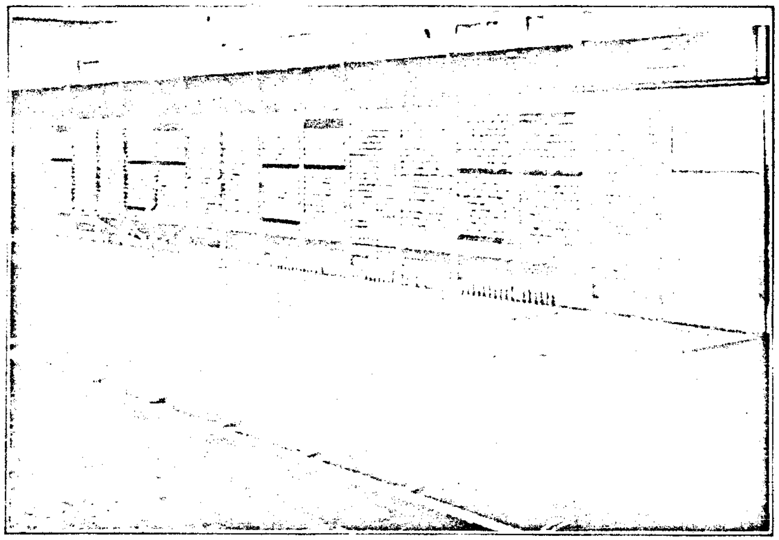


Fig. 269.—A multiple P.B.X. switchboard. (*Courtesy of Bell Telephone Laboratories.*)

readily to reach all of the lines. In the rear of the section are mounted the relays and other apparatus for the trunk circuits and tie lines, also the apparatus for the miscellaneous common circuits of the board. The next six sections are the "regular" operating positions, and at the end of the switchboard line-up is a "foot" section. The first front panel of the foot section has a portion of the lines multipled therein, for use of the operator at the last regular position. In the rear of this section is space for additional trunk-line circuit apparatus. The iron framework of both the head and foot sections is the same as for the regular sections and both are provided with keyboards to match the regular sections. All the key shelves and plug shelves are covered with dull black phenol fiber to minimize the wear.

A rear view of the head end of this switchboard is shown in Fig. 270. When distributing frames are installed external to the board, the head end is provided with a cable turning section.

A local power plant is usually provided with the multiple board, although frequently in the smaller sizes the batteries are charged over conductors from the central office and the ringing

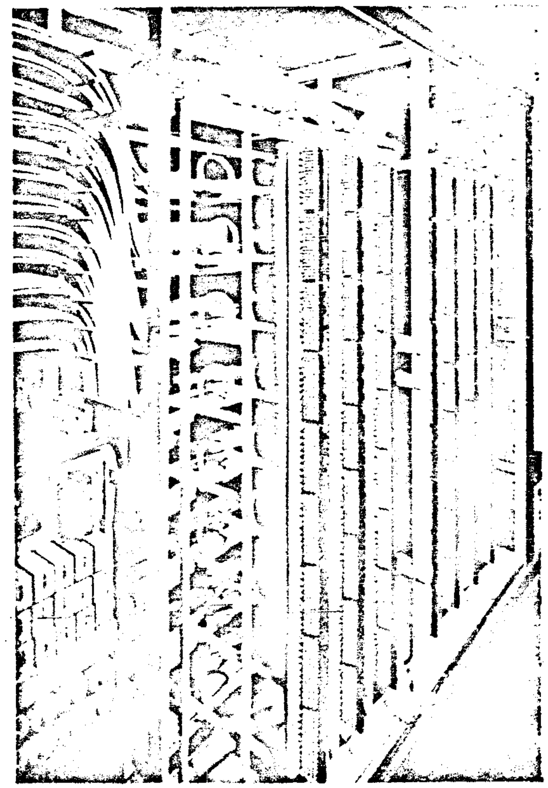


Fig. 270.—Rear view of head end of multiple P.B.X. switchboard. (*Courtesy of Bell Telephone Laboratories.*)

current is supplied in the same manner. When this board is used as the manual part of a combined manual and dial P.B.X., as will be described later, the power is supplied from the local power plant provided for the switching apparatus.

Dial P.B.X. Systems.—The increased use of dial central offices has resulted in an increase in the use of the dial-type private branch exchange. Automatic Electric Company, makers of Strowger type of automatic equipment, have adopted the abbreviation "P-A-X" for the "private automatic exchange." Several types are available to meet the needs of various-sized establishments, such as for different numbers of station lines and trunk lines, and different characters and volumes of traffic. Strowger-type step-by-step switches or rotary switches are generally used as the switching means, but, in some cases, the switching is accomplished by relays. The dial P.B.X. systems are of the two- or three-digit types, serving up to one hundred or more station lines. Both line-finder and line-switch principles are employed in the non-numerical switching.

These systems provide for complete local service between the P.B.X. stations and may be so arranged that all stations are afforded public-exchange service or that some shall be allowed incoming service only, while others may be denied all exchange service.

The general method of operating the dial P.B.X. system is that each station originating a call dials to establish connection with any other station line, with a central-office trunk or tie line, or with the attendant's telephone. An incoming call signals the attendant, who, after answering, completes the connection by dialing the desired station. The attendant can also originate or complete calls to the central office or an associated P.B.X. Even though all connections are made by dialing, it will be noted that an attendant, or some person at one of the stations, is required to intercept and distribute the incoming calls, except that for night service incoming calls may be arranged to go direct to some predetermined station lines. Through dialing, from one P.B.X. to the local stations of an associated P.B.X., is frequently provided for.

Rotary-switch Type.—Dial systems employing rotary-type switches are used in small establishments requiring not over twenty station lines. This type is customarily available in two sizes: one for an ultimate capacity of nine station lines, three trunk lines, and two connecting or link circuits; and the other for twenty station lines, five trunk lines, and four link circuits. The nine-station size requires two digits in the station number and the twenty-station size three digits. A complete installation of this system requires an attendant's cabinet, rotary-type switching apparatus, and a local power plant. The switching apparatus and power plant are housed in a sectional-type metal cabinet.

The switching apparatus consists of rotary switches of the non-homing type used as line finders, rotary switches of the homing type used as connectors, and rotary switches which are a combined homing and non-homing type used for the trunk-line switches. The finders and connectors are arranged to operate in pairs and the unit is called a "finder-connector." The switching apparatus and power plant are of the same types as previously described in connection with the Strowger system.

The attendant's set consists of a small metal cabinet with keys and lamps mounted in it and, on top, a hand telephone set with

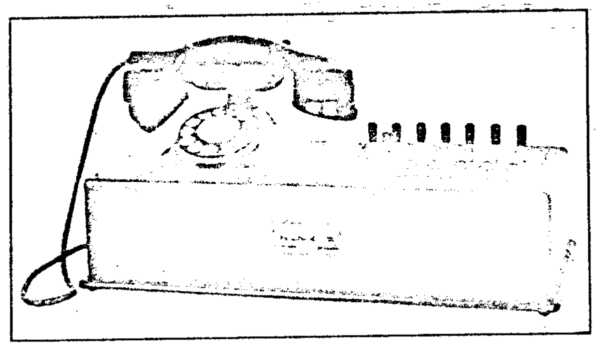


FIG. 271.—Attendant's set for rotary-switch type P-A-X. (*Courtesy of Automatic Electric Company.*)

dial. The cabinet occupies but a small space and, since the connections are brought to it through a flexible cord, it may be readily moved about upon the desk. Figure 271 shows such a set used with the twenty station-line and five trunk-line system. The five two-way lever keys at the right end of the group are associated with the five trunk lines. The forward position of these keys (lever moved forward from attendant) is the trunk answering position, and the reverse position is the trunk release position. The back row of lamps are the trunk answering lamps which light when incoming calls are waiting on the trunk lines. The front row of lamps are supervisory lamps which light when the receiver at the connected station is replaced on the hook switch. The next two keys at the left of the trunk-line keys and lamps are one-way lever keys for connecting two predetermined trunk lines for night service. The front key at the extreme left is the battery cut-off key used for night service. The left back key is a two-way lever key and, when pressed forward, connects the hand set to the attendant's line and, in the reverse position, is used when dialing the central office.

Figure 272 shows a P-A-X switchboard for the twenty-line system, this being recognized as of the sectional type. The top shelf has a terminal block for the trunk lines and multiple of the station lines at the right. At the left of this, enclosed with a metal cover, are the trunk rotary switches. At the left of these

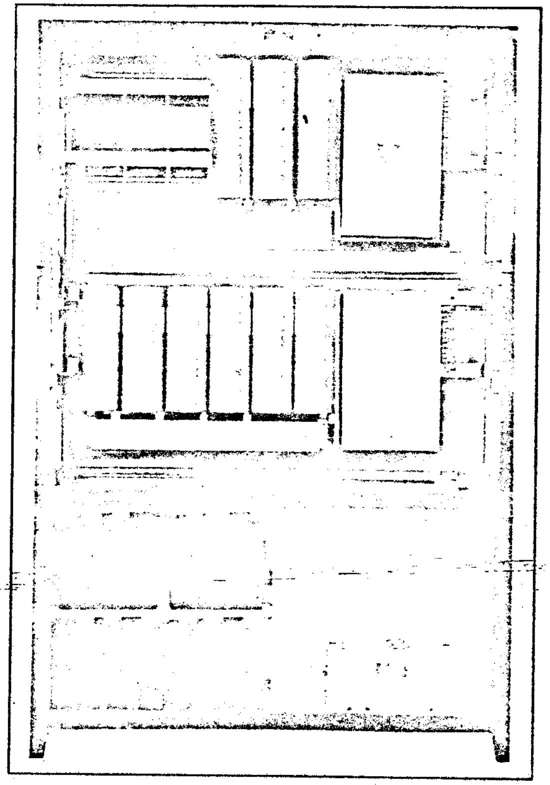


FIG. 272.—Rotary-switch type P-A-X. *(Courtesy of Automatic Electric Company.)*

are, first, the common trunk relays, and extending to the extreme left is space for five two-way trunk-relay units, of which two are equipped. The middle shelf has the station-line terminal block at the right; next, enclosed in a metal case, the finder and connector rotary switches; next, toward the left, are the ringing vibrator and tone and the special-service relays; and the four metal covers at the extreme left enclose four sets of finder-con-

nector relay units. Below these are the line and alarm relays. The bottom shelf is for the power plant. At the left are the storage-battery cells and at the right the rectifier for charging the batteries.

The stations have regular dial-type instruments, a two-wire circuit connecting each with the switchboard. Additional stations may be provided for by connecting two instruments to a station line and using code ringing—a short ring for one and a

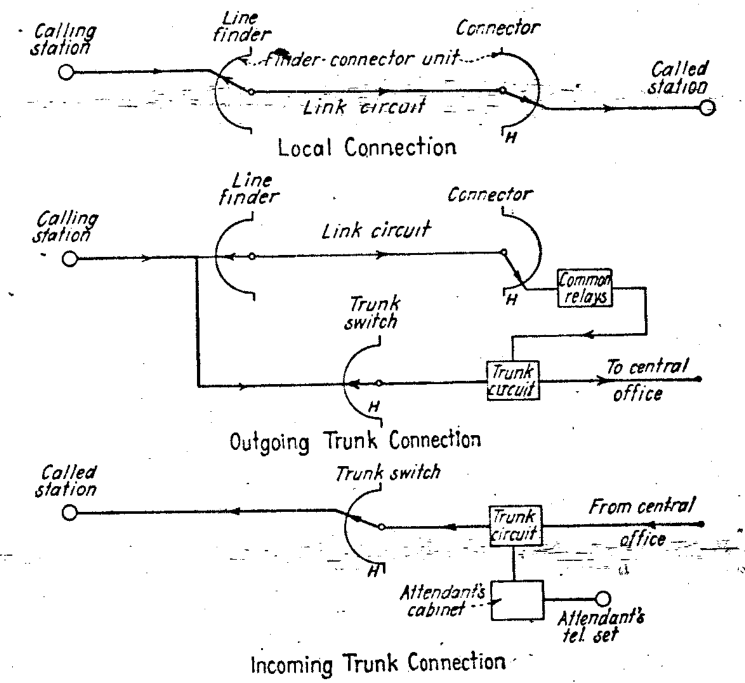


FIG. 273.—Schematic of connections through rotary-switch type P-A-X.

long ring for the other—however, interconnection cannot be made between the two stations connected to the same line.

Figure 273 shows in schematic form how connections are made through this switchboard. The upper diagram shows a connection from one local station to another. When the receiver of the calling station is lifted, a line finder starts to locate the calling line and, when found, the dial tone is connected. The first two digits dialed (twenty-line system) cause the wipers of the associated connector to rotate and connect with the contacts of the desired station line. The third digit causes the bell to ring.

When both parties hang up, the finder wipers are not moved but the wipers of the connector are returned to the "home" position. The station lines are multipled through the banks of all the finder-connector units.

Outgoing calls to the public exchange are made by the subscriber's dialing a number assigned for exchange service. Such a connection is shown in the center diagram of Fig. 273. A line finder operates as before and the number dialed causes the connector to rotate and select a non-busy central-office trunk. The switch of the selected trunk line, operating as a line finder, rotates to the bank contacts of the calling station line, when the finder-connector is released and the connector returns to the home position. The bank contacts of the trunk switches are multipled to the corresponding bank contacts of the finder-connector units. The connection from then on is made through the dial or manual central-office apparatus in the usual way.

Incoming calls from the public exchange, shown in the lower diagram of Fig. 273, are all intercepted by the attendant, except when the circuits are connected for night service. An incoming call is indicated by a lighted answering lamp associated with the trunk at the attendant's cabinet. The attendant lifts the hand set and operates the associated "Ans." key. This causes the trunk switch to rotate to the home position and then operate as a connector. The attendant dials the first two digits of the called station number, causing the trunk switch to rotate to the contacts of the called line. Then, if the line is idle the supervisory lamp lights and the attendant dials the third digit, thus ringing the station bell. The attendant may wait for the called station to answer or retire from the connection by restoring the "Ans." key and replacing the hand set. If the called station is busy, the supervisory lamp does not light after the attendant dials the second digit. She may then inform the calling party that the person he wants is busy or wait until the supervisory lamp lights, indicating that the line has become free, and then dial the last digit to ring the station.

If desired, outgoing connections may be established by the attendant. The local station desiring the connection dials the attendant's number and, after giving the name or number of the outside person, hangs up. The attendant first operates the "Ans." key of a free trunk and then the "Dial Central" key, thereby seizing the idle trunk. If the call is for a dial office, the

attendant, upon hearing the dial tone, dials the exchange number wanted. When the called party answers, the attendant restores the "Dial Central" key, thus causing the trunk switch to rotate to the home position and to act as a connector. She then dials and rings the station wishing the connection.

The local power plant is provided with batteries for 24-volt service in the nine-station size and for 48-volt service in the twenty station-line size. The batteries are floated continuously and any of the methods of charging previously described may be used. The ringing current is usually obtained from ringing vibrators. The talking battery is obtained from the local power plant for local connections and from the central office over the trunk conductors for trunk connections.

Another form of rotary-switch-type system used for P.B.X. service, and in general the dial substitute for the manual-key-type intercommunication system, has been developed. This system is designed to provide local and central-office service for residences and small business offices requiring up to twenty station lines, five trunk lines, and four connecting links. It provides local service between all local stations and exchange service to all or only a part of the stations. Each of the stations permitted exchange service is equipped with a special telephone set, having keys mounted in the base, or a regular set with keys mounted on a separate base. The other stations are provided with regular dial telephone sets.

The set for the stations permitted exchange service is like the regular Strowger cradle-type hand set except that it has a special sub-base which has three one-way locking lever keys and a push-button key. The key at the right, designated "Out," is operated before making an outgoing trunk call, the next key, marked "Ans.," is operated when answering an incoming trunk call, and the key at the left, designated "S," is for holding one trunk connection while answering another trunk call; five stations in an installation may be equipped with the "S" key. These lever keys are locked when operated but when the hand set is replaced on the cradle the operated key is unlocked and restored to normal. Since, therefore, the switch of the cradle cannot be used to flash a manual operator or to correct a dialing error, the push-button key above and at the right of the lever keys is provided for that purpose. In this arrangement, only one "Out" and one "Ans." key is required for all the trunk lines.

Strowger Switch Type.—Several sizes of automatic P.B.X. systems employing Strowger-type ("up-and-around") switches have been designed by the Bell Laboratories and the Automatic Electric Company to meet the need of those establishments for which the maximum capacity of the rotary-switch type would be too small. Both the line-switch and line-finder methods of station-line non-numerical switching are employed. The line-finder arrangement utilizes step-by-step type finder switches, and the line-switch method employs self-aligning plunger-type

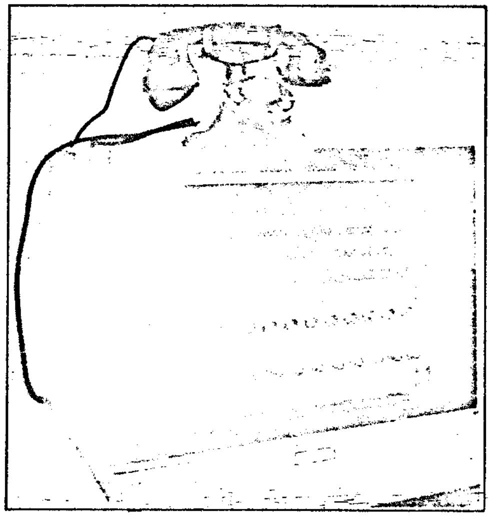


FIG. 274.—Attendant's cabinet for step-by-step type P.B.X. (*Courtesy of Bell Telephone Laboratories.*)

line switches. This switching apparatus is of the same type as previously described in connection with the Strowger system.

Figure 274 is a front view of one style of cabinet used with the step-by-step line-finder P.B.X. system. Near the top is a horizontal row of lamps and keys with designation strip that are associated with the auxiliary and various alarm circuits of the cabinet and switching apparatus. Below are the lamps and keys associated with the ten central-office trunks or tie lines, and at the left are two keys associated with the attendant's telephone circuit. Each trunk has two keys and three lamps. One key is used to connect the trunk to the attendant's telephone circuit or to hold a connection until a desired station is available, the second key connects a station line to a central-office trunk for

night service, and the three associated lamps show the status of any trunked call in progress. One of the two keys associated with the attendant's telephone circuit is operated before she dials and the other, when she originates or transfers a call. If more trunks are required than can be accommodated in one cabinet, a second one is provided which increases the trunks to nineteen.

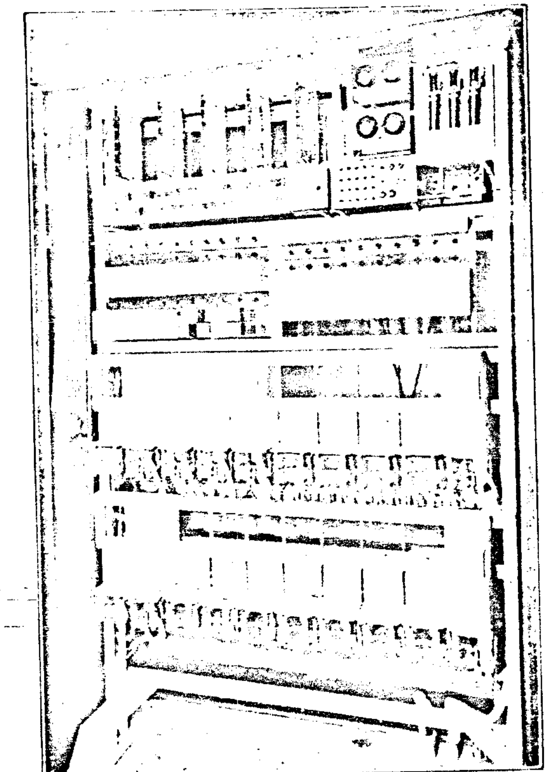


FIG. 275.—Step-by-step type P.B.X. switchboard—line-finder side. (*Courtesy of Bell Telephone Laboratories.*)

The switch frames used with this form of the step-by-step system are of the double-sided type, the line finders being mounted on one side and the selector-connectors on the other. The frame is enclosed in a metal casing with doors on both sides to give access to the apparatus. The line-finder side with the doors open is shown in Fig. 275. On the top shelf are mounted the terminal blocks and at the right is a miscellaneous panel; below on the same shelf is a fuse panel, and a jack panel for testing and busying the line finders. The second shelf contains the line and cut-off relays for the station lines and also miscellaneous relays. The two lower shelves are for mounting the line-finder switches. Banks are provided for twenty switches, of which seven are equipped in the illustration. These line finders have 100-point banks. On the selector-connector side of the frame, the top shelf contains the attendant's telephone-circuit unit and four trunk-circuit units. The remainder of this shelf and the second shelf are reserved for additional trunk or tie-line circuit units. The two lower shelves are equipped with banks for twenty selector-connectors. The selector-connectors have 100-point banks which are multipled to the line finders, therefore providing for a total of 100 station, trunk, and tie lines.

On an originating call, the removal of the receiver from the hook switch causes a line finder to operate and connect the calling station line to an idle selector-connector. The calling party, on hearing the dial tone, dials the desired number, consisting of two digits for a station line or the attendant's line and one digit for a central-office trunk or tie line, after which the selector-connector operates and connects the calling station to another station line, to an idle trunk, or to a tie line. When desired, outgoing calls may be handled by the attendant, as previously described for the rotary-switch type of system.

An incoming call signals the attendant who operates an associated trunk key, learns the station wanted, and dials the number. If the station is busy or does not answer, she may dial another station or hold the connection until the station wanted is free. When both parties hang up their receivers, the switches are released automatically. If the called party wishes to have the incoming call transferred to another station, the attendant is summoned by a movement of the hook switch. She then releases the connection to the first station and dials the second station.

In the system employing line switches instead of line finders, the operations are the same as just described, except that a line switch extends the connection to an idle connector. The details of both these methods of switching have been previously described in Chap. III.

The tie lines to associated P.B.X. boards are frequently so arranged that calls between the stations may be made without the intervention of an attendant. The calling party dials the number assigned to the tie line and then dials the number of the station wanted in the associated P.B.X.

Combined Manual and Dial Systems.—These systems are used by establishments requiring more than about one hundred station lines, and when the station-dialing feature is preferable to the manual method, as, for example, when the associated central office is of the dial type. A complete installation consists of a manual switchboard, step-by-step switching apparatus, relay racks, distributing frame, and a local power plant. Depending on the number of station lines, two, three, or four digits are dialed to secure a local connection. To connect with the central office, only one digit is dialed and, to reach a tie line, one or two digits are dialed, depending on the number of tie-line groups. Only one digit is required to reach the P.B.X. operators, the number zero being usually assigned for that purpose. This system provides for a capacity of from about one hundred lines to approximately three thousand lines, or to the capacity of the associated manual multiple board.

The method of operating the combined manual and dial system is much the same as previously described for the step-by-step dial-type system, except that incoming calls are completed through the switchboard line jacks of the called stations instead of being dialed by the operators.

The manual switchboards used with this system are either the non-multiple or multiple types, depending on the size and requirements of the installation. The manual board is used for completing manually all incoming calls. Outgoing calls to a central office, to the attendant or to a station of an associated P.B.X., may be completed either by switching apparatus operated by the station dials or manually by the operators. However, usually it is preferable to have the stations dial all outgoing calls.

The automatic switching apparatus consists of either line switches or line finders for the non-numerical station-line switching, and the local and dialed outgoing connections are completed through step-by-step selector-connectors or selectors and connectors when the number of stations is such as to require the additional switching step. The line-finder switches are of the 200-point step-by-step type similar to those described in Chap. III.

The switch frames used with the line-finder-type systems are of the iron framework style and are arranged for mounting various types of shelf units—single or double—for line finders, selector-connectors, or selectors and connectors. Each single-shelf unit of line finders mounts 9 switches and the double unit 20. This arrangement permits various numbers of line finders per group from 9 to 40, which makes it possible to take care of a wide variation of originating traffic in different installations. The connector-shelf units mount 10 switches on a single shelf and 20 on a double shelf. This also provides considerable flexibility to meet variations in terminating traffic. Each switch frame has a capacity for a total of 80 switches, 40 on each side. The unit shelf arrangement is also utilized with the line-switch-type sys-

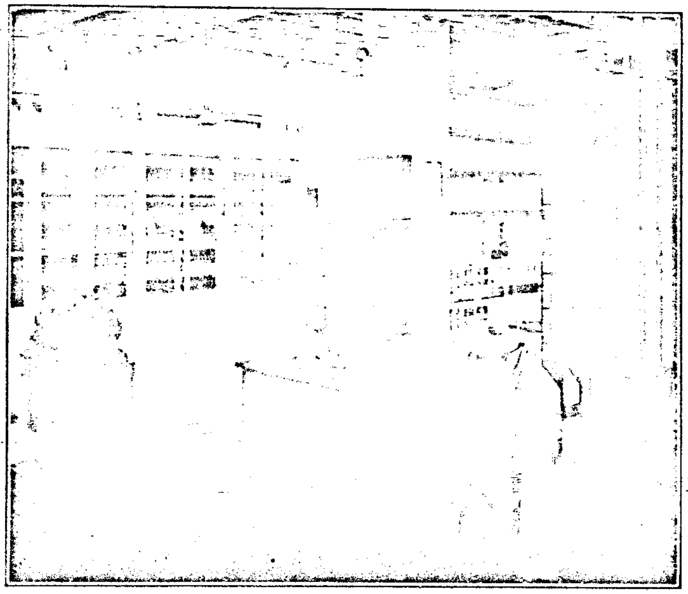


FIG. 276.—Switch room of a 300-line P-A-X system. (*Courtesy of Automatic Electric Company.*)

tem; however, sectional-type frames are employed and the same flexibility of equipment is provided.

The relay racks and distributing frames are the same as those already described for small central offices. The unit method of mounting equipment is used also for the relay rack. Equipment for trunks, tie lines, and miscellaneous circuits is arranged in self-contained units, each unit usually consisting of one type of circuit. These units are assembled, equipped, and wired at the factory and each is provided with a terminal block which requires only the connection of the switchboard cable in installing.

The power plant is the same type as used for small step-by-step central offices and furnishes current also to the manual board.

A partial view of the switchroom of a 300-line P-A-X system is shown in Fig. 276. At the right will be seen a portion of the M.D.F. and directly back of it is a switch frame equipped with selectors, at the top, and trunk repeaters on the two bottom shelves. In the foreground is a supervisor's desk provided with complete testing equipment. The rotary line switches, enclosed in casings with glass doors, are at the left in the rear. Between the test desk and the rotary line switches is a motor-generator set for charging the storage battery (not shown). The power board is mounted in a casing which is a continuation of the casing for line switches, only a small portion of it being visible at the extreme left.

CHAPTER XI

TOLL SWITCHING

Telephone traffic between subscribers whose lines are connected to different local exchanges is ordinarily called "toll traffic." Each message in such traffic usually is charged for according to a standard schedule of rates and hence the name "toll." Toll-message charges vary according to the distance involved, the kind of service, and the length of conversation. The kinds of service are broadly of two classes: first, "station-to-station" and, second, "person-to-person" service. On station-to-station service the calling party agrees to talk with anyone answering at the distant telephone and on person-to-person service he requires that a particular person be reached at the distant telephone. In the case of person-to-person service, attempts to reach the called party at point other than the one originally designated will be made, if necessary, and the calling party so desires. On station-to-station service reduced rates are offered during the evening and night hours. The base or initial time period for long-distance messages is 3 minutes, and for suburban messages 5 minutes except for the more remote points, when only 3 minutes is allowed in the initial period.

Toll traffic is generally classified as "short haul" or "suburban" for distances up to the neighborhood of about 50 miles, and "long haul" or "long distance" for connections between more widely separated points. The majority of the short-haul traffic is handled by the "A," or local answering, operators who complete and supervise the connections. This procedure is called the "'A'-board toll method." The long-haul traffic is handled by toll operators who complete and supervise the connections and this procedure is called the "toll-board method." The particular method of operating employed is dependent on a number of factors, such as the volume of traffic between different points, the distance between points, the kind of circuits available, the transmission quality of the circuits, and the speed of service desired. The volume of traffic is dependent to a great extent on the rates charged for the service and has a very decided influence on several

of the other factors. The increase in toll traffic in the United States during the past few years has made necessary many changes in methods of toll switching, the increase having been particularly noticeable between many widely separated points. Notwithstanding this increase, the addition of circuits, provided mostly by cable conductors, and improved operating methods have actually resulted in a decided improvement in the speed of service. This reduction in time required to make connections has resulted in permitting calling subscribers to remain at the telephone for over 95 per cent of the toll calls made, and in an average speed of service of less than 1 minute.

The wire plant represents by far the greater part of the toll-system investment and therefore operating methods must be such as to maintain as high a use efficiency on that portion as possible. The wire plant of the toll system will be treated more specifically in a subsequent volume.

General Toll-switching Plan.—The methods employed in toll switching must necessarily be coordinated with the entire toll plant. Circuits must be provided in sufficient numbers and so arranged that connections between any two telephone stations can be made in a reasonably short time and without too many intermediate switching points. Also, the entire telephone plant must be designed for such standards of transmission that connections, when established, will permit satisfactory conversation. In order adequately to meet these requirements in the United States, a fundamental arrangement of the toll wire plant and standard routing of toll messages has been established. This fundamental scheme is called the "general toll-switching plan."[1]

The plan consists of: first, a number of established "regional centers," which are toll-switching offices located in various parts of the country and completely interconnected by direct circuits to form the basis of a country-wide toll network; and, second, a greater number of "primary outlets," which are toll-switching offices having direct circuits to one or more regional centers, and each having direct circuits to all the "toll centers" in the area for which it serves as the primary outlet. The primary outlets also are connected to each other within as large an area as practicable, usually a state. The "toll centers" are the toll-switching offices which serve directly the local and various other exchanges, called

[1] OSBORNE, H. S., A General Switching Plan for Telephone Toll Service, *Trans. A.I.E.E.* June, 1930. Also *Bell System Technical Journal*, July, 1930.

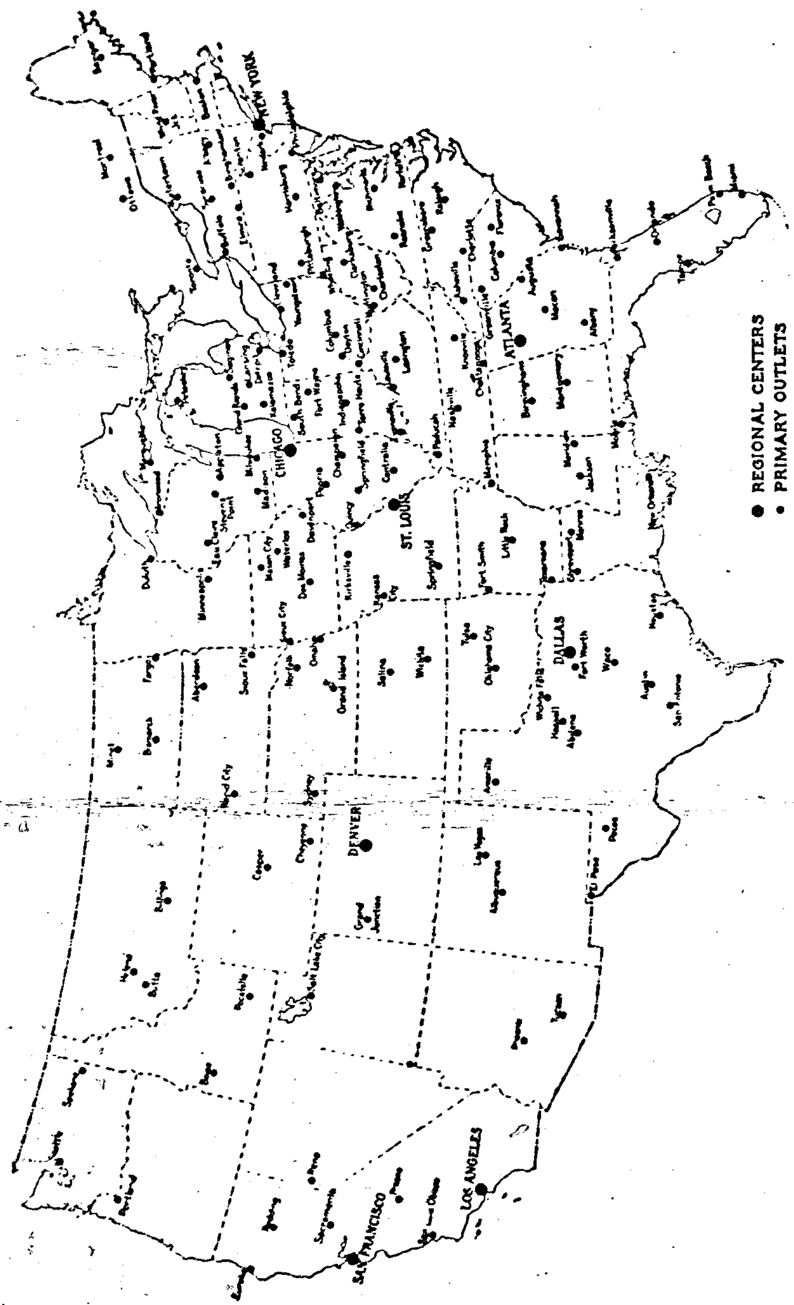


Fig. 277.—Map of regional centers and primary outlets in the United States. (*Courtesy of Bell Telephone Laboratories.*)

"tributary offices," within a local area. The toll centers, in addition to having direct circuits to primary outlets, frequently have direct circuits between one another and in many cases have circuits direct to regional center. In order to provide alternate routes to the regional network, it is found desirable in some cases to utilize a supplemental group of outlet offices, which have direct-circuit connections to regional centers. These offices are known as "secondary outlets." Another type of switching office, defined as "secondary switching point," is used in some instances to provide alternate routes for intra-area traffic to reduce undesirable back hauls. Figure 277 shows the present arrangement of regional centers and primary outlets in the United States. The large dots are the regional centers, of which there are eight, and

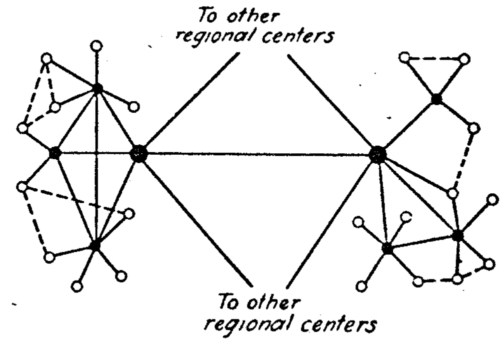


Fig. 278.—Diagram of typical toll routes.

the small dots are the primary outlets representing approximately one hundred and fifty toll-switching points. In addition, there are approximately twenty-five thousand toll centers which are not shown on this map.

In order more clearly to show the arrangement of direct circuits, Fig. 278, which shows only a very small portion of the complete system, has been prepared. The large and small dots represent regional centers and primary outlets respectively, and the small circles the toll centers. The solid lines are the fundamental (direct-circuit) routes of the general plan and the dashed lines are supplementary direct-circuit groups between toll centers. It will be noted that the regional centers are interconnected by direct-circuit routes; that the primary outlets are connected to their respective regional centers, and in certain cases to one another; and that the toll centers are connected to their respective primary outlets, and in some instances to each other, by supplementary direct-circuit groups. This arrangement fulfills one of the fundamental requirements, that of permitting toll connections to be established with as few intermediate switching points as possible. In the complete system (Fig. 277), any two toll centers directly connected to primary outlets and in the same regional area may be connected by the use of not over three intermediate switches, and in different regional areas by not over four. At the present time, 80 per cent of the toll messages are handled over direct circuits, 17 per cent with one intermediate switch, and 3 per cent with more than one intermediate switch.

This toll-switching plan has been designed to meet present and predicted future conditions in regard to volume and distribution of toll traffic and is subject to modification to conform with changed conditions. However, the number of regional centers and primary outlets may be changed from time to time without departing from the principle of the plan.

Manual Toll Switchboards.—In the smaller exchanges, where the toll traffic is relatively light and requires only a few switchboard positions, the switchboard is ordinarily a continuation of the local switchboard with the subscribers' multiple extended into the toll positions. These toll switchboard positions usually are similarly equipped and each operator handles incoming, outgoing, and through traffic. The offices of medium size have toll switchboards which are separate from the local boards and at which all classes of toll traffic are handled with outward, inward, and through traffic segregated on separate positions. These boards secure connections with the local subscribers' lines by recording or recording-completing trunks, and switching or dial-switching trunks. The larger exchanges, and particularly the multi-office, have separate toll switchboards segregated into groups for the different classes of connections, such as outward, inward, and through, and for special service positions, such as directory and routing. The regular positions are connected to the subscribers' line equipment by means of trunks, as outlined for medium-sized offices.

The customary groups of regular positions are known as:

"Combined line and recording positions," (*CLR*-outward) which serve the local offices, receive and record the originating long-distance calls, and make the first attempt at completion while the calling subscriber holds the line.

"Non-method positions," which have a selective arrangement of toll lines and handle those toll calls which do not result in completed connections on the first attempt and others which cannot be handled by *CLR* operators.

"Inward positions," which handle all calls incoming from distant offices to stations of the local offices. These positions have access to the toll lines and toll-switching trunks to the local offices. The toll lines for outward service at the *CLR* board appear with lamp signals at the inward positions, grouped according to the cities served.

"Through positions," at which are established connections between other toll centers not directly connected. No connections are made to local-office stations at these positions.

The very large toll switchboards in addition to the regular positions usually have the following special positions:

"Directory positions," which are provided with telephone directories of the principal cities and at which are furnished the called telephone numbers when the calling subscribers do not know them.

"Routing positions," which supply the necessary toll-circuit routing information to *CLR* and through operators for points not reached over direct circuits. The authorized routes are based on frequent traffic engineering studies of the entire toll network throughout the territory.

"Toll tandem positions," which provide a means of making connections to toll lines which, owing to lack of space, are not available in the toll line multiple of the *CLR* and non-method positions.

"Traffic trouble positions," to which all line and equipment trouble is reported.

"Office 'B' positions," which provide a means of communication between various positions or supervisors in the toll office, of reaching long-distance terminals, and in unusual cases by use of subgroups of trunks to local offices, for *CLR* operators to reach local offices which cannot be reached by direct trunks from their positions.

"Ticket distributing positions" which are central distributing points of the pneumatic-tube distributing system for the assorting and distributing of toll tickets to the proper positions.

"Ticket filing positions," at which the completed toll tickets are received and the elapsed conversation time and proper charges computed and entered before forwarding to the billing department.

"Service supervisors' positions," which handle service criticisms and other miscellaneous contacts with subscribers.

"Service observing positions," at which the service is observed on a sufficient number of selected calls to check the service as a whole.

"A"-board Toll Method.—As before stated, the short-haul toll or suburban service is generally handled by what is known as the "A"-board toll method. This is the simplest method and is the same as used for measured-service local calls, except that instead of recording the message by register key and meter the operator

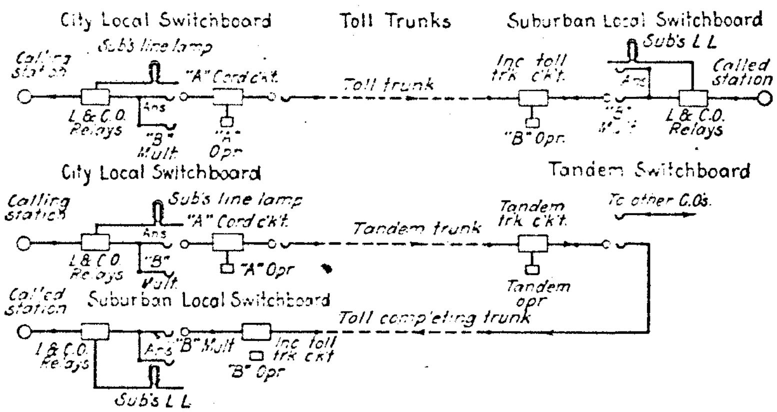


FIG. 279.—Schematic diagram of "A"-board toll connections.

writes a toll ticket. A schematic "one-line" diagram of a connection by this method is shown in the upper portion of Fig. 279. This will be recognized as the same as a connection between two subscribers in the same local exchange. Handling this class of call reduces somewhat the number of calls that the "A" operator otherwise could care for, but it is the most desirable method for short-haul toll business from the standpoint of economy and satisfaction to the subscriber. This method, if used exclusively, would necessitate direct trunks between all the city and suburban central offices and frequently the volume of toll traffic between many of the offices is not sufficient to warrant direct trunks.

In order to secure reasonable trunk-group loads and to obtain the advantages of the "A"-board toll method, an additional

switching point, known as the "tandem switchboard," is introduced. Direct trunks to and from each of the city offices and to and from each of the suburban offices are terminated at the tandem switchboard, thereby consolidating the traffic and producing larger and more efficient trunk groups. The tandem system for local-exchange areas already has been described in previous chapters, and the same principle is employed in short-haul toll service. In fact, the tandem method was first developed for use in manual toll service.

In the lower part of Fig. 279 the "A"-board toll method with tandem trunking is illustrated. The "A" operator receives the call, writes a ticket, and then by the straightforward method passes the exchange or office name and telephone number desired. The tandem operator then extends the connection to the "B" operator at the called office. The method of extending the connection will depend upon the type of system used; it may be by pulsing the office name code and the telephone number, which is received by a call indicator or call announcer at the called office, or by the straightforward method as shown. The "B" operator extends the connection to the called station through the "B" multiple or, if the office is of the dial type, through a switching train. If trunks are available and the called station is not busy, the connection is completed while the calling subscriber remains at the telephone, almost as quickly as a local-exchange connection. Calls handled by the "A"-board toll method are usually station-to-station calls, except in those dial offices where the "A" and toll boards are combined and in the smaller tributary offices where these offices reach their toll center over ring-down trunks.

Toll-board Method.—Long-distance or long-haul service is generally handled through separate toll boards, since, in all except the very small offices, it would not be practical to extend the toll lines to the local switchboards and, furthermore, the operating methods required are not compatible with the regular work of the "A" operators.

The method usually employed for long-haul traffic is known as the "combined line and recording" and for convenience is called the *CLR* method. In this, the functions of long-distance recording and toll-line operating are performed by one operator. A typical toll connection using this method is shown schematically in Fig. 280. The calling subscriber is answered by the "A" operator and, after asking for "long distance," is connected to the *CLR* operator over a recording trunk. The *CLR* operator records the details of the call on a toll ticket and requests the subscriber to hold the line. If the calling subscriber does not know the telephone number of the party wanted, the *CLR* operator obtains this information from a directory operator, but in case the information is not available at her office she will later request the inward operator at the terminating point to furnish it. The operator then selects an idle toll line to the terminating toll center and passes the call to the inward operator there. When the desired toll center cannot be reached over a direct toll line, the *CLR* operator secures the necessary routing information

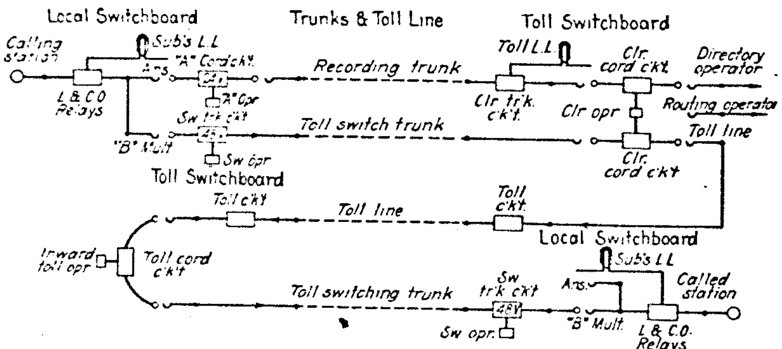


FIG. 280.—Schematic of combined line and recording (*CLR*) long-distance toll-board connection between manual offices.

from a routing operator before starting work on the toll line. In such a case, the connection is extended through one or more intermediate switching points, where the call is handled by a through operator.

After the call has been passed to the inward operator at the distant point, the *CLR* operator selects a switching trunk to the proper central office, secures connection with the calling subscriber's line, and the original connection over the recording trunk is released. The subscriber, meanwhile, has remained at the telephone and this establishing of another connection to his line accomplishes the purpose of supplying 48-volt battery to his transmitter instead of the 24 volts supplied by the "A" cord circuit. The inward operator at the distant toll center selects a trunk to the desired office and extends the connection to the called station. The *CLR* operator supervises the call and times the conversation and at completion takes down the connection.

The inward operator receives a disconnect signal from the called station and, after challenging to determine that the connection is no longer desired, takes down the connection there. If the circuit used has been built up through one or more intermediate points, the *CLR* operator passes a clearance order before releasing the connection. The *CLR* operator then sends the completed ticket to the ticket filing desk, by a pneumatic-tube system, by messenger, or by other means.

If for any reason the connection desired cannot be established immediately, or if delay is encountered in reaching the called party, the calling subscriber is requested to hang up and is advised that he will be called as soon as the connection can be completed.

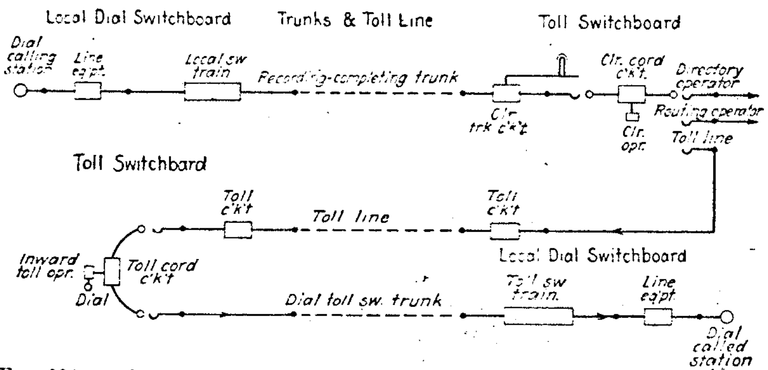


FIG. 281.—Schematic of combined line and recording (*CLR*) long-distance toll-board connection between dial offices.

The toll ticket is then sent to a delayed-outward position or non-method position and the connection completed as will be described later.

In case of calls originating at dial telephone stations, the *CLR* operator is reached by the subscriber's dialing a code number, which extends the connection over a recording-completing trunk. This trunk is also suitable for use in completing the call, as the local switch train which extends the connection is arranged to substitute 48-volt battery for the regular 24 volts and thereby eliminates the necessity of using switching trunks for that purpose. When the distant station called is also connected to a dial central office, one of several methods may be used. A complete toll connection between two dial stations is illustrated in Fig. 281, in this drawing the inward toll operator's position being shown equipped with a dial or key set. In another arrangement, the inward toll operators have no dialing equipment and secure connections to the dial stations through cordless or call-distributor "B" positions.

The operation of the non-method positions is essentially the same as for *CLR* positions, except that these positions are not provided with recording and recording-completing trunks. The

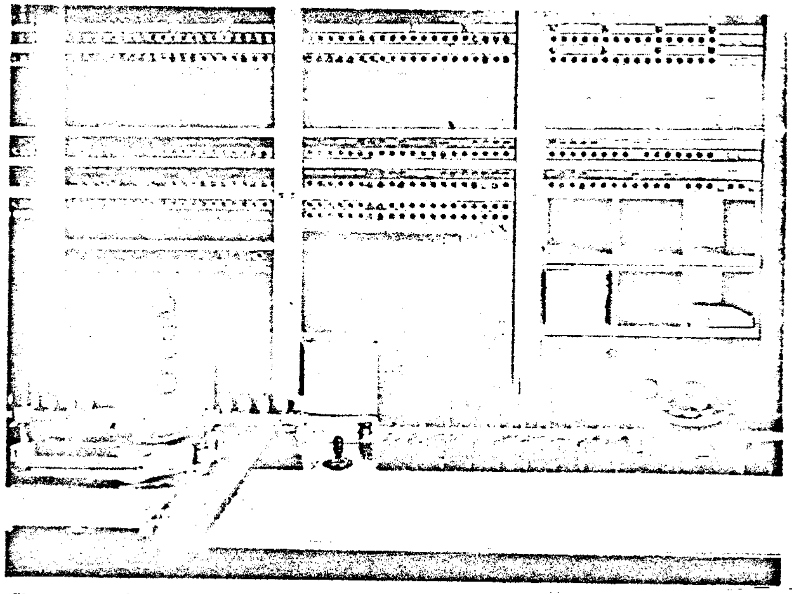


FIG. 282.—Combined line and recording (*CLR*) switchboard position. (*Courtesy of Bell Telephone Laboratories.*)

function of these positions is primarily the handling of connections on which there has been some delay in completing. When delayed connections are completed, the calling subscribers are reached over switching or dial-switching trunks, the toll line operations being the same as previously described for *CLR* positions.

Figure 282 shows a front view of a *CLR* position. In the face equipment, at the top, are the multiple switching trunks, next below the multiple of toll lines with visual busy signals, and below these in the center panel are the recording trunks. The lower strip of ten jacks in the left panel are interposition trunks. The keyboard equipment consists of the calculagraph at the left and a dial at the right. The six sets of keys, lamps, and plugs in the center of the position are associated with the toll cord circuits

and at the left and right of these are various positional keys, such as ringing, dialing, and coin control. On the front portion of the key shelf is a glass-covered routing and rate chart.

Toll Tandem Board Method.—In toll central offices serving large metropolitan areas, the face-equipment space of the *CLR* boards is frequently insufficient to accommodate the recording and recording-completing trunk answering jacks, the switching trunk multiple, and the complete toll-line multiple. This condition has led to the development of the "toll tandem board," at which all the toll lines are multipled and to which toll tandem trunks are extended from the *CLR* board. A connection from a local to a distant city station via a toll tandem board is illus-

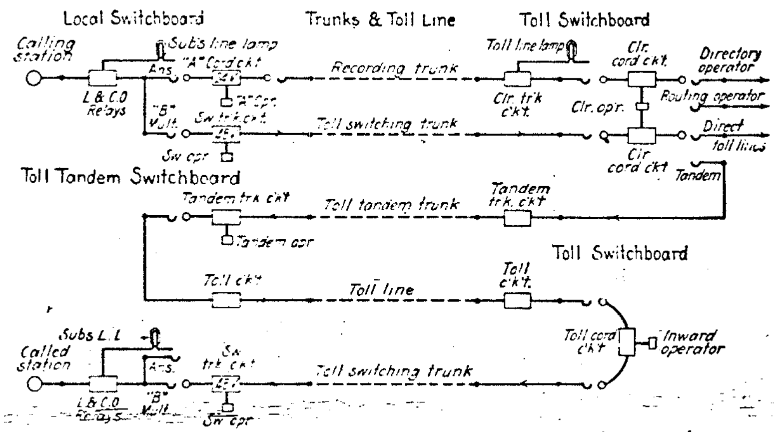


FIG. 283.—Schematic of long-distance toll tandem board connection.

trated in Fig. 283. The *CLR* positions still have access to the direct toll lines to the principal points and much of the traffic is handled over these as previously described. However, when a call is for a point reached through the toll tandem board, the *CLR* operator extends the connection, by a toll tandem trunk, to the tandem operator who connects with a toll line to the point wanted.

The toll tandem board is designed to work on the straightforward, automatic-listening, and automatic-ringing basis and automatic disconnection of the operator when a connection is plugged through. To facilitate locating an idle toll line in a desired group, each jack in the tandem board has an idle-line indicating lamp associated with it. These lamps are located above the respective line jacks in combined lamp-socket and designation-strip mountings. The lines of each group are so connected that the associated indicating lamps function in sequence from left to right and, if the first line of a group is idle, its associated lamp is lighted, thus indicating an idle line. This lamp remains lighted until the line is taken by an operator, when the indicating lamp of the next idle line is lighted. Thus only one lamp in a group is lighted at a time and that indicates the first idle line of the group, counting from left to right. These arrangements improve the operating efficiency and result in adding only a relatively short time interval to the total operating time when connections are extended through toll tandem boards.

The toll tandem operator is essentially a switching operator and arrangements are made to pass information back to the *CLR* operator by means of signals. For example, if all the toll lines to the point desired are busy, the *CLR* operator is informed automatically by means of "overflow" circuits. Each group of toll lines has an overflow jack and associated lamp, located at the head of the group. The lamp is wired in sequence with the idle-line indicating lamps and lights when all the lines are busy. When an incoming tandem trunk is plugged into an overflow jack, a steady cord supervisory lamp signal is transmitted back to the *CLR* operator. The connection over the toll tandem trunk is maintained and, when one of the toll lines becomes idle, the *CLR* operator is so informed by a change from the steady lamp signal to a fast flashing signal. She then selects another tandem trunk and repeats her order for the toll line. In addition "common overflow" circuits, individual to each tandem position, are provided. When the group overflow circuit is in use and another connection is requested for the same point, the incoming tandem trunk is plugged into a jack of the common overflow circuit and the second *CLR* operator is informed, by a slow flashing cord supervisory lamp, that a call is already waiting for a connection to the same point. Under these conditions, the second *CLR* operator abandons the connection for later completion.

Figure 284 is a view of a portion of a toll tandem board showing fifty incoming tandem trunk cords per position and a section (two positions) capacity for 3,600 toll lines with their associated idle-line indicating lamps.

Dial Toll Switchboards.—Several types of toll boards designed to utilize the principles of automatic telephone switching are in service in the United States and European countries. These

systems in some cases employ cord connecting circuits supplemented by dialing features for certain selective functions, while in others the cords have been dispensed with entirely and the complete toll-line selection accomplished through dial- or key-set-controlled switches. The latter type of system is generally more applicable to relatively large toll-switching centers, where the operating advantages are sufficient economically to warrant their use.

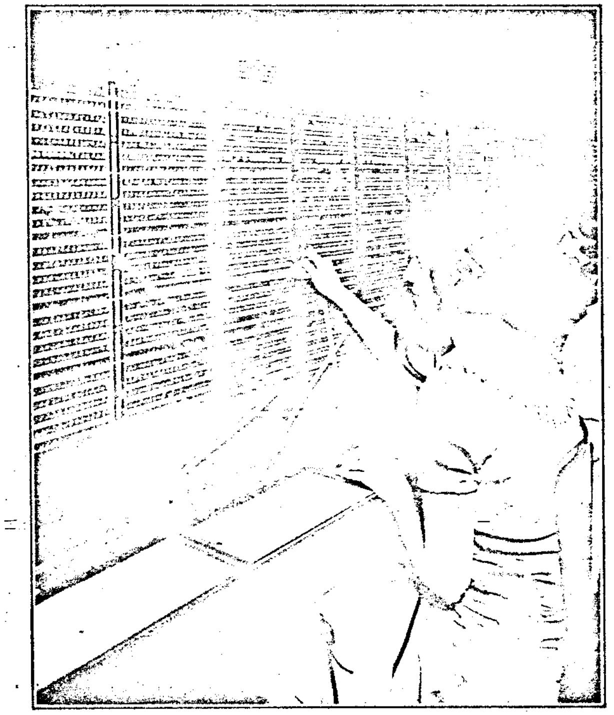


FIG. 284.—Toll tandem switchboard.

Dial Short-haul Tandem Boards.—Dial tandem systems have been developed for handling suburban toll service in areas where a large portion of the local central offices are of the dial type, and also to facilitate the handling of short-haul traffic of large metropolitan areas. When used in connection with dial offices, operators are usually required at the tandem office to control the trunk selections to the distant offices. In some of the larger metropolitan centers, dial apparatus of the panel type is employed also for handling calls from manual offices. The panel-type method of tandem operation has already been described in connection with the panel exchange system.

In some instances, no operators are required at the tandem offices, the entire switching being controlled by dials at the switchboard positions of the manual offices and through sending equipment at the special "A" operators' positions in the dial offices. Of course, calls for offices not equipped with call indicator or call-announcer positions must have the number of

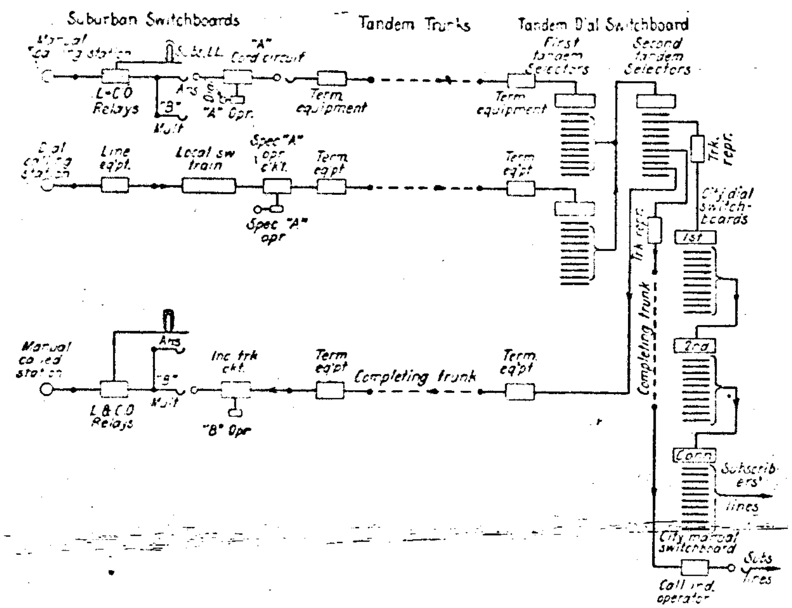


FIG. 285.—Schematic of dial short-haul tandem toll-board connections.

the wanted station repeated to the incoming operator. An example of a tandem system of this type is that in southern California, centering about Los Angeles. The central offices in the short-haul area are manual common-battery and magneto, dial step-by-step (Los Angeles exchange, mainly dial), and a few semi-automatic. Since the dial offices in this territory are all of the step-by-step type, that type has also been used for the tandem system.

A schematic diagram of typical toll connections for the dial short-haul system is given in Fig. 285. The drawing has been made with particular reference to calls originating at suburban

points; however, calls from the city exchange would be handled in the same manner. Two groups of tandem selectors are provided, one as shown and another for the calls from the city stations. In the upper portion of the diagram is shown a connection from a suburban manual office and immediately below one from a suburban dial office. At the upper right is the tandem selector switch train, at the right below this is a city dial office switch train, and at the bottom is indicated a connection to a city manual office with call-indicator positions. The manual "A" operator or special dial "A" operator receives the call, writes the ticket,

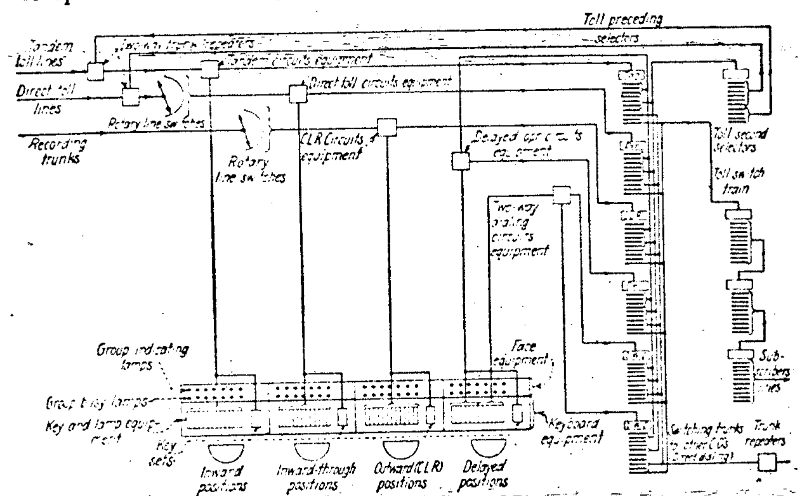


FIG. 286.—Schematic of Strowger automatic toll-board system.

and extends the connection by dialing the office code and station number wanted. These operators also time the messages and have complete supervision of the connections. At the lower center and left portion of the drawing is shown a connection to a suburban manual office. In this case, the functions of the originating "A" operator are the same as before, except that the office code only is dialed and the station number repeated verbally to the incoming "B" operator at the suburban office.

Strowger Automatic Toll Board.—The Strowger automatic toll board is an example of a complete key-set-controlled system utilizing the principles of the Strowger step-by-step telephone-exchange switching system. This toll board is designed to be operated in accordance with the standard methods previously described. A schematic diagram of a typical arrangement of this system is shown in Fig. 286. At the upper left are trunks from a toll tandem office, direct toll lines are immediately below, and beneath these are the recording trunks from the local exchange. These recording trunks are in practice separated into two groups: one for regular subscribers and one for coin-box paystation service. However, for the sake of simplicity but one type of circuit has been shown. The toll lines are terminated in two-way trunk repeaters, and immediately to the right are rotary line switches. These line switches are of the "homing" type and serve to distribute the traffic to the switchboard positions. The small squares in the upper center of the drawing represent the various relay groups associated with the different classes of trunks. At the lower part of the drawing are the toll operators' positions. The classes of positions shown in this typical arrangement are: inward, inward-through, combined line and recording (*CLR*), and delayed-call. While only one position of each class has been shown, it is to be understood that a sufficient number of each would be provided to handle the traffic properly. At the right of the drawing is the step-by-step switching equipment for extending the toll connections to the desired destinations. The first vertical row of switches represent the toll preceding selectors. These selectors are of the one-digit type and serve to extend the connections to the local toll switch train, to the toll switch trains of other central offices, to delayed-call operators, and to toll second selectors. The second selectors extend the connections to other toll lines. Toll third selectors would be added when the number of toll lines require them. The second selectors shown are of the two-digit type, so that the bank levels may be subdivided to provide for toll lines in groups of less than ten.

A call coming through some other toll board or tandem board will cause a line lamp to light at one of the inward-through or inward positions. The operator will answer with the associated "talk" key and learn the connection desired. If the call is for a local-exchange station, she will operate the proper keys of the key set and extend the connection to the called subscriber's line. If the call is for some other office, the connection will be extended by means of the key set to the proper toll line or switching trunk. If the called subscriber's line is busy or no toll lines are available, the call must be passed to one of the delayed-call positions. In order that an operator may properly identify the call to be passed, each position has in the face equipment "group-indicating" lamps. A separate lamp is provided in each position and associated with each of the toll-line groups, and, when the "talk" key is operated, the lamp for the group over which the connection has come will light and thereby inform the operator of the particular point from which the call is coming. The face equipment is also provided with "group-busy" lamps, and, when the operator notes a lighted lamp indicating that all the lines in a particular group are busy, she will at once transfer calls for that group to a delayed-call operator. The delayed-call operator will record the details on a "call-order" ticket and attempt to complete the call as soon as possible, as will be described later. The connection will then be cleared from the position at which it was originally answered.

Calls from local-exchange stations are extended to the *CLR* operators over the recording trunks, as previously explained in connection with manual toll boards. These calls are distributed through the rotary line switches to one of the *CLR* positions, where operator writes a toll ticket and attempts to complete the connection desired by means of her key set. In the majority of cases, this is accomplished while the calling subscriber remains at the telephone, and in many other cases after only a slight delay. In case of temporary delay, the calling party is instructed to hang up and that he will be called, his line meanwhile remaining connected to the *CLR* position. These operators have facilities for "ringing-back" the calling station over the recording trunk, and, when the delayed connection has been completed, she recalls the calling subscriber. If the *CLR* operator finds it impossible to complete the connection within a specified time, the call is passed to a delayed-call operator and the subscriber's line released.

The delayed-call operators, as the name implies, are provided for the purpose of completing connections on which some delay is expected or has been experienced. "Call-order" tickets are written for all such calls and these operators complete the connections as rapidly as the called stations can be reached. The trunk-circuit equipment for the delayed-call positions is in general of two classes. One consists of the circuits over which the delayed-call positions are reached by other operators and the other of "two-way dialing" circuits, by means of which connections may be extended to both the calling and called stations.

A typical dial *CLR* switchboard position is shown in Fig. 287. In the face equipment, the group-indicating and group-busy lamps are located above the ticket file compartments, in combined lamp-socket and designation-strip mountings. On the key shelf, the key group of two rows at the extreme right is the "dialing" key set. This consists of ten digit keys, a start key, and an error key. At the left of this group are two sets of keys and lamps, and these, together with the two at the extreme left of the key shelf, are common to the position and are for splitting a connection, ringing in either direction, operating coin-box paystation apparatus, etc. The six sets near the center of the posi-

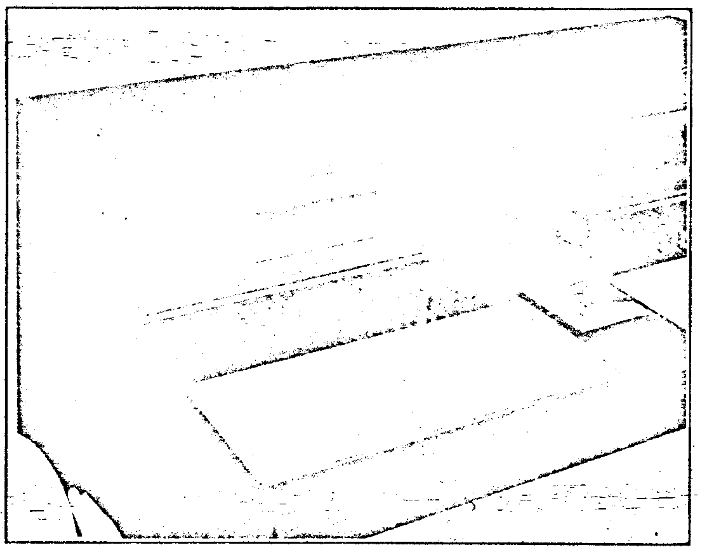


Fig. 287.—Strowger automatic toll-board position.

tion are the recording trunk-circuit keys and supervisory lamps. These keys are used in answering calls, monitoring, and releasing connections. The three lamps at the rear of each of these keys are the regular calling, supervisory, and guard lamps. The two sets of keys and lamps at the right of the center are for coin-box paystation service and have the same functions as those just described. The time stamp is at the right of the position, and the front of the key shelf has a glass-covered instruction and routing chart.

INDEX

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