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OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 112

TELEPHONE SERVICE

JUNE 24, 1921

PRICE, 65 CENTS
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ABSTRACT

Service in general, service grades, and classification required to meet the needs of the users and service development as related to the telephone plant are considered in an introductory section.

This is followed by four sections in which the telephone plant and its operation are described. The first of these comprises brief descriptions of the most important developments of the art arranged approximately in chronological order. The second is descriptive of manually operated equipment with due consideration of the many varieties in use. The third is descriptive of three basic systems of automatically operated equipment commonly known as the automatic system, the automanual system, and the panel type, machine switching system. The fourth is descriptive of outside line wire plants by means of which telephone stations are connected with central offices and central offices with each other.

The plant sections are followed by a traffic section in which the handling of calls from a quantitative standpoint is considered. This includes the determination of amount of plant facilities and number of operators required.

By means of the descriptions given in the preceding sections the reader is prepared for a discussion of service from an analytical standpoint. In the next section the elementary characteristics of telephone service which are peculiar to the nature of the service and to the manner in which it is rendered are explained in relation to grade of service.

A section regarding public relations is included to cover commission regulation of telephone service and a conclusion regarding the subject of service standards. A statistical section is appended.

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I. INTRODUCTION

1. TELEPHONE UTILITY

A telephone utility may be defined as a business entity which renders telephone service to the public for compensation. The laws relating to telephone utility regulation generally specify every corporation, company, association, partnership, or person, their lessees, trustees, or receivers, that undertakes to render telephone service to the public for compensation through direct ownership, operation, or management, or indirectly through control. In some States mutual telephone companies, even though operated on a cooperative basis, are considered as telephone utilities.

2. TELEPHONE SERVICE

The product which a telephone company sells is service. Telephone service comprises the furnishing of the necessary telephone plant and the operation of the plant so that any user thereof will, upon demand, be so connected to any other user thereof that the two parties can talk with each other when they desire to do so. The unit of measure for telephone service is the completed call or connection.

3. GRADE OF SERVICE

In general the grade of telephone service which a community requires varies with the telephone development of the area. In particular localities special needs have to be considered in the determination of what grade of service should be rendered. In all cases, however, the general satisfaction of the majority of the users is the most important criterion of good service.

4. SERVICE CLASSIFICATION

Service is classified as well as graded to meet the needs of the users. The average user requires frequent connection with parties in the same community, less frequent connection with parties in neighboring communities, and infrequent connection with parties at long-distance points. The average user requires, furthermore, prompt connection within the same community, less prompt connection with neighboring communities, and accepts the varying degrees of promptness incident to connections with long-distance points. There have naturally resulted several distinct classes of service to meet these needs. Service is also classified according to facilities provided and according to methods of charging for the service.

Local Service.—The term local service is applied to connections between parties within the same community. The same community usually means the same city, town, or village, though not necessarily so, as two or more may be so near together that their business and social interests are common; furthermore, a city may be so large that it can properly be divided into several communities. Thus local service is always restricted to a certain local area which is known as the local service areas.

Local areas may comprise or include rural areas in which the telephones are widely scattered and in which the lines are generally much longer than those in urban areas. Special facilities are required to meet rural service needs.

Toll Service.—The term suburban toll service is applied to connections between parties located in neighboring communities. The term long-distance service is applied to connections between parties in communities which are separated by distances or conditions which make the need for connections comparatively infrequent for the average telephone user.

Toll lines are in general more costly than local lines and of course the cost of rendering service increases with the distance. These facts, combined with the comparatively infrequent need for this service on the part of the average telephone user, have resulted in placing the charges for this service on a combined time and distance basis for each call. Hence the application of the term toll to this class of service.

Subscriber and Public Service.—The users of telephone service are generally divided into two groups. Those users having need for a considerable amount of local service generally enter into contract with the telephone company for that service, are known as subscribers, are furnished with private telephones, and pay at stated periods. Those users having need for occasional service are generally served by public telephones and pay cash for each completed call. Frequency of use is, however, not the only basis for this division of users. Convenience is often the determining factor. Many users are subscribers for this reason, and many subscribers use public telephones for the same reason.

Subscriber service is divided into two classes: Private service and semipublic service. Telephones for private service may be in any location, but telephones for semipublic service are usually placed at business locations where they are accessible to the general public. For semipublic service the subscriber guarantees a minimum return, all charges are on a per call basis, and the public pays cash for each call.

FLAT AND MESSAGE RATE LOCAL SERVICE.—Private subscriber service is divided into two classes according to the method of charging. These are known as flat and message rate classes. The flat-rate method of charging for service puts no restriction on the number of calls to which each subscriber is entitled. The message-rate method of charging for service puts all charges on a per completed call basis, coupled with a minimum charge entitling the subscriber to a certain number of calls per month or per annum. Message-rate service may be also divided into two classes according to the manner in which the charges are collected. Charges are usually paid directly to the company each month, but in some localities the companies furnish coin collectors with the telephones by means of which the charge for each message is collected in advance.

BUSINESS AND RESIDENCE SERVICE.—Flat-rate service is divided into two classes known as business and residence service. This classification is based primarily on the difference between the average amounts of service required by business and residence subscribers.

UNATTENDED AND ATTENDED PUBLIC SERVICE.—Both public and semipublic telephone service also may be divided according to the manner in which the charges are collected. In both cases the charges are usually collected by means of coin collectors associated with the telephones. Less frequently the charges are collected by attendants. In the case of public telephones the attendants are usually employees or agents of the telephone company. In the case of semipublic telephones the attendants are practically always the subscriber or his employees.

INDIVIDUAL LINE, PARTY LINE, AND PRIVATE BRANCH EXCHANGE SERVICE.—Both subscriber and public telephone service are classified also according to the plant and operating facilities required for the service. A subscriber may be served by one or more individual lines or may share a party line with one or more other subscribers. A public telephone is usually served by an individual line, but party lines are sometimes used for public telephones. A private subscriber may be provided with private switching equipment which, together with the associated local telephones and lines, is known as a private branch exchange. It is connected to the associated central office by lines which are known as private branch exchange trunk lines.

5. TELEPHONE PLANTS IN GENERAL

The term plant is commonly applied to all property of a telephone company used for rendering telephone service. It includes all buildings, grounds, implements, furniture, fixtures, supplies, etc., but for the purpose of this publication it is only necessary to consider the three main divisions of the operating plant known as station equipment, central office equipment and the outside line plant.

The design of the telephone plant is dependent upon the nature of the service to be rendered. The plant furnished for any community is designed to render the classes of service required and the grade of service desired. The amount of plant furnished depends upon the service demands, upon the probable rate of increase, and also upon the grade of service desired.

The plant in each community is more or less divided according to the classes of service rendered. The plant is also naturally divided into working and spare plant. The provision of the proper amount of plant requires the most careful forecasting of the future development of the service.

6. SERVICE DEVELOPMENT

Before any new telephone plant facilities are provided, a comprehensive study of the area in which it is proposed to render the new service is usually made to determine the business prospects. This statement applies to facilities in new areas and to additional facilities in old areas. The prospects for new business in any area will, in a great measure, determine both the nature and the amount of the facilities required within a reasonable future.

The bulk of the telephone plant must be provided in advance, and the cost thereof will have an important bearing on the cost of the service. Those portions of the telephone plant which require the greatest degree of foresight for economical construction and location are the central office buildings and their equipment, and the underground construction. These are of a semipermanent nature and involve large costs. Exhaustive forecasts of the probable telephone development are, therefore, imperative in order to avoid changes involving even greater costs.

It is, therefore, the common practice to estimate for not less than 20 years ahead and to prepare a comprehensive fundamental plan of procedure. This plan is revised at intervals of a few years and forms a systematic basis for all major additions to the plant. Minor additions to the plant are based on annual estimates of probable new business and changes in existing business.

7. OBJECT AND SCOPE OF THIS CIRCULAR

The object of this circular is to describe telephone service in such a manner as to give the reader a fairly comprehensive understanding of what is involved in rendering telephone service and what the elements of the service are which determine its grade.

Some knowledge of how telephone service is rendered is a prerequisite for understanding a discussion of graded telephone service. The scope of this circular, in so far as telephone practice is concerned, is limited to those operating methods of all systems which are most essential. The detailed description of apparatus and operating technicalities have been avoided as far as possible. More detailed and more technical presentations are reserved for subsequent publications.

8. TREATMENT OF THE SUBJECT

A brief outline of the development of the telephone art is given first. It serves as a historic background for obtaining a proper estimate of present-day achievement and is explanatory in nature to descriptions which follow. Only the most important developments are mentioned. Each of these is of a fundamental nature and marks a stage of development, but all of these together cover only a part of the total. The other part includes a very large number of lesser developments, which, in the aggregate, are of far-reaching importance. These pertain chiefly to the choice of materials, improvements in the design of apparatus and in methods of manufacture, installation, construction, operation, and maintenance to secure greater efficiency, dependability, and reduced cost. This type of development has been practically continuous since the invention of the telephone.

The description of the telephone plant follows and is divided into three parts which respectively consider the equipment of manual switching systems, the equipment of automatic switching systems, and the construction of the outside line plant. In describing manual switching systems an attempt has been made to cover the most important elements of all the many varieties.

The description of automatic switching systems includes the three basic types. One is commonly known as the automatic system, another is a semiautomatic system which is known as the automanual system, and the third is known as the panel-type machine switching system. The first two systems are in service to a sufficient extent to make them typical of present-day practice. The third system is practically a new system.

Economic conditions in this country during the past few years have been such as to greatly stimulate the development of automatic switching equipment and to expedite its very general adoption. The introduction of the panel-type system on a very large scale in large cities seems so imminent as to warrant the inclusion of a brief description in this circular. As this system is not typical of present-day practice the sections which follow its description will contain no special reference to this system. There is another semiautomatic system in use in one city, but this system has not been considered for the reason that the installation was made on an experimental basis.

All equipment descriptions are given from an operating standpoint and cover the common classes of service. Descriptions of power equipment and of maintenance equipment are entirely omitted. The description of the outside line construction is intended to furnish a view of the completed plant.

The section on telephone traffic supplements the operating descriptions given under plant-equipment headings by considering the handling of calls of common classes. This section, however, is mainly concerned with the rendering of service from a quantitative standpoint and with the basic principles underlying the determination of the amount of plant facilities and number of operators required for handling all classes of calls.

The section on the principal elements of telephone service presents the elements in groups designed to bring together the elements having a common service relation. Each element is con-

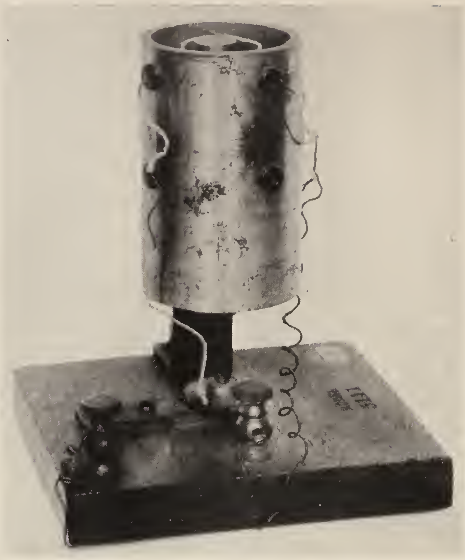

FIG. 1.—*Bell's Centennial receiver*

This device comprised the operating elements of a modern receiver assembled in an elemental manner. These are a permanent magnet, a coil of insulated wire associated with the magnet, and a soft iron diaphragm. The diaphragm—not shown by the illustration—was placed on top of the iron cup and was retained there by magnetic attraction. This receiver was not arranged for direct application to the ear

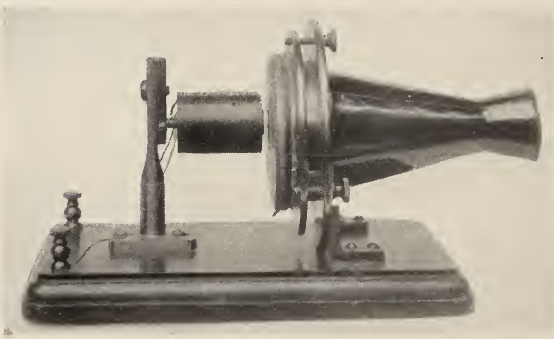

FIG. 2.—*Bell's Centennial transmitter*

This device was an adaptation of the receiver for transmitting purposes. A membrane diaphragm was used, and a soft iron disk was attached thereto. This disk was placed at the center of the diaphragm and the magnet directly in front of the disk. When the diaphragm was vibrated by sound waves the corresponding movement of the disk induced telephonic currents in the coil of insulated wire which was connected to the line circuit sidered with a view to showing its relation to the grade of service. Efforts have been directed to thus outlining a basis for future work along the line of service standards, but no attempt has been made in this first telephone publication to formulate any service standards or to assign any values.

The last section is with regard to public relations now largely governed by commission regulation. Reference is made only to the more important phases of the general subject, which have received attention. A conclusion is drawn regarding the subject of service standards.

9. ACKNOWLEDGMENTS

The Bureau of Standards acknowledges the cordial cooperation of the various telephone interests, engineering, manufacturing, and operating, in the preparation and helpful criticism of the manuscript and in procuring suitable illustrations. It also desires to express its thanks to Prof. Dayton C. Miller, Case School of Applied Science, for generously furnishing specially prepared photographs of wave forms.

II. DEVELOPMENT OF THE TELEPHONE ART

1. BELL'S INVENTION AND DEMONSTRATIONS

The telephone art originated in the invention in 1876 of a device by Alexander Graham Bell, which had the fundamental characteristics of the present-day receiver. It could also be used as a transmitter. The most important public demonstration of this invention was made in 1876, at the Centennial Exposition in Philadelphia. The exhibit consisted of a short interior telephone line, with a receiving device at one end and a transmitting device at the other end. The transmitting device differed in details of construction from the receiving device, but not in basic principles of operation. Though the apparatus was of crude construction, the practical operation of this exhibit was very successful, and it was followed by other demonstrations, both public and private, which established the commercial practicability of the telephone. The development of the telephone art was thus started and was rapidly continued in several parts of the country.

2. EARLY APPLICATIONS

The earliest commercial applications of the telephone were for private-line service between two stations connected by a single line. Later, more than two stations were connected by the same line. The outside lines were of iron wire, supported by poorly insulated attachments to housetops and slender poles, and were run from station to station with the earth used to complete the circuit.

It was very soon apparent that an exchange system, by means of which the various lines in a community could be interconnected upon request, would be desirable. Such a system for telegraphic purposes had already been developed, and many of the telegraph systems were soon equipped with telephones. Other exchanges were established for telephonic purposes only, and these were naturally provided with switchboards of the telegraph type for switching the telephone lines. During this stage of development, which occurred in 1876 and 1877, the telephone instruments were not uniform in construction or performance, the intensity or volume of the reproduced speech was relatively weak, and the transmission limit was considered to be about 20 miles.

3. EARLY SIGNALING DEVICES

It was also soon apparent that the practical use of a telephone required means for signaling from one telephone to another and later from each telephone to the switchboard and from the switchboard to each telephone. A very early scheme for signaling made use of the receiver at the called station, which was caused to sound by means of a battery and a circuit interrupter operated by hand at the calling station. Another early scheme made use of an electric bell at the called station, which was rung by means of a battery and a push-button key at the calling station. In order to eliminate the need for signaling batteries, a crude form of hand-operated electric generator was developed during the latter part of 1877 to replace the battery interrupter, and during 1878 a bell was devised for use with such generators. Subsequent improvements in these devices made them similar in many respects to the same type of apparatus still extensively used in small communities.

When generators and bells came into use it also became necessary to equip the telephone with means for switching the telephone line either to the signaling apparatus or to the talking apparatus. This was first accomplished by the use of a simple hand-operated switch which was supposed to be left in the signaling position when the telephone was idle and which was moved to the talking position when the party desired to talk. Trouble ensued because the parties neglected to restore the switch to the signaling position when through conversing.

Various automatic switches were devised to prevent such neglect. Even in those days hooks were provided for supporting the receiver while idle, and the combination of a receiver hook and a switch solved the problem, as one could at least be expected to hang the receiver on the hook when through talking. The switch attachments on the hook connected either the signaling or the talking apparatus to the line, depending upon whether the receiver was on or off the hook.

An early method of signaling the switchboard was by means of telegraph apparatus or by combinations of such apparatus and bells, but as lines grew in number a more compact form of signal was devised, and one was attached to each line. This signal was of the electromagnetic type now commonly used for annunciators. When energized by an electric current a hinged piece is unlatched and thereby permitted to drop. The device is therefore known as a drop. When a connection was established between two lines a line drop was included therein to give a ring-off or clearing-out signal.

4. EARLY BATTERY TRANSMITTER AND THE INDUCTION COIL

As a practical telephone transmitter, Bell's telephone was limited to relatively short-distance operation for the reason that its power output was necessarily limited by the small amount of power available from the sound waves. Thomas A. Edison, recognizing this limitation and also the inherent possibilities of much greater power output from a transmitter based upon the principle of varying the resistance of, and hence the current in, a battery circuit, directed his attention to the discovery of the most suitable material and form of variable resistance for such a telephone transmitter, and found in March, 1878, that a particular form of carbon would give excellent results. He made a transmitter having a button of carbon (lampblack) so mounted and connected in the circuit that sound vibration in the air caused corresponding variation in the carbon-contact resistance which produced fluctuations in the strength of current flowing through the transmitter circuit. By this means the energy of the sound waves was, in effect, used merely to operate a throttle valve, thus allowing more or less power from the battery to flow in the local transmitter circuit. Edison also recognized the advantage of separating the transmitter circuit from the line circuit, and to accomplish this and still maintain the proper relations between them he introduced a small transformer, which became known as a telephone induction coil.

The introduction of the variable-resistance transmitter also required an additional switch for opening and closing the local battery circuit. This operation was accomplished mechanically by the use of an extra pair of contacts on the receiver-hook switch previously referred to.

Other forms of carbon transmitters were developed during 1878. One, in which fine particles of carbon were used as the variable resistor, was invented by Henry Hunnings; another, in which a small platinum piece made a loose contact with a polished block of hard carbon, was invented by Francis Blake. The carbon block and platinum contact were so mounted with respect to the transmitter diaphragm that the sound waves causing the diaphragm to vibrate would thereby produce variations in the pressure at the contact point and thus cause corresponding variations in the current. This form of transmitter gave very distinct articulation and was sufficiently powerful for the telephone service of that date. It was in general use for a period of about 15 years.

5. EARLY TELEPHONE SWITCHBOARDS

As early as 1879 it became evident that the telegraph type of switchboard was not well adapted for telephone service. This was largely because of the fact that telegraph connections were comparatively infrequent and of rather long duration, whereas telephone connections were frequent and of short duration. Telephone service, furthermore, required prompt disconnection, and the increasing number of lines required a switchboard of compact construction and of a sectional nature to which addition could be made from time to time.

The first telephone switchboard which met the requirements had each line wired through a spring connecting device to the line signal or drop. The spring connecting device was the forerunner of the modern switchboard jack. It was used, as it is to-day, in connection with a metal plug to which was attached a cord composed of suitably insulated and protected flexible conductors. When the plug was inserted in the jack the line drop was disconnected, a practice which still obtains for many switchboards. The first cords had plugs on each end, and two such cords were used to establish a connection with the aid of an intermediate connecting bar to which other plug connections were made for ringing and listening purposes. With each of the intermediate connecting bars another drop was associated through a telegraph relay, and thus a ring-off or clearing-out signal was provided.

The intermediate connecting bars were shortly dispensed with and two cords, each having a plug at one end, were substituted for the two-plug cords. These cords were associated in pairs permanently wired together; a clearing-out drop was permanently wired to each pair, and push-button keys were provided for ringing and listening purposes. Thus the first so-called standard switchboard of about 1884 was evolved.

These standard switchboards were constructed in sections for one operator each and of a fixed capacity. When all of the lines which a section could serve were connected to it, another section was installed, and still others were added as required. The usual practice, as it is to-day, was to place the sections close together, in which case each operator could reach not only the line jacks on her section or position but also those on the sections adjacent. Each section was connected to those sections which the operator could not reach by means of lines which had jack terminals at each end. Such lines were termed trunk lines. Telephone lines terminating on nonadjacent sections were connected together by means of a pair of cords on each section and a trunk line between the sections.

The first exchange systems comprised a single central office. It was early determined that a single central office had a limited capacity from an economic standpoint; therefore as local systems grew in extent other central offices were installed and interoffice connections were estbalished over trunk lines.

6. METALLIC CIRCUITS

It has been previously stated that the early telephone lines used the earth as a part of the circuit. Such lines are known as ground lines and are nearly always more or less noisy. This is partly because of earth currents and partly because of induced currents from other working circuits. Whether such a line will be noisy is partly dependent upon local conditions.

The first plan adopted for avoiding these noises was to provide a group of lines with a wire which was used by all lines of that group in common instead of the earth. This plan, however, did not effectually prevent the several lines in a group from being disturbed by currents from other lines in the same group. It was found by 1884 that the only way to eliminate the disturbances caused by the use of the common ground wires was to make every line a two-wire or complete metallic circuit.

Using two wires per line greatly increased the cost and general adoption was therefore delayed. Those lines which gave the most trouble were first so reconstructed, together with long lines generally. Trouble resulting from earth connection increased when electric railroads and electric light and power circuits were introduced, to an extent which made ground lines impracticable except in more or less isolated rural sections of country.

7. COPPER LINE WIRE

At the time the telephone was invented it was well known that copper was a much better conductor than iron, but only soft copper wire was available. The cost of copper wire of a given size was much greater than the cost of iron wire of the same size, its tensile strength was much less, and it therefore required supports at more frequent intervals. Copper wire was immediately adopted for all inside wiring because small sizes had the necessary conductivity and could be easily supported, but not for outside lines because the combined cost of the wire and the required supports was prohibitive. Galvanized iron wire had previously been used successfully for telegraph lines, and this wire was also adopted for telephone lines.

Iron wire, though galvanized at the start, lacks durability, and as telephone lines steadily increased in length its poor conductivity also became detrimental. On the other hand, the increasing use of the telephone reduced the importance of the greater cost of copper, and a method of hard drawing copper wire was devised which gave it a tensile strength about equal to iron.

Hard-drawn copper wire was first put into telephone service in 1883 for one long line. Its use was so successful that it was soon adopted as standard for all long-line construction and eventually for a large part of the telephone line construction of the country. The result was a great improvement in the service generally and a great increase in the distance over which telephonic communication was practicable.

8. BRIDGING TELEPHONES

During the early development of the telephone the relative arrangement of the signaling and talking apparatus was such that the talking current had to pass through the bell winding. Furthermore, when several telephones were connected to the same line they were wired in series and in a manner similar to that used for telegraph apparatus. The bell windings opposed the talking currents, the series connections were troublesome, and the bells were inefficiently operated.

In 1889 a new ringing system was invented by J. J. Carty in which the bell circuit was made practically independent of the talking circuit. Each bell was wound with many turns of fine wire and was connected directly to the two line wires. The talking apparatus was also connected directly to the two line wires. Such connections have the form of a bridge from one line wire to the other, and hence the use of the word bridging as applied to telephones.

The system was effective because the new bells offered such great opposition to talking currents that the loss through them was practically nil and because such bells could be rung very efficiently. Furthermore, the bells on party lines were thus made independent of each other to the extent that ringing current for any one did not have to pass through all the others.

9. TRANSPOSITIONS

While the adoption of metallic circuits freed the telephone lines from much electrical disturbance, it did not do so entirely. Parallel electric circuits are subject to mutual interference. If telephone lines are paralleled by other types of electric circuits the telephone lines may be made noisy by the other circuits. If telephone lines are paralleled by other telephone lines the conversation on one circuit may be heard more or less faintly on another circuit. In such cases what is heard is called cross-talk.

The explanation of cross-talk disturbances was announced in 1889, and the remedy was promptly applied. Such disturbances are practically eliminated by exchanging the position of the two wires of each line, or transposing the wires, at sufficiently frequent intervals, and by having the transposition points on each line bear a certain definite relation to those on each other line. On open-wire lines transpositions are made at intervals of about 1000 feet. Insulated wires are twisted together so that complete transpositions are obtained every few inches.

The disturbances caused by parallel electric circuits have been the subject of much study. Considerable reduction of these can generally be effected by systematically transposing both the power and the telephone circuits so that a mutual balance between them is obtained.

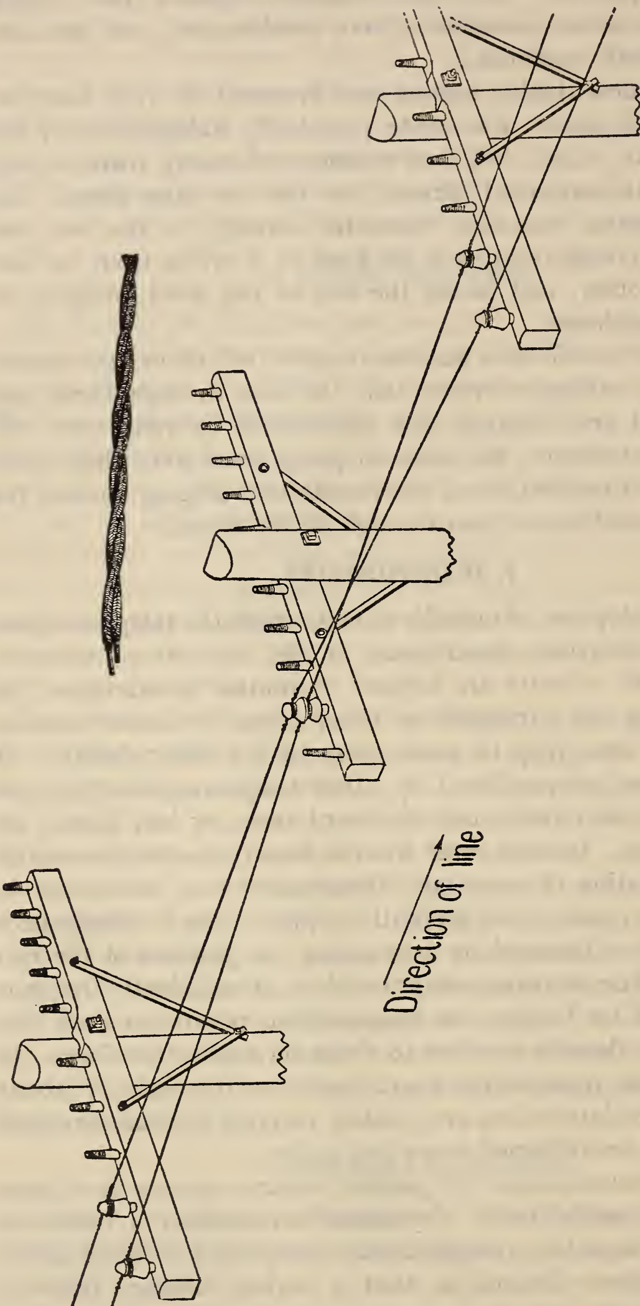

Fig. 3.—*Transposition of line wires*

The larger illustration shows how a single transposition of the two wires of an open wire line is made. One wire crosses over the other at the middle pole where a special insulator is provided to support both wires. Two adjacent spans of wire are involved in making the required exchange of location and hence the distance between transpositions can not be made less than the length of two spans. The smaller illustration shows how the two wires of an insulated-wire line are transposed by twisting the two wires together. Twisted-pair wires are therefore continuously transposed and an exchange of location is effected twice on each complete turn of one wire about the other.

10. SELECTIVE RINGING

The telephone bell which was developed for bridging telephones was of the simple polarized type, which is still used to a large extent in connection with certain types of switching equipment. This bell is rung with alternating current, and it responds throughout a comparatively wide range of frequency. The ringing frequency was originally standardized at about 16 cycles per second, but somewhat higher frequencies are now common.

In the early days of party-line service, stations were always rung according to a code of long and short rings, or of short rings only, to indicate numbers. The parties on the same line called each other without the aid of an operator. This method of ringing is still extensively used, particularly in suburban or rural localities. It is considered objectionable in many localities, because each party must listen to each call in order to recognize his own call, because the code can easily be confused by careless ringing, and because each call notifies all parties on a given line of calls for the other parties.

While the simple polarized bell has no selective characteristics in itself, whereby any one on a given line can be rung independently of the others, it can be used for selective ringing on two-party lines by connecting one bell between one side of the line and ground, by connecting the other bell between the other side of the line and ground, and by ringing each bell via its side of the line and ground. Semiselective ringing for more than two stations on the same line can be obtained with these bells by connecting one-half of the bells between ground and one side of the line, by connecting the other half of the bells between ground and the other side of the line, and by code ringing all of the bells in each group via their side of the line and ground. By this method only those bells on one side of the line are rung at the same time, and the code indicates the one that is called.

Simple polarized bells with selective or semiselective connections as described above were introduced very early in the development of the art, and such use has been continued to the present time in connection with certain types of switching equipment. As full selective operation with these bells was limited to two-party lines and as also there was great need for full selective operation on party lines with more than two stations, many attempts were made to devise bells with selective characteristics. Only two such bells have been standardized and used to any great extent. Both of these are modifications of the simple polarized bell.

One method is to provide a light spiral spring on one side which holds the bell clapper as far as it can go toward that side. Such a bell is known as a biased bell. The clapper can be moved from its normal position by a current in one direction only. If an intermittent current of the proper strength and in the proper direction is passed through a biased bell the current causes the clapper to strike one gong, and the spring causes the clapper to strike the other gong. An intermittent current was used at first, but has been generally superseded by the so-called superimposed ringing current, which is a combination of an alternating and a direct current. This current has a succession of strong pulses in one direction with weak pulses in the opposite direction between the strong pulses. The strong pulses move the clapper against the spring tension, and the weak pulses assist the spring on the return strokes. By this means an even ring is obtained.

The other method is to support the moving parts of the bell by flat springs and to weight the clapper rod. By varying the thickness of the springs and the mass and position of the weights each bell of a set is given a natural period of vibration which materially differs from that of the others. Such a bell is known as a harmonic bell. It gives a maximum response to an alternating current of a particular frequency and practically no response if the frequency differs materially from that to which the bell is tuned. The frequencies commonly used are 16⅔, 25, 33⅓, 50, and 66⅔ cycles per second.

Full selective ringing is obtained on four-party lines by the use of biased bells, by connecting two bells between ground and one side of the line, by connecting the other two bells between ground and the other side of the line, by reversing the connections of each pair of bells on one side of the line with respect to each other, by ringing one pair of bells on opposite sides with a current essentially in one direction, and by ringing the other pair of bells on opposite sides of the line with a current essentially in the opposite direction. Semiselective ringing may be obtained for an eight-party line by adding four more bells connected and rung in the same manner, in which case two bells are always rung at the same time, but the rings must be differentiated by a code.

Full selective ringing on either four or five party lines is obtained by the use of harmonic bells by merely connecting all bells between the two sides of the lines and ringing each bell with current of the frequency to which it only responds. Full selective

FIG. 4.—*A multiple switchboard—magneto type*

The switchboard shown by this illustration is of the obsolete bridging-multiple type which had noncut-off jacks and electrically restored drops. A group of 100 line drops and one row of 12 clearing-out drops are located near the top of the switchboard at each operator's position. The multiple jacks are below the drops. The answering jacks are below the multiple jacks next to the shelf. Plugs and keys may be seen on the shelf ringing may be obtained for an 8 or 10 party line by adding double the number of bells, by connecting half of them between ground and one side of the line, by connecting the other half between ground and the other side of the line, and by ringing each bell with current of its particular frequency via its side of the line and ground.

11. MULTIPLE SWITCHBOARDS

The line capacity of standard switchboards was gradually increased up to the maximum number efficiently served by the average operator, and the 100-line unit became the most common. The actual number of lines connected in any case was, of course, dependent upon the amount of service the lines required.

As a central office grew in size and the number of offices increased, the percentage of the connections which had to be trunked increased; the number of lines an operator could serve was thus reduced, and the trunking problem became a serious one. Trunking methods of the period not only delayed the connections, but they increased the cost of the service and reduced its accuracy.

The solution of the problem was reached by providing all lines with extra jacks sufficient in number and so located as to bring one within the reach of each operator. The extra jacks were called multiple jacks, and a switchboard equipped with such jacks was called a multiple switchboard. Such a switchboard was adopted for the larger central offices in 1887.

The multiple switchboard retained the sectional feature of construction which is so essential from an economic standpoint, but a multiple section was arranged to serve three operators; that is, it had three operators' positions. The line drop and the line jacks (answering jacks) were divided into three groups and located in front of three operators just as they would have been for three one-position sections. The multiple jacks, however, were distributed in a uniform numerical order throughout the section.

As far as a single section was concerned, only the middle operator could reach all of the multiple jacks in the section; but when several sections were lined up together to form a complete switchboard, all operators, except those on the two end positions, had a complete multiple within their reach. When the two end positions of a multiple switchboard were used in the same manner as the other positions, extra multiple jacks were provided, so that the end operators also had a complete multiple within reach.

While, by means of a multiple switchboard, each operator could complete a call with respect to any other line terminating at the same switchboard, she could not see whether the called line was busy or not. This fact led to the development of the so-called busy test, which enabled the operator to obtain this very necessary information.

Early multiple switchboards were equipped with multiple jacks which, when operated by a plug, disconnected the line drop. This involved so-called series wiring through jacks, which, in large boards, required an undesirable number of spring contacts in the talking circuits. This disadvantage was overcome about 1891 by the development of the bridging multiple switchboard, which made use of jacks which did not disconnect the line drop. A new type of line drop was devised which could be permanently connected to the line without detriment and which could be electrically restored to its normal position when a plug was inserted in any jack. By this means the restoring of drops by hand was eliminated. The bridging multiple switchboard with line drops continued as standard for large central offices until the installation of the common-battery system of equipment and operation.

12. OUTSIDE LINE CABLES

As the number of telephone lines increased the running of the necessary wires from the central office to the subscriber stations became a great problem. A few wires on a pole line were a simple matter from a constructional standpoint and were not unsightly; but when the number of wires reached hundreds and thousands, great constructional difficulties arose, and the required structures became intolerable. The natural plan of procedure was evidently to use much smaller wires, to insulate the wires, and to assemble them in bundles with the necessary mechanical and electrical protection; but from the electrical standpoint no satisfactory method of so doing was evident. It required several years of experimental work, tests, and trial installations to develop a successful cable, which was achieved about 1890 and was adopted in 1891.

This cable was formed of comparatively small soft copper wires, each wrapped with dry paper ribbon; wires were twisted in pairs and assembled in layers of spiral form having reversed directions. The whole core thus formed was covered with an air and water tight sheath consisting mostly of lead. This form of cable has been standard up to the present day for outside use.

Lead-covered cables were first supported by poles and elevated railroad structures, where available, but poles were unsightly in

FIG. 5.—*A piece of 1200-pair cable*

This piece of cable was specially prepared to illustrate its construction. At one end the individual pairs of paper-insulated wires are shown in a tangled mass. In practice the wires are grouped and spliced to the wires of smaller cables for terminating purposes. The 1200 pairs of terminals required are arranged in rows, properly numbered, and each pair of wires is cut to the proper length to reach its pair of terminals. The other end of this piece of cable shows the several spirally-applied layers of twisted pairs

Fig. 6.—*Telephone with Blake transmitter*

The transmitter and associated induction coil are both mounted inside the small wooden box placed below the bell box. The transmitter is carried by the hinged cover or door. When this door is open the mechanism is exposed to view and is accessible for adjustment or repair

Fig. 7.—*Telephone with solid-back transmitter*

The transmitter is carried by a movable arm. The associated induction coil is mounted inside the hollow base to which the arm is attached. The face plate of the transmitter carries the entire mechanism and may be easily removed for replacement purposes. Adjustments are seldom required many localities and railroad structures were unsatisfactory because of vibration. The development of an underground system of conduit and manholes for such cables was then begun, and it is now the standard form of outside highway construction for all congested city areas.

At the present time the standard wire used in underground cable construction for subscriber lines measures less than three-hundredths of an inch in diameter, and as many as 1200 pairs of wires may be assembled into a single cable having a diameter of about 2½ inches, which may be drawn into a single subway duct. While underground construction involves large expenditures, the investment required per line is, on the average, less than for bare wires on a pole line, and the annual charges which enter into the service costs are very much less.

13. TRANSMITTER DEVELOPMENTS

The Blake transmitter which was so extensively used in this country up to about 1893 was satisfactory for local service, but attempts to increase its range met with failure. The steadily increasing length of toll lines compelled transmitter improvements, and the so-called solid-back type of transmitter (described in detail under "Telephone plant") was devised and gradually evolved into the present-day transmitters which are manufactured by several companies in forms which differ principally in details.

The solid-back transmitter first replaced the older forms of transmitters at those stations which handled exclusively toll business or a large amount of toll business. The increasing use of the telephone finally demonstrated the fact that every telephone was a potential source of revenue from toll business, and the solid-back transmitter was adopted for practically all telephones.

14. COMMON-BATTERY SYSTEM

Up to about 1891 practically all telephones were operated with local batteries for the transmitter and with hand generators for signaling purposes. The expense of maintaining such equipment was a large portion of the cost of rendering telephone service, the use of the hand generators on the part of the subscribers was erratic, particularly with respect to giving the disconnect signal, and the central office switching systems in use in the large offices involved an undesirable amount of operating labor; hence the incentive for the development of a better system, particularly adapted to large central offices. The development of the common-battery system resulted.

The term common battery implies a battery which is used in common for a group of telephones. As applied to a telephone system it differentiates that system from the system which requires a battery for each telephone. Each central office has its own group of lines, and the scheme of using a common central office battery was very attractive from its inception. This was because of its possibilities as a source of power for the operation of central office signals as well as the possibility of eliminating the local telephone batteries.

Common batteries were first used in connection with small groups of short lines and in central offices for operators' transmitters, but it was several years before the general transmission problem was solved with respect to central offices, which, of necessity, have lines of varying length.

Even the early solution of the problem involved such a radical change from existing equipment that small trial installations were required. The system was first applied to three large central offices during 1896, 1897, and 1898. These installations proved the practicability of the system, and the conversion of practically all other large local central offices to the new system followed within a few years.

The common-battery system as finally developed and installed not only put the telephone transmission on a common-battery basis, but it also put most of the signaling on a new basis. Hand generators were dispensed with, and by means of signal lamps, under control of the telephone hook-switch, the operator was enabled to know at all times whether her attention was required or not. Furthermore, the use of common batteries also resulted in the development of efficient intraoffice and interoffice trunking systems, which included disconnect and guard signals, machine ringing for larger offices, and ringing signals for smaller offices where manual ringing was continued. In general the operating service was materially improved with respect to quality and dependability. Furthermore the number of calls which the operators could handle was greatly increased, and corresponding economies were thereby effected.

Because of the larger investment involved, common-battery equipment did not prove economical for small central offices, which therefore retained the older form of local battery equipment. Modified types of common-battery equipment have,

FIG. 8.—*A common battery*

The large storage battery in the foreground of the illustration supplies current for the transmitters of all telephones connected to the central office in which the battery is located. It also supplies current for most of the signaling circuits associated with the common-battery switching equipment. This battery has eleven cells and an average electromotive force of about 24 volts

however, been developed which are less expensive, and as a result the size of local battery central offices is limited to a few hundred lines.

15. PHANTOM TRUNKS

As early as 1882 schemes were devised for making more electric circuits out of a given number of pairs of wires than there were pairs. Where two similar and adjacent circuits exist, it is possible by the addition of suitable devices called phantom (repeating) coils to establish a third telephone circuit. The third circuit uses the two wires of each of the existing circuits as the respective sides of the third circuit. Each of the side circuits is known as a physical circuit in distinction from the third circuit, which is known as a phantom circuit, probably because it has no individual wires of its own. In order to use two working circuits as the sides of a phantom and without mutual interference, the construction of the circuits must be rigidly uniform, they must be free from all extraneous disturbances, and the method of connecting with the side circuits in order to produce a phantom must be also electrically symmetrical.

These facts were not known, of course, in the early days, and a comparatively long time elapsed before they were known, and another period of development then followed before successful results were obtained. About 1905, phantom circuits became a definite part of the telephone art, and their use has since become fairly general. The cost of a phantom circuit may now be as low as one-tenth of the cost of one of its side circuits.

16. LOADING COILS

Up to 1902 the maximum length of so-called standard cable through which telephone transmission was considered commercially satisfactory was about 32 miles. Satisfactory transmission could be obtained for a greater distance by using larger cable conductors than those of standard cable, but the gain in many cases would not justify the increased cost. For these reasons the amount of cable that could be used was very restricted. Systems were so designed that the maximum electrical opposition to transmission for any connection which might be established would not exceed the equivalent of 32 miles of standard cable.

In 1899 Michael I. Pupin announced a practical method of counterbalancing the electrical property of telephone lines most detrimental to telephone transmission. Between 1899 and 1902 the practical application of Pupin's method was worked out in detail. In brief, it consists of connecting coils of insulated copper wire on ring-shaped cores of soft iron wire, into each circuit and at certain substantially regular intervals. These devices are called loading coils. A loading coil has a separate winding for each side of the line circuit, and the coils are connected in series with the two line wires. Both the electrical constants of the loading coils and their spacing are determined from the electrical characteristics of the line to be loaded.

Loading coils were applied to toll lines which had the greatest need for relief, and the first application had the practical effect of doubling the range of transmission through standard cables. Other applications have attained even better results. Applications to aerial wire lines were delayed by the need of minimizing the variation of the electrical properties of such lines, but a fair degree of success has been obtained.

While the use of loading coils has been practically confined to trunk-line circuits, it has made possible a much greater use of unloaded cable in local exchange circuits. Thus very considerable economies in line construction have thereby been effected, and the dependability of the line plant has been increased. The use of loading coils alone on toll lines again extended the range of the telephone transmission, and the use of both loading coils and large cable conductors made possible all cable toll lines between Boston, New York, Philadelphia, and Washington.

About 1911 the problem of loading phanton circuits was solved, and so successfully as to extend the range of telephone transmission in this country over a distance as great as from New York to Denver, or a distance of over 2000 miles.

17. AUTOMATIC SWITCHING SYSTEMS

Many inventors have labored to devise a system in which machines would take the place of the operators. Only a few years after the invention of the telephone, patents were issued for devices having this end in view. The first successful system originated in the invention of an automatic switching machine by A. B. Strowger in 1891.

While the basic plan of automatic switching was practicable for small communities, it required many years to develop it into a system which would meet the service requirements of a large city. Also, while the basic device was workable, it required association with many other devices in order to render modern service.

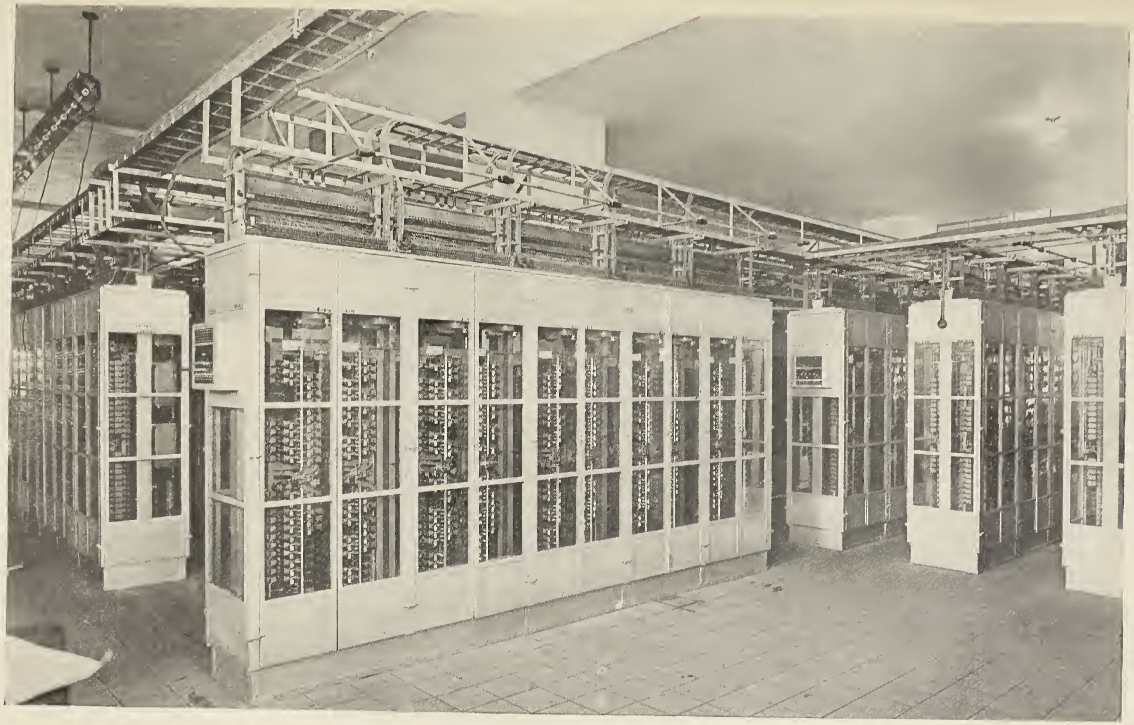

Fig. 9.—*Automatic switching equipment*

This illustration is here given merely to show the general arrangment of the switching equipment in a central office. The arrangement is such that only a small portion of the equipment of a large office can be shown by a single picture. The devices shown by this view are known as line-switches of the plunger type. These are inclosed in dust-proof cases made of steel and having glass panels. Operation may be observed without opening the doors

FIG. 10.—*Loading coils on an aerial line*

The coils used for loading purposes are placed in iron pots, filled with insulating compound and closed with water-tight covers. The illustration shows several of these iron pots attached to a substantial double pole structure. The coils are connected to the associated line wires with short lengths of insulated wire. (See page 27.)

FIG. 11.—*A repeating amplifier bulb*

This is an evacuated bulb containing a plate, a grid, and a filament. The bulb is mounted in a socket to facilitate its replacement and its connection to the equipment by means of which it is energized and associated with a line circuit. The associated equipment known as a repeater unit is shown by Fig. 48

About 1905 the system was redesigned on a common-battery basis, and subsequently the use of the earth for signaling purposes was abandoned. The automatic system of switching then became a real competitor of the manual system of switching from the standpoint of ability to render satisfactory service. At the present time it is being extensively applied.

18. SEMIAUTOMATIC SWITCHING SYSTEMS

During the period of development of the automatic switching system several semiautomatic systems were also developed, but comparatively few installations have been made. As its name implies, a semiautomatic system is partly manual and partly automatic in operation. All calls are received by operators, but the switching operations necessary to the establishment of connections are performed by automatic equipment under control of the operators. The distribution of all calls among the operators is a notable feature of semiautomatic operation.

19. RECENT DEVELOPMENTS OF THE MANUAL SWITCHING SYSTEM

Extensive developments of the common-battery manual system have been made in the past few years for the purpose of increasing the traffic-handling capacity and the quality of operation. These results are attained by the addition of electromechanical devices which bring each call within the reach of more operators, which give certain operations precedence over others, and which materially lessen the labor involved in the establishment of a connection by performing certain operations without the operator's assistance. Each of these developments will be considered in the section on the "Telephone plant."

20. REPEATING AMPLIFIERS

Other things being equal, the longer a telephone line the weaker the transmission will be. In all stages of telephonic development there has been a distance limit beyond which it was not commercially practicable to give telephone service.

From the early days of the telephone, inventors have endeavored to extend the distance limit by associating one telephone circuit with another in such a manner that the weak currents in one circuit would control a stronger current in another. For telegraphic purposes this was easily accomplished by means of a device called a repeater, but the telephone problem was a much more difficult one for the reason that the stronger current must be practically identical in form to the weaker one.

All early telephonic devices for repeating purposes were electromechanical devices. They did act as amplifiers, but they also introduced distortion to a serious degree. Even the best of them had a limited commercial application.

The successful repeating amplifier of to-day had its origin in an invention of a particular form of wireless telegraph detector by Lee DeForest about the year 1900. It was called the audion. Formal announcement of this invention was made in 1906. It was later recognized by telephone engineers as comprising the elements of a telephone repeating amplifier, and a particular form of this device was subsequently developed for this purpose.

In appearance this device is like an ordinary electric lamp, but the bulb contains a plate and a grid in addition to a filament. It acts as an electric valve under control of the weaker current. Connection to the two telephone lines is made by the aid of circuits, including other devices which, taken altogether, make up the complete repeating amplifier. Although the audion is itself a one-way device, successful two-way repeater circuits have been developed.

The practical application of this repeating amplifier has been eminently successful and at once extended the range of telephonic communication very greatly. Commercial transcontinental telephone service has resulted, and large economies in telephone construction have been effected by the practicability of using smaller conductors.

21. SIMULTANEOUS TELEPHONY AND TELEGRAPHY

In the early days the demand for long-line service was small, and under even the best conditions the wires were idle for a large part of the time. It was natural that an additional source of revenue should be sought by using the wires for other purposes.

While it was early known that the characteristics of the currents used for telegraphy and telephony were different, it was some time before practical devices were produced which would permit the flow of one current and stop the flow of the other in a circuit. The production of such selective devices led to their practical application for the simultaneous use of a line for telegraphy and telephony.

In brief, the arrangement is such that only the line wires are used in common. The telegraph apparatus is connected to the line through devices which will not permit the flow of the telephone current to that apparatus, and the telephone apparatus is connected to the line through devices which will not permit the flow of the telegraph current into the other apparatus. In this manner all mutual interference is prevented.

Long telephone lines are, at the present time, very generally used for simultaneous telegraphy and telephony, but the telegraphic use is generally restricted to leased-line service. This is for the reason that telephone companies do not usually handle general telegraphic messages. The additional revenue derived from the telegraphic service has been helpful in the extension of long-distance telephony.

22. RADIOTELEPHONY

Radio or wireless telephony passed from the experimental stage about the year 1906, when a distance of 60 miles was successfully covered. The range of reliable communication was increased to about 500 miles in the next 10 years. Naturally war requirements greatly accelerated the development of this art so that trans-Atlantic telephone communication was actually accomplished in 1916 and shortly after even communication from Arlington to Hawaii, a distance of over 5000 miles.

Owing to atmospheric disturbances known to radio workers as "static" and heard in the telephone receivers as hissing and crashing noises which interfere with the reception of signals, radio communication has been greatly impaired. Recent developments, however, have brought the effects of these disturbances largely under control so that the range of communication is being extended and many other features incident to efficient communication introduced.

The successful transmission of signals through space by electrical means requires the use of alternating or oscillating electric currents ranging in frequency, or the number of oscillations per second, from 20 000 to several million.. This current is transferred to a wire or antenna, one end of which is generally connected to the earth and the other end elevated into the air. Some high-power stations have antennas which reach heights of 600 feet and more.

The electrical energy present in the antenna is transmitted or radiated through space in the form of waves, popularly known as radio waves, and these radio waves arriving at the receiving antenna produce therein currents which correspond to those in the sending antenna but are very much less in magnitude. The electric circuits, which are associated with the antenna at the receiving station, are arranged so that they may be adjusted or tuned for maximum response, and means are provided for amplifying the received current and changing it into a form capable of actuating a telephone receiver, thus transforming the electrical energy into audible sound.

In radiotelegraphy signals are produced by varying the antenna current at the sending station in accordance with a telegraphic code so that the signals received are sounds of long and short duration. The oscillating currents used in the early days of radiotelegraphy were of an intermittent and irregular type, but later means were devised for generating an oscillating current of unvarying strength. This development marked the beginning of radiotelephony, for such a uniform oscillating current may be made to vary in magnitude in correspondence with the current variations produced by speaking into a telephone transmitter. The high-frequency oscillating current may be regarded as the carrier of the variations or modulations produced by the voice speaking into the transmitter at the sending station. The radio waves produced by these carrier currents, and known as carrier waves, arriving on the antenna of the receiving station are transformed, and the voice modulations which have been impressed on these carrier waves are reproduced in the telephone receiver and heard by the listener at the receiving station as speech.

The necessity for tuning the electric circuits at the receiving stations makes the receiving station selective for wireless waves and carrier waves of a particular frequency and renders the receiver insensitive for waves of other frequencies. This tuning feature therefore makes it possible for radio communication between two stations to be carried on without interference from other stations.

23. MULTIPLEX TELEPHONY

In the latter part of the year 1918 a successful service trial was made of a system of multiplex telephony which utilizes high-frequency alternating currents as the carrier currents to be modulated by the voice speaking into the transmitter. In such a system the electrical energy is transmitted over an ordinary telephone wire, and communication between any pair of stations is effected by tuning them selectively, as in radiotelephony; that is, either of a pair will respond to the other but not to any other stations of the system. In this manner it is made possible for a number of conversations to take place simultaneously over the same wire without interfering with one another. In practice metallic circuits are required to prevent inductive disturbances between different circuits.

At the present time three single circuits are in commercial multiplex use. One runs from Baltimore to Pittsburgh, provides the equivalent of five distinct trunk circuits (as well as several telegraph circuits), and carries Washington-to-Pittsburgh business. The five multiplex circuits (equivalents) are continued from Baltimore to Washington by five separate metallic circuits. The other two circuits, respectively, run from Boston to Bangor and from Harrisburg to Chicago.

III. TELEPHONE PLANT—EQUIPMENT OF MANUAL SWITCHING SYSTEMS

Manual switching is done by means of equipment which requires the services of switching employees known as operators. While most of the work is done by hand, many of the detail operations associated with switching in large central offices and even in many small central offices are performed automatically, and the degree of such automatic operation is being steadily increased.

A very large percentage of the switching equipment in this country at the present time is of the manual type. As the telephone art has been mainly developed with manual switching equipment, it naturally follows that such equipment has been designed for rendering all classes of service.

1. LOCAL EQUIPMENT

That portion of the equipment by means of which local service is rendered is termed local equipment, or sometimes local-exchange equipment. On account of the volume of local service rendered the local equipment constitutes the major part of the total equipment. A particular local equipment may wholly comprise or it may include rural-line equipment, which is designed especially for rural-line service.

Each subscriber or patron must be provided with an assembly of apparatus which is called a telephone set or, for brevity, a telephone. An installed subscriber telephone is known as a subscriber station. An installed public telephone is known as a public station. Each telephone must have a line by means of which connection can be established from one telephone to another. Each telephone line must terminate in a central office, at which point switching facilities must be provided for connecting lines together. Naturally a central office is located centrally with respect to the stations it is to serve.

There are two distinct types of telephone station and central office equipment, each of which, unfortunately, is known by more than one name. The common designations, magneto equipment and common-battery equipment, have been selected for use in this publication. Magneto equipment is also known as local-battery equipment. Common-battery equipment is also known both as central-energy and as relay equipment. Magneto equipment requires the use of a small talking battery at each station and also a special device for signaling the central office. Common-battery equipment is supplied with electric current from one large battery, which is located in the central office and which serves both for talking and for signaling the central office.

TELEPHONE STATION EQUIPMENT

Each telephone must comprise the requisite apparatus for enabling the calling party to signal and to be signaled by the central office; to register the called number at the central office by talking or by mechanical means; to talk to the called party; and to signal the central office to the effect that disconnection is desired.

Signaling Equipment.—With magneto equipment the act of signaling the central office is accomplished by means of a hand generator, also called a magneto, which produces an electric current for the operation of a central office signal. The hand generator may also be used to signal other stations on the same line. With common-battery equipment the central office is signaled by merely lifting the receiver from the hook, because the switch which is associated with the telephone hook closes the circuit of the central office signal.

All telephone stations are signaled by means of bells, which are regularly a part of all telephone station equipment. Bells may be of the simple polarized type, the biased type, or the harmonic type, depending upon whether the ringing is nonselective or selective and upon the type of switching equipment with which they are associated. The essential characteristics of these bells have been considered in the section on "Development of the art."

The simple polarized bell is regularly used in connection with magneto switching equipment for individual lines and code-ringing party lines. The simple polarized bell is not used to any great extent with common-battery switching equipment. It has been

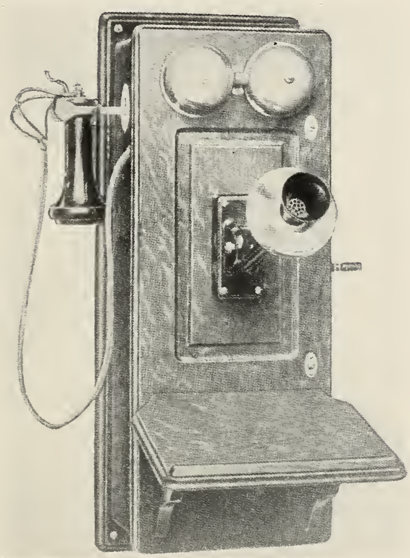

FIG. 12.—*A magneto telephone*

This is a complete set arranged for mounting on a wall. The hand generator, bell ringer, hook-switch springs, induction coil, and battery are placed inside the wooden box. The mounting includes a writing shelf

FIG. 13.—*A common-battery telephone*

This is a complete set arranged for mounting on a wall. It is more compactly arranged than a magneto set and comprises less equipment. The bell ringer, hook-switch springs, induction coil, and condenser are in the small box beneath the writing shelf

very generally superseded by the biased bell, both for individual lines and for two-party lines, upon which the stations are usually rung selectively by virtue of selective connections. All common battery lines are subject to variations in current strength, incidental to switching, which in many cases will cause the simple polarized bell to lightly tap, and thus give false signals. The use of the biased bell eliminates tapping to a great extent. Another reason for using biased bells instead of simple polarized bells is that economy can be effected. In those central offices equipped for selectively ringing four-party line stations having biased bells the apparatus used for ringing one of the party-line stations may be used for ringing individual-line stations as well.

With magneto equipment the disconnect signal is given to the central office by again operating the hand generator. With common-battery equipment the act of replacing the receiver on the hook causes the hook switch to open the line circuit and thus to signal the central office to the effect that disconnection is desired. In both cases, however, a different signal is operated from that which received the original call.

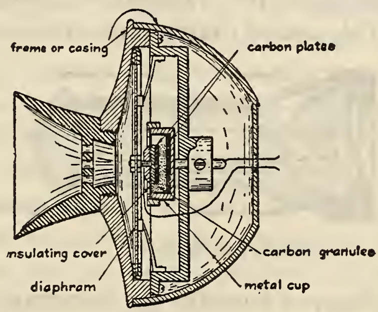

FIG. 14.—*Transmitter*

TRANSMITTER.—The transmitter is the device into which the user talks and by means of which the voice is associated with an electric circuit. It has a thin metal disk, called a diaphragm, which is supported at its edge by the frame or casing of the device and which is attached at the center to a small carbon plate. The carbon plate is inside of a metal cup having a flexible insulating cover through which the attaching pin passes. The metal cup also contains a second carbon plate which is carried by a metal plate and a post passing through the rear face of the metal cup. The space between the carbon plates is about three-quarters filled with carbon granules, which are kept from contact with the metal cup by suitable insulating material. The metal cup, together with the contents, is called the transmitter button.

The transmitter button is connected into a battery circuit when the receiver is off the hook and the electric current passes through the button, that is, from one carbon plate to the other by way of the carbon granules between the plates. The carbon granules make electrical contacts with each other, but these contacts offer very appreciable opposition to the passage of the current, and the degree of opposition is dependent upon the contact pressure.

When a person talks into a transmitter the voice of the speaker causes a disturbance of the air which is in the immediate vicinity of the diaphragm and the air in contact with the diaphragm exerts a varying pressure, which corresponds to the speech sounds. The diaphragm is thus caused to vibrate and in so doing varies the contact pressure exerted by one carbon granule on another. The varying pressure on the carbon contacts varies the opposition or resistance which the button as a whole offers to the electric current. The current is thereby varied in strength as the air pressure on the diaphragm varies.

Receiver.—The receiver is the device by means of which the user hears the transmitted speech of the other party. It also has a thin metal diaphragm which is usually made of soft iron. The diaphragm is supported at its edge by the shell or casing of the device, and its center is directly in front of a small electromagnet. The electromagnet is also supported by the shell, and its pole pieces are rigidly held close to but not touching the diaphragm. All receivers require an initial magnetization. This may be furnished by means of permanent magnets, as illustrated in the figure, or by means of the current which is normal to a common-battery line.

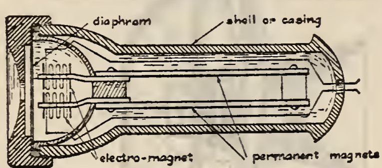

Fig. 15.—*Receiver*

When a current which has been caused to vary in strength by a transmitter passes through the electromagnet of a receiver, the electromagnet exerts a correspondingly varying pull on the diaphragm. Thus the receiver diaphragm is caused to vibrate. The vibrating receiver diaphragm causes a periodic vibration of the air in its immediate vicinity which corresponds to the original vibration of the air caused by the speaker's voice in the immediate vicinity of the transmitter. This vibration of the air at the receiver is heard as speech when it falls upon the ear of the listener.

Protector.—All telephones which are served by outside lines which can in any manner come into contact with electric light or electric power lines, or which are subject to lightning discharges, are protected by a device called a protector. A protector usually comprises two fuses, one for each line wire, and two small carbon-block air-gaps leading to earth, one for each wire, by means of which high-pressure electric currents can pass through the fuses and air gaps directly to the earth. The fuses are usually mounted in insulating tubes and the carbon blocks are covered with a metal or glass cap.

For magneto telephones another device known as a heat coil is often included in the protector. A heat coil is connected between each line fuse and the telephone. It operates on a weak current in a definite length of time and in such a manner as to open the line circuit to the telephone before damage to the bell or generator can result.

Inside Wiring.—The wiring between the telephone and the point of entrance of the outside wires is known as inside wiring. It includes wiring to earth for a ringing ground and for the protector, if one is required. The outside wires enter the building but they terminate just inside on the protector, if there is one, or on a connecting block or at a direct splice to the inside wires.

Inside wiring is done with twisted insulated wire, unless a ringing ground is required and a protector is used. In such a case triple-conductor insulated wire is used from the telephone to the protector where connection to ground may be obtained for ringing purposes. When a ringing ground is required and no protector is furnished a single insulated wire is run from the telephone to the earth. Electrical connection to earth is usually made by attachment to a water or gas pipe or to a rod which is driven into the ground.

Inside line wires and ringing ground wires are attached directly to the building and are run in the most inconspicuous manner possible and clear of all other electric wires, pipes, and metallic surfaces. Should it be necessary to cross any of these, additional insualtion is provided for the telephone wires. Protector ground wiring is usually done with a larger and more heavily insulated wire which is supported entirely by insulators and run to earth by the most direct route available.

Rural Equipment.—Rural lines have two prominent characteristics. One is their length, and the other is the number of stations which may be served by each line. Practice varies widely, but rural lines will probably average 8 miles in length and 10 stations per line. Lines having a greater length than 15 miles and more than 20 stations are unusual. As commonly constructed, rural lines have a comparatively high resistance.

Long rural lines with many stations are usually provided with magneto equipment, and frequently this equipment is especially designed to meet the conditions by including very high resistance bells which require a weak operating current, and special hand generators which are able to ring properly the many bells simultaneously. Some stations are provided with push-button keys which are used in conjunction with the generator to signal the central office only.

Incoming calls, which are usually rung according to a code, are often misunderstood, and the wrong party answers and may remain on the line; that is, keep the receiver off the hook for listening purposes. Such use of an ordinary telephone seriously interferes with the ringing of the other stations and also uses up the local transmitter battery unnecessarily. It is frequently the practice to so arrange the bell circuits as to minimize the effects of listening on the line and also to provide latching devices for the hook which allow the hook to rise a sufficient distance to close the receiver circuit but not the transmitter circuit until the latch is released by hand.

Extension Equipment.—At subscriber stations a need frequently exists for more than one bell in order that incoming rings may be heard at points more or less distant from the telephone. Separately mounted bells are used to meet this need. Such bells are called extension bells. Loud-ringing extension bells may be furnished for noisy locations.

Another frequent need is for additional service stations in connection with a single line when the one line is sufficient for the total service. Each additional telephone, when so installed, is called an extension station. It may or may not be provided with a bell. Additional needs are met by the provision of apparatus for switching in and out of service both bells and telephones; also for talking and signaling directly between telephones.

Public Telephone Equipment.—Public telephone stations require special equipment in addition to the regular telephone equipment. Signs are provided for the identification of such stations, and coin-collecting devices are very generally used. Booths which are comparatively soundproof are frequently provided, and at those locations where the demand for public telephone service is especially great, as in large railroad stations and public buildings, special switching equipment is often furnished, by means of which the several telephones are switched in and out of service and the service supervised by attendants.

Fig. 16.—*A private branch exchange switchboard*

This is a switchboard of the common-battery type having a capacity for forty lines. The white dots on the vertical face of the switchboard indicate the glass caps covering line lamps. Above each line lamp is a line jack. This switchboard is equipped with eight pairs of cords. Each pair of cords has a supervisory lamp, a listening key, and a ringing key. These are located on the horizontal shelf in alignment with their associated cord pairs. A small switchboard of this type is usually furnished with battery current from the central office by means of wires used only for this purpose. This current supply is not used, however, for talking on central office connections. These obtain current via the central office lines. Ringing current may also be furnished by means of special wires from the central office. This switchboard has a hand generator which may be used as an emergency source of ringing current

Coin collectors are arranged for collecting either one or more sizes of coins and are of two general types. The prepayment type requires the deposition of a coin in order to call the operator; the postpayment type does not. Both types of collectors are arranged so that the operators are informed by tone signals of the value of each coin deposited. The prepayment type of coin collector is also arranged so that the operators can either collect or return the deposited coin or coins as occasion may require.

Private Branch Exchange Equipment.—A business concern requiring a number of telephones for general service may also require them for private service; that is, for connection with each other. To meet this need economically switching equipment is furnished and usually maintained by the telephone company. Such an installation is known as a private branch exchange.

The line capacity of the switching equipment for private branch exchanges ranges from about five lines to several thousand lines. In general the design and operation of the switching equipment is similar to those of a central office having a corresponding size. The type of equipment used in any case is, however, usually the same as that of the associated central office. It is thought that the following description of central office equipment will suffice for an understanding of private branch exchange equipment operation.

CENTRAL OFFICE EQUIPMENT

Small central office equipments are such that special buildings are not required, but large equipments require buildings which are especially designed for the purpose. The most important requirements relate to permanency, strength, arrangement of floor space, and the reduction of the fire hazard, both external and internal.

A central office is both a terminal center and a switching center for all of its associated telephone lines. Special equipment is required for the termination of these lines, the number of which may be very large. Each office is provided with the necessary switching equipment, which may be of the magneto or of the common-battery type. Usually the central office is also the power center, the maintenance center, and the information center for all of its telephone stations.

In addition to the above a central office is usually provided with equipment for the comfort and convenience of employees.

In some cases it is also provided with equipment for the instruction of employees.

That portion of the central office equipment which requires the services of operators is usually separated from the remainder. It is placed in an operating room which is, to a certain degree, isolated from outside disturbances and which is usually well lighted and well ventilated.

To describe only the manual switching equipment, which is most common, even in the general manner which is consistent with the scope of this publication, would fail to give the reader a correct understanding because of the rapidly changing status of this branch of the art. For this reason manual switching equipment will be referred to under two headings which distinguish between that which is commonly used and that of the newer types.

Line Terminal and Protector Equipment.—Each telephone line must end in certain central office equipment for signaling and switching purposes. Each central office therefore has inside lines provided with line equipments to which the outside lines can be connected. It is necessary that facilities be provided so that any outside line may be connected with any inside line and for this purpose terminals are required for both outside and inside lines. These terminals are usually mounted on a steel frame, known as a main distributing frame, which is so constructed as to facilitate the connection of any outside line to any inside line.

All outside lines which may be in any manner subject to electrical hazards are provided with carbon-block air-gaps leading to earth and heat coils, which do not essentially differ in operation from those used for telephone stations. Line fuses are seldom required. These protectors are compactly mounted on steel plates which are attached in the vertical position to one side of the main distributing frame. Each plate may carry from 100 to 400 protectors.

Terminal blocks carrying rows of metal terminals usually having a capacity for 20 lines each, are attached to the other side of the main distributing frame. These may be attached either singly in the vertical position or in the horizontal position so as to form continuous rails. Both protectors and terminal blocks serve as terminals for lines. In some cases the protectors and in other cases the terminal blocks are used for outside line terminals. Outside and inside line terminals are cross-connected with short lengths of flameproof wire sometimes known as jumpers.

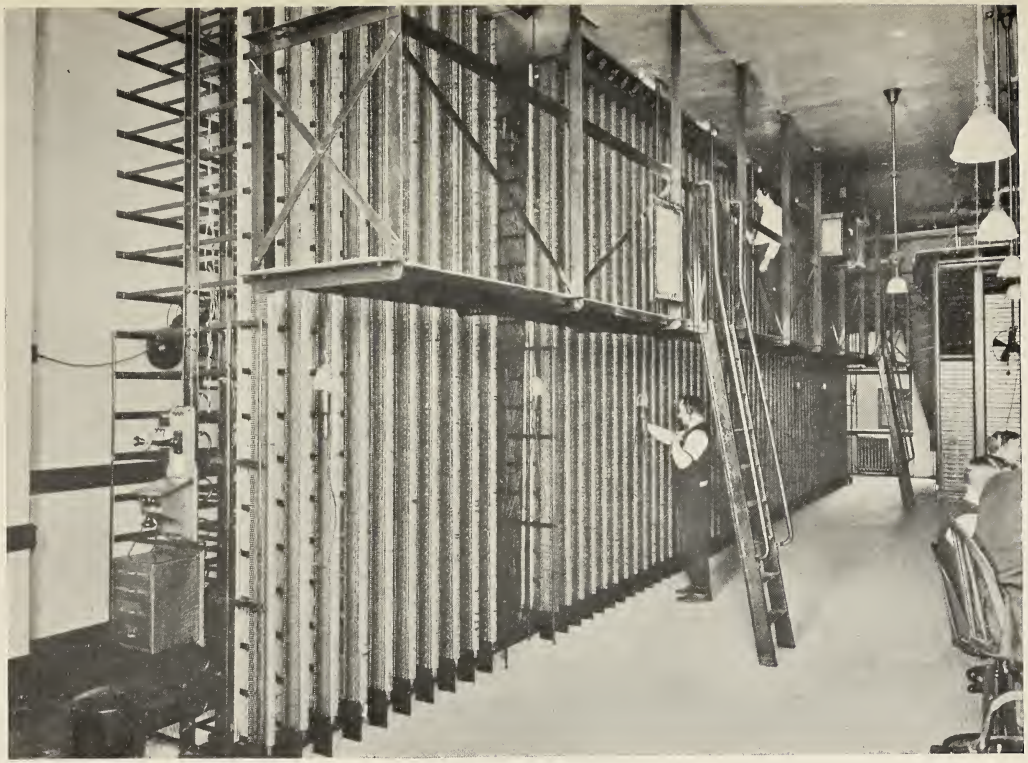

Fig. 17.—*Central office protectors*

The protectors are mounted close together on the long vertical plates attached to the main distributing frame. Each plate carries protectors for 400 lines. Every fifth protector is marked to indicate the conductor numbers. The cable numbers are on the number board above the plates. The line cables reach the protectors through a cable slot in the floor. The terminal blocks are on the rear side of the frame and none are shown

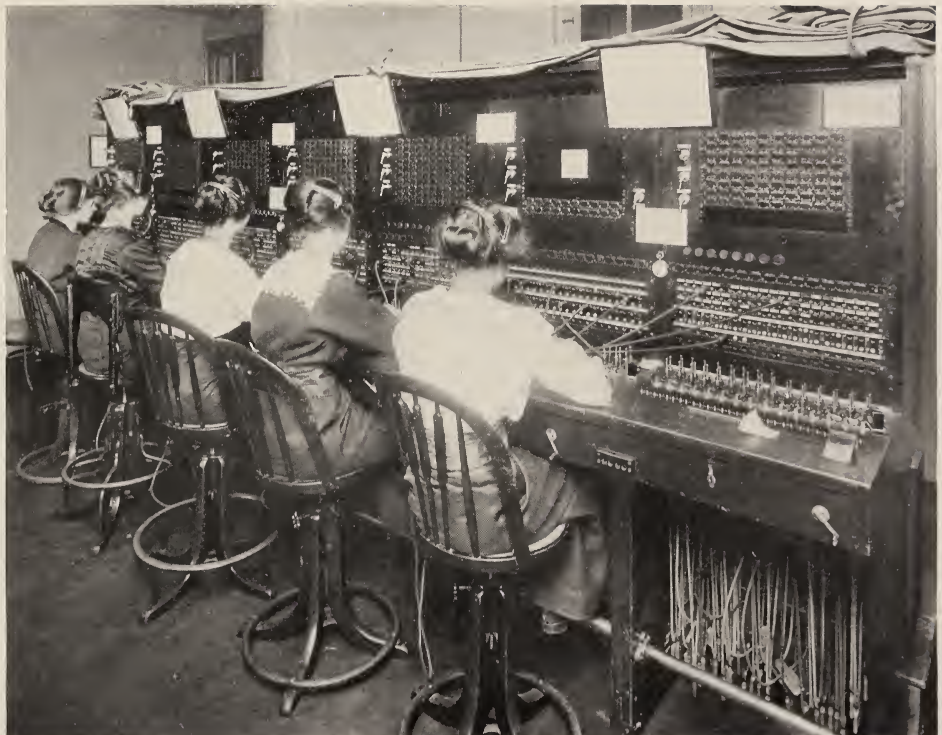

FIG. 18.—*A magneto switchboard*

This switchboard has seven one-position sections. The two at the right are for trunk lines and the other five for station lines. The line drops are near the top. The jacks are near the keyboards. The clearing-out drops are just above the jacks. Eight transfer-trunk signals may be seen on the first section just above the clearing-out drops. The back row of plugs and cords are for these trunks. Each of the fifteen pairs of cords has a listening key and two ringing keys

Switching Equipment—Commonly Used.—The primary function of the switching equipment is the interconnection of lines, but it has certain associated functions of equal importance. By means of this equipment the central office is signaled, talking connections are established, lines are tested for busy conditions, called stations are rung, calls may be registered, and other subordinate switching operations are accomplished. Switchboards are provided for the use of the switching operators who perform the switching operations.

The Switchboard.—The general form of a telephone switchboard will be evident from an inspection of the several illustrations. The two features with which the following description is concerned are the vertical face and the horizontal shelf in front of which the operators are seated. That portion of the apparatus to which the operators must have access is mounted in the face or on the shelf of the switchboard; other portions which are closely associated with this apparatus are mounted inside of the switchboard, and the remainder is mounted on suitable steel frameworks located near the line terminals.

Small switchboards are constructed of wood only, but large switchboards, which carry a comparatively heavy load of apparatus and cable, usually have a steel frame which is inclosed by a wooden casing. The switchboard as a whole is divided into sections, each of which is arranged for one, two, or three operators, depending upon the type of switchboard used. Small offices usually have one-position sections. Multiple trunk boards usually have two-position sections. Multiple switchboards at which calls are received are usually arranged for three operators per section. The several sections of a switchboard are placed end to end so as to form one continuous switchboard.

The switchboard shelf has a boxlike construction, and each operator's position is provided with a hinged cover on which the keys, and usually the supervisory signals, are mounted. Each such cover is known as a keyboard. The apparatus is mounted and wired on the underside, and the operating portions project above. Between the keyboards and the face of the switchboard is the plug shelf, which is usually faced with leather or fiber to deaden the sound of and to protect the wood from dropping plugs.

Both the height and width of a switchboard section are limited by the reach of the operators while seated. Whether a switchboard has one, two, or three position sections, efficient operation requires that an operator shall be able to reach all of the lines on the two adjacent positions, as well as those on her own position. On a multiple switchboard each operator must be able to reach the most distant jack of the multiple associated with her position. The length of a switchboard as a whole is dependent upon the number of operators required.

The number of lines which can be brought within the reach of each operator is limited by both the space within her reach and the minimum practical dimensions of the line signals and jacks which must be mounted in that space. Present-day standards of design limit the number of multiple jacks per section to approximately 10 500, which number is therefore considered as the maximum line capacity of a single multiple switchboard.

Line Equipment.—If the equipment is of the magneto type, the operators are usually signaled by electromechanical devices called drops, which are operated by the hand generators of the telephones. If the equipment is of the common-battery type, the operators are signaled by small electric lamps. Each line is provided with a line relay which upon operation closes the lamp circuit.

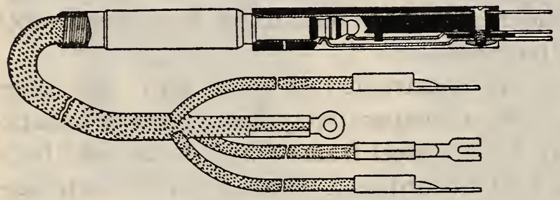

Fig. 19.—*A plug and jack connection for a three-conductor cord*

Both line drops and line lamps are so associated with a bell circuit through a switch that when desired a call will also be indicated by the ringing of the bell. The bell is used during late night hours; hence its name—night bell.

Lines are connected together by flexible cords made of braided cotton and cotton twine and containing stranded tinsel conductors which are insulated with silk. Each cord ends in a so-called plug, which has a metal end piece for each conductor of the cord. The plugs fit into sockets called jacks, which have metal springs or sleeves with which the metal end pieces of the plugs connect. Each telephone line has at least one jack, by means of which originating calls are answered. This jack is known as an answering jack. In small central offices answering jacks are also used for connection purposes when the lines are called, but in large central offices it is usual to provide each line with other jacks for this purpose. These other jacks are known as multiple jacks, and as many such are provided for each line as may be necessary to bring one within the reach of each operator who may have occasion to call stations on local lines.

Drops, line lamps, answering jacks, and multiple jacks are all mounted in the face of the switchboard. With magneto equipment the answering jacks may or may not be closely associated with the line drops; practice differs in this respect. In many cases the drops are restored by hand; and in other cases each answering jack is located directly beneath its line drop, and the insertion of the plug mechanically restores the drop. With common-battery equipment each answering jack is usually located directly above its line lamp. The insertion of a plug in the answering jack, or in any multiple jack of a line, results in extinguishing a lighted line lamp.

Although in some localities single-wire lines are used, switchboards always have two wires per line for the talking circuit. On magneto lines where drops are used for line signals it is the usual practice, for transmission reasons, to so arrange the equipment that the insertion of a plug in a jack cuts off the drop from the line. On common-battery lines where relays are used to control the line lamps these relays are also cut off by the act of inserting a plug into a jack. In small boards cut-off jacks are used for this purpose, but in large boards cut-off relays are used, and these are wired into a third wire circuit which is associated with each inside line and each cord circuit.

Drops are mounted on plates which are attached to the switchboard. They are always numbered and may also be marked to indicate the class of service to which the associated line is entitled. Line lamps are set into sockets which are mounted in strips of 10 or 20, and each lamp is covered by a glass cap having a metal ring which fits into the socket. The caps diffuse the light, keep out dust, and are so marked as to identify the class of service to which the associated line is entitled. With magneto equipment the answering jacks are either mounted singly in panels or are attached to the drop mounting. Multiple jacks are not used to any great extent with magneto equipment. They may be mounted singly or in strips. With common-battery equipment answering jacks are always mounted in strips, and the number per strip corresponds to the number of line lamps per strip. Multiple jacks are usually mounted in strips of 20. Both answering and multiple jacks bear line numbers, but answering-jack numbers are usually on detachable plates, so that any jack can be given any number.

The face of a common-battery switchboard is divided into vertical panels to facilitate the mounting of the strips of lamp sockets and jacks. Each panel of line lamps, or in some cases each group of panels associated with each operator's position, is provided with a pilot lamp which is so associated with all of the line lamps in each group that the lighting of any line lamp will cause the pilot lamp to light also. Pilot lamps are much larger than line lamps and are set into individual sockets which are usually mounted in the rail below the panels. The sockets carry glass caps of corresponding size. When a line lamp is extinguished by the insertion of a plug in a jack, the associated pilot lamp is also extinguished if no other line lamps in the same group are lighted.

Reference has been made above to at least one line lamp and answering jack for each line. One line lamp and answering jack per line is the usual practice if the switching equipment is of the common-battery type, but in those cases where space is available two or three line lamps and associated answering jacks may be provided. These are known as multiple line lamps and multiple answering jacks and are always placed in different sections of the switchboard. Their purpose is to bring each call within the reach of more operators.

In certain cases where space is available in the face of the switchboard, because the ultimate capacity of the central office has a comparatively small limit, jacks for answering purposes only may not be provided. The line lamps are then associated with multiple jacks which are used for both answering and calling. The line lamps may also be multiplied with the multiple jacks, in which case the associated multiple jacks may be considered as multiple answering jacks.

In a few cases party lines have been provided with double sets of multiple jacks. For two-party line service such an arrangement gives a jack for each station. Each pair of line wires is connected in the usual manner to one set of multiple jacks and reversed where connected to the other set of multiple jacks. By this means two-party selective ringing service may be given by associating a single ringing device with the proper jack.

Message Registers.—A device known as a message register is commonly used in large central offices having common-battery equipment for registering calls originating at stations having message-rate service on individual lines. A message register is

FIG. 20.—*A group of message registers*

The illustration shows only the face of the registers as they appear when looking through a glass panel door of the steel frame on which they are mounted. The indicated numbers are read at regular intervals and the number of calls registered since the last reading is obtained by subtraction

essentially an electrically operated counter which on operation changes the number which it displays to a number which is larger by one. Registers are usually mounted on framework in a glass and steel cabinet having doors, which are kept locked and are accessible only to authorized persons. One register is associated with the third wire of each line and bears the line number. The movements of the registers are controlled by the operators.

A Operator's Position Equipment.—An operator who answers originating local calls is known as an *A* operator. Each *A* operator has as many pairs of switching cords as she can efficiently use. With each pair are associated the necessary supervisory signals (lamps or drops), switches for ringing which are called ringing keys, and talking connection switches which are commonly called listening keys but preferably called talking keys.

The operator usually answers a call by inserting a back plug of a pair in the answering jack of the calling line and by operating the associated listening key to connect her telephone to the calling line. After learning the number of the station desired she determines whether or not the called line is busy. If not busy she inserts the front plug in a jack of the called line (if she has it within her reach) and rings the called station. The operator can talk on either cord of a pair by means of the one listening key and thus to both parties of a connection at the same time.

In small offices having but one jack per line the operator can see whether or not a line within her reach is busy. In larger offices where multiple jacks are usually provided, a busy test is required. The busy test is associated with the third-wire circuit previously referred to and is arranged so that when a plug is inserted in any jack all other jacks of that line are connected to a source of current in such a manner that any operator can determine by merely tapping the rim of a jack with the tip of a plug (listening key operated) that this condition exists and without inserting the plug in the jack. If a busy line is so tested the operator hears a click in her receiver for each tap. Busy lines are thus guarded against intrusion.

If the equipment is of the magneto type each pair of cords has at least one clearing-out or ring-off drop by means of which the operator can receive a disconnect signal and by means of which she can be signaled at any time after the connection is established. However, she must listen on each connection in order to learn when the called party answers, and frequently also to learn when she should disconnect, because the calling party may forget to give a disconnect signal. In some cases a clearing-out drop is associated with each cord of each pair so that the operator can thereby identify a signal from either party to a connection. Where a single drop is used for each pair of cords, the arrangement is such that when either party rings off, the bell of the other station is rung; but where two drops are used, the arrangement is such that ringing the bell of the other station is prevented. Clearing-out drops are usually mounted in the face of the switchboard and restored by hand, but in some cases they are mounted in the keyboard, and they may then be restored by the operation of the associated listening key.

If the equipment is of the common-battery type a supervisory signal lamp is associated with each cord. These lamps light when the connecting telephone hook is down, and the light is extinguished when the hook is up. These enable the operator to know when the called party answers, when each party hangs up, and she can be signaled by either party working the hook slowly down and up. The lamps are set into individual sockets. The sockets are mounted in the keyboard and are provided with glass caps to diffuse the light and to keep out the dust, and may be provided with metal guards to protect the caps from dropping plugs. These lamp caps are usually of three colors and are arranged with the colors in regular succession. To facilitate identification of the cords it is also usual to have the pairs of cords of the same color as the associated lamp caps. In some cases it is also the practice to provide a pilot lamp for the answering supervisory lamps on each operator's position.

Listening keys are operated by small handles called levers and are of the locking type; that is, they remain in the position in which they are placed. Ringing keys may be operated either with levers or push buttons. Ringing keys on *A* operator's positions are usually nonlocking and therefore restore to the normal position as soon as pressure is removed.

If the equipment is of the magneto type it is usual to provide each cord with a ringing key. Code ringing is done by operating the key the proper number of times for a certain length of time and at certain intervals, as required by the code in use. If selective ringing is furnished it is usual to provide each operator's position with a master key having the required number of operating positions. This key must be set in the correct position to

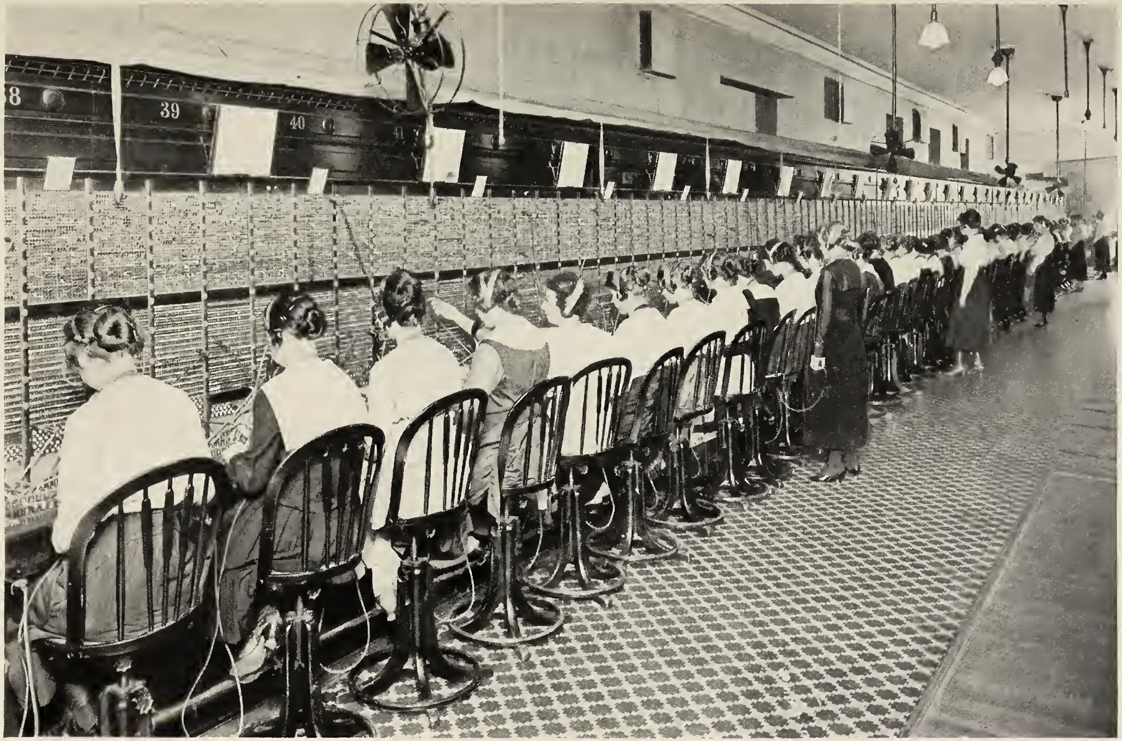

Fig. 21.—*A common-battery switchboard*

This is a local-service switchboard having the usual three-position sections and served by *A* operators. The standing operators are supervisors. From the top down may be noted the multiple line jacks, the multiple outgoing trunk jacks, and small groups of line lamps with an answering jack above each lamp

ring the desired station before the ringing key associated with the cord is operated.

If the equipment is of the common-battery type it is usual to provide ringing keys for the front (calling) cords only. Individual-line service and code-ringing party-line service require but one ringing key per cord, but selective-ringing party-line service requires as many ringing keys per cord as there are selections to be made, except where master ringing keys are used. Which will be used, of course, is dependent upon the relative amount of party ringing to be done. It is thought that individual keys per cord, using lever keys for two-party service and push-button keys for four and five-party service, are the most common practices. When more than one ringing key is used for each cord, indicators by means of which the operator is enabled to know which one was last used are associated with the keys.

When a station on a selective-ringing party line calls for another station on the same line, it is necessary for the calling party to hang up the receiver while the operator rings the called station, because the connecting of the talking equipment of a telephone to a line prevents ringing of bells on that line. Such a call is known as a reverting call. When reverting calls are handled with common-battery equipment it is necessary for the operator to leave one plug connected with the line to supply talking current and to disconnect when the one supervisory signal lights.

Those positions which serve public-telephone lines require extra equipment if the telephones are provided with the prepayment type of coin collector. This extra equipment comprises a collect key and a return key for each answering cord and also a pilot lamp for each operator's position. The lamp lights whenever the operation of a key on its associated position properly energizes a coin-collecting or a coin-returning device and thus serves as a guard signal.

Those positions which serve message-rate lines equipped with message registers require extra equipment for operating registers. This extra equipment comprises one register key for each answering cord, and also a pilot lamp and a position message register for each operator's position. The lamp lights, and the position register registers one call whenever the operation of a register key properly energizes a line register. The lamp thus serves as a guard signal, and the position register totals the calls handled. When a line register is once operated it remains in the operated position until the operator removes the plug from the line jack.

Trunking Equipment.—Whether an *A* operator alone will or will not complete a particular call is dependent upon whether she has or has not a jack of the called line within her reach. It is obvious that calls for lines terminating in other central offices can not be completed by one operator. Calls for lines terminating in the same office are in many cases completed by the *A* operator who receives the call, but in both small and very large central offices a second operator may be required for a large part, or all, of the connections which are local to a particular central office.

Connections requiring the services of two operators are completed over special lines called trunk lines, or simply trunks. The *A* operator connects the calling line to a trunk line, and the other operator connects the trunk line to the called line. Such a call or connection is said to be trunked. Local calls are always trunked between central offices in the same local service area and may be trunked within particular central offices when, for economic reasons, it is undesirable to provide all lines with multiple jacks within the reach of all *A* operators.

When a second operator is required to assist an *A* operator in completing a local call such operator is usually another *A* operator if she is located in a small central office; otherwise she is usually a so-called *B* operator. Trunking between two *A* operators will be referred to as *A–A* trunking and between an *A* and *B* operator as *A–B* trunking. As the *A* operator's switching equipment has been described, *A–A* trunking will be covered under this heading. Both *B* operator's equipment and *A–B* trunking will be considered under the next heading. There are two important cases of *A–A* trunking; one applies to interoffice calls and the other to intraoffice calls.

A–A trunking is used between two small offices and between one large and one small office, particularly when the small offices have magneto equipment. The trunking is usually handled on a ring-down basis; that is, signals are passed from operator to operator by ringing on the trunk lines. However, if one or both of the offices have common-battery equipment, line lamps may be associated with the trunk lines through relays which respond to the alternating ringing current, and other equipment may be provided which causes the supervisory signals to operate in the normal manner.

A–A intraoffice trunking is used in central offices having magneto equipment. Such offices usually have no multiple line jacks, and connections must therefore be established between the answering jacks. Each operating position is provided with trunks to each other position which the operator can not directly reach. These trunks may terminate in jacks at both ends or in jacks at the outgoing or sending end and in plugs at the incoming or receiving end, depending upon the operating methods in use. Such trunks are known as transfer trunks. The station lines are so terminated that the numbers identify the terminal positions. Each operator thus knows on which position the answering jack of any called line is located.

Each operator is usually provided with a number of small push-button keys which enable her to talk directly to each other operator at nonadjacent positions. The talking circuits associated with these keys are known as call circuits or order wires. The calling operator orders connection to the called line and also assigns the trunk to be used. If the trunks have multiple jacks before several operators, as is often the case, the calling operator selects the first idle one by testing. The called operator sees at a glance whether the called line is busy or not, and if not busy she connects the assigned trunk to the called line.

Where the trunks have jacks at both ends each operator uses a pair of switching cords to establish a connection and also supervises it. The called operator does the ringing. Where the trunks have plugs at one end only, the calling operator uses a pair of switching cords and she rings the called station via the trunk, which merely serves to lengthen the reach of her calling cord. The incoming or plug end of each trunk is provided with a lamp or magnetic signal which indicates when the calling operator makes a connection with the trunk and when she releases it. These signals notify the called operator when to make disconnection. Thus, although two operators are required to establish the connection and to make the disconnection, only the calling operator supervises it.

B Operator's Position Equipment.—*B* operators assist *A* operators in handling calls trunked to offices having multiple line jacks by testing the called lines, by connecting the trunks to the called lines, and by ringing the called stations. They receive their orders and disconnect signals from the *A* operators who have entire control of the connections and the disconnections. As *B* operators have no occasion to connect with their trunk lines, they are not provided with listening keys.

The trunk lines between *A* and *B* operators are always used for calls in one direction only. They are equipped at the outgoing end with multiple jacks within reach of all *A* operators who have occasion to use them; and at the incoming end each trunk terminates in a single cord and plug with which are associated the necessary busy-test equipment, ringing keys, and signal lamps. Each *B* operator's telephone set is so connected with the tips of her idle trunk plugs that she can test the called lines in the usual manner. This connection is opened when the plug is inserted in a jack. The cords, keys, and lamps are located on the switchboard shelf essentially the same as for *A* operators. A trunk is connected to the called line by merely inserting its plug in a multiple jack of the line required.

Calls from an *A* to a *B* operator are passed over a special trunk line known as a call circuit or order-wire circuit, which terminates in the telephone set of the *B* operator. The *A* operator connects her own telephone set to the respective call circuits, each accessible to a group of *A* operators, by means of small push-button keys located on the keyboards, at each *A* operator's position. Because of this method of passing calls the trunk lines associated with call circuits are known as call-circuit or order-wire trunks.

As a *B* operator can see at a glance which trunks are idle, she assigns the one to be used for each call immediately after receiving the called number and then makes a busy test on the multiple jack of the called line. When the *A* operator receives the trunk assignment she disconnects her telephone from the call circuit and then connects the calling line to the assigned trunk. In certain cases, however, it has been found desirable to have the *A* operator make a busy test on the assigned trunk, and special equipment may be provided so that this can be done without again operating the listening key. Such tests prevent double connections resulting from connection with busy trunks in case the *B* operator makes an error in trunk assignment or in case the assignment is misunderstood by the *A* operator.

Should the *B* operator find that the called line tests busy she reports the fact to the *A* operator by inserting the plug of the assigned trunk in a special busy-back jack to which a tone circuit is connected through an interrupter. The *A* operator's calling supervisory lamp is thus flashed at regular intervals, and the calling subscriber hears the interrupted tone and usually hangs up before the *A* operator identifies the flashing signal and reports to him.

Both the supervisory lamp and the ringing key equipment for individual incoming trunk lines usually differ in operation from the similar equipment provided for *A* operator's use. For each trunk cord there is provided at least one supervisory lamp which lights when the plug is inserted in a jack (if the *A* operator has not plugged into her end of the trunk line); is extinguished when the *A* operator plugs in, and is again lighted as a disconnect signal when the *A* operator releases the trunk by removing her plug.

Where the code method of ringing is employed an additional supervisory lamp is required to notify the *B* operator of the answer of the called party. This lamp also lights when the plug is inserted in a jack, and the operator rings at intervals until the lamp is extinguished or until she gets the disconnect signal from the *A* operator. Either the disconnect lamp or the ringing lamp also usually serves as a guard signal and lights in case of a premature disconnection. In some cases a flashing guard signal is provided.

It is now the usual practice to substitute relay operation for ringing-key operation in connection with incoming trunks serving for connection to individual line stations only. Such trunks are referred to as keyless trunks. The ringing begins as soon as the plug is in the jack, if the *A* operator has taken up the trunk, or just as soon as she does so, and continues until the called party answers. As keyless operation can be used only in an office having no party lines, or having a jack per station multiple, it is not the most common practice.

Ringing keys for incoming trunks are usually of the locking push-button type and are so arranged that the operation of any one key of a set associated with a particular trunk line releases any other key that may have been previously locked down. In those cases where individual-line stations and party No. 1 on party lines are rung by the same key, it is the practice to keep these keys normally depressed on all idle trunks because there are more calls for these stations together than for all others. Thus for most of the calls the operation of a ringing key is avoided at the time a connection is established.

Keyless-trunk ringing relays and locking keys are used with a method of ringing which is called machine ringing. Each ringing current supply lead is carried through an interrupter which permits the ringing current to flow for about two seconds out of each six. In some cases a relay is provided through which the ringing current passes during the ringing period and to which battery current is connected during the silent period. This relay operates when the called party answers either during a ringing or a silent period and stops the ringing. In other cases battery current alone is provided for such a control relay and the ringing is thereby stopped only during a silent period.

If the ringing is done manually the *B* operator is informed by the ringing signal when the called party answers, but if machine-ringing equipment is used the connection is completed as far as the *B* operator is concerned when she has depressed the proper ringing key. In all cases when the called party answers the supervisory signal associated with the *A* operator's calling cord is extinguished just as it is for a nontrunked call. The *A* operator either makes sure that the desired connection is completed or reports to the calling party that the called party does not answer.

A–B trunk operation is nearly always used between large central offices in the same local service area and very frequently for intraoffice calls in very large central offices of a multioffice area where the percentage of calls which do not have to be trunked is so small that the expense of providing multiple jacks before *A* operators is not warranted. In this case the calls which are local to such an office are also trunked.

Tandem B Operator's Position Equipment.—In large multioffice local areas where each office must have trunk connection with each other office it is frequently found more economical to operate *A–B* trunks in series or in tandem, as it is called, than to provide each office with direct trunks to each other office. Calls to groups of offices are then routed through one of the offices which is centrally located with respect to the others in the group, and that office is provided with *B* operator's position equipment, which is arranged for connecting incoming call-circuit trunks, known as tandem trunks, with outgoing call-circuit trunks, known as completing trunks. Such a *B* operator's position is known as a tandem *B* operator's position or simply as a tandem position.

The call-circuit equipment at the tandem position is so arranged that the tandem operator disconnects the incoming circuit or circuits from her telephone when connecting with an outgoing call circuit, and so that a distinctive tone is placed on each disconnected call circuit in order that the *A* operators may know that such call circuits are temporarily inoperative. Tandem trunks and completing trunks are provided with equipment which enables the *A* operators to have the same supervisory control of the through connections as would be obtained were the calls handled over single call-circuit trunks.

Information Operators Equipment.—The information equipment is used by information operators, whose duty is to furnish information which is in character supplementary to the directory. It is assumed that the reader is familiar with both the subject matter and the arrangement of directories. New directories are issued at regular intervals, usually several times per year. The intervals are, of course, dependent upon local conditions with respect to the number of new subscribers, the number of stations discontinued, and the number of changes in call numbers. A directory is necessarily correct only at the time of issue and it must therefore be supplemented by information service.

Information operators are provided with special desks having line equipment designed only for receiving calls and for signaling back to the calling *A* operator. Information operators usually do no switching. The equipment may be either of the magneto type or the common-battery type, depending upon the type of switching equipment with which it is associated.

Information operators are also provided with directory lists which are kept up to date and also with supplementary lists arranged in numerical order and by addresses. These lists are bound in book form and a special rack is mounted on large desks to hold the books within easy reach.

While all offices give information service, they do not all have information equipment and information operators. In cities having multioffice local areas it is the usual practice to provide one centralized information desk and operating force. In this case lines are provided from all of the associated offices.

Multiple-Marking Equipment.—There is certain information with reference to called lines which each operator must have quickly available. A system of marking multiple jacks so as to give a large part of the required information is now in general use. Only the more important cases will be mentioned.

When a group of lines is required for a single subscriber, as is usually the case for private branch exchange service, only the first number is listed in the directory. Consecutive numbers are usually assigned to lines in such a group and each group of multiple jacks is marked with a continuous white line placed beneath the jacks. The operator tests each line in succession and gives a busy report in case all the lines of a group are busy.

When a station is called it is necessary for the operator to know that such a station exists, as much time would otherwise be wasted on wrong-number calls. All idle multiple jacks are closed by black signal plugs which are inserted in the jacks. All multiple party-line jacks are marked with colored stripes to indicate the party stations actually on each line. These stripes have a quadrant form and are usually referred to as quadrants.

If an individual-line station number has been changed or if another station is temporarily receiving calls for that station, a signal plug bearing the new or other number is inserted in each multiple jack. If a party-line station number has been changed or if another station is temporarily receiving calls for that station, that fact is indicated by a particular marking on each multiple jack, and the new number may be obtained either from a bulletin on the switchboard or from a so-called multiple-marking operator who is provided with complete records of all special information concerning called lines which can not be well indicated at the jacks.

Traffic Registers.—It is the usual practice to provide *A* and *B* positions in common-battery central offices with electromechanical registers for counting calls handled. These are operated by means of push-button keys. The keys are mounted on the key shelves of the respective positions, but the registers are usually mounted in a cabinet at one end of the switchboard. Each operation of a key causes the associated register to count one call.

Rural Switching Equipment.—Switching equipment for rural lines is usually of the magneto type. In some cases the signaling of the central office is put on a common-battery basis with local-battery transmission, and in other cases where the lines in question are not too long both signaling and transmission may be on the common-battery basis.

In small offices using magneto equipment for local switching no special switching equipment is required for rural lines except that, if ground-circuit lines are to be connected to metallic-circuit lines, special cord circuits are usually provided for this purpose. These each include a repeating coil by means of which the line circuits are linked electromagnetically. By this means a ground-circuit line may be assoiciated with a metallic-circuit line for talking purposes without directly connecting the one electrical circuit with the other, thereby confining the unbalanced condition to the ground circuit portion of the entire line circuit.

It is the usual practice on rural lines for the parties on the same line to signal each other by code ringing. In those cases where the station equipments are provided with push-button keys to be used when calling the central office, code ringing between parties on a line is not indicated to the operator. If such keys are not provided the central office signal, drop or lamp, is operated by all ringing on the line. If the lines terminate in drops, as they usually do, the action of the drop indicates to the operator whether she is being called or whether one party on the line is calling another party on the same line.

Where rural lines are served by a common-battery switchboard either line drops or line lamps and line relays may be used. The cord circuits for switching rural lines having magneto equipment differ from those for switching the local lines having common-battery equipment in that they are arranged for connecting rural lines to rural lines and also for connecting rural lines to common-battery lines. In the first case no battery current is supplied to the connection, and the signaling is all on a ringing basis. In the second case battery current is supplied to the cord connecting with the common-battery line for talking and for signaling the operator. No battery is supplied to the cord connecting with the rural station, and the operator is signaled, as in the first case, on a ringing basis.

Universal Switching Equipment.—In some cases it is the practice to provide equipment for line circuits which can be readily converted from the generator-signaling basis to the battery-signaling basis. Such circuits are known as universal line circuits. Similarly, universal cord circuits, arranged for either magneto or common-battery operation, may be provided. These circuits may be fully wired in the switchboard and equipped for such operations as may be required at a particular time. By means of universal circuits economy may be effected in the process of converting from magneto to common-battery operation. A switchboard having universal line and cord circuits is known as a universal switchboard. Such a switchboard has been found to prove in for certain single-office districts.

Switching Equipment—Newer Types.—The newer types of manual switching equipment differ from the commonly used types with respect to certain specific operating methods which apply to common-battery equipment only. These newer operating methods all involve the installation of additional equipment which is designed to aid the operators in handling calls and to thus improve the quality of operation.

General Application of Call Distribution.—As has been stated, calls may be distributed among a number of operators by means of multiple line lamps and multiple answering jacks for the purpose of securing a quicker response. This method of call distribution is now being provided in many cases. Another operating feature is also being added which permits only one operator to make connection with the calling line. Confusion is thereby prevented in case more than one operator should answer.

Machine Ringing on A Positions.—The provision of machine-ringing equipment for *A* operators eliminates most of the labor involved in manual ringing and puts *A* and *B* operators' ringing on the same basis of operation. It also makes possible certain other operating methods. This provision, however, has not as yet been made to any great extent, being in fact more or less limited to single-office areas.

Ringing Tone for Calling Party.—The provision of a comparatively small amount of extra equipment enables the calling party to hear a distinctive tone each time the called station is rung. This tone is referred to as a revertive ringing tone or as an audible ringing signal. It is effective in reducing the amount of operator's work required for slow-answer calls and therefore is being provided very generally.

Elimination of A Operator's Ringing Supervision.—When both machine ringing and the ringing tone for the calling party are provided, it is in certain cases found practical to eliminate ringing supervision on the part of *A* operators by adding equipment which converts the calling supervisory lamp into a ringing guard signal and enables the calling party to stop the ringing by hanging up the receiver. The calling supervisory lamp is extinguished when the ringing key is operated and thus acts as a guard on the operation of the key. The calling party hears the ringing tone and hangs up if no answer is obtained.

With this method of operation no lamp is lighted before an *A* operator unless it demands her immediate attention, whereas with ringing supervision a number of calling supervisory lamps may be lighted for considerable periods of time. Hence the application of the term "dark key shelf" to this method of operation. Supervisory pilot lamps may also be furnished for both the answering and calling cords.

Immediate Disconnection of the Calling Party.—Additional equipment may be provided by means of which the busy condition is removed from the calling party's line just as soon as the receiver is placed on the hook. Thus the line is freed for incoming calls regardless of whether the plug used for the previous connection remains in the jack or not.

Newer Methods of Signaling on Recalls.—When a calling party desires to make a new call immediately after a previous call and before the *A* operator has had sufficient time to disconnect, her attention is usually drawn to the recall by the flashing (intermittent lighting) of the answering supervisory lamp, which is effected by moving the telephone hook down and up.

One method of making response to a recall signal more prompt is to associate an audible signal with each flashing answering supervisory lamp. Another method is to associate a mechanism with each flashing answering supervisory lamp in such a manner that the flashing operation is continued at regular intervals from the time the telephone hook makes its first upward movement until the operator answers. Thus the flashing, once started by the calling party, continues without further action on his part.

Still another method is to provide the necessary equipment to transfer the new call from the answering supervisory lamp to the line lamp. The connection is transferred on the first downward movement of the telephone hook, and the successive upward movements each light the line lamp. Line-lamp signals are much more conspicuous to the operators than nonflashing supervisory signals and may be answered by several operators; hence the quicker response. If multiple line lamps and answering jacks are also used to distribute calls among a still greater number of operators, the response may be very prompt.

Elimination of Listening-Key Operation.—Additional equipment may be provided by means of which the one act of placing an answering plug in a line jack also results in connecting the operator's telephone to the line, and in this manner the first operation of a listening key may be eliminated. The second operation required by means of which the operator disconnects her telephone is effected by the one act of placing the calling plug in a jack. Listening-key operation may, however, be retained in certain cases for handling recalls.

Additional Secrecy Attainments.—The elimination of listening-key operation by the method just described also prevents the operator from hearing any part of the conversation between the calling and called parties. Though special listening keys are provided for use on recalls, the secrecy feature may be maintained by suitable equipment. The provision of equipment which prevents more than one operator making connection with any one line, and to which reference was made under call distribution, also prevents operators from listening on busy lines at idle multiple jacks.

Elimination of Traffic Register Operation.—Traffic registers are usually operated by hand. The labor involved in such operation on the part of *A* operators has in certain cases been eliminated by providing equipment for associating such operation with some other operation which must be made, as, for example, the insertion of the answering plug in a jack of a calling line. Also by this means the certainty of operation is assured.

2. TOLL EQUIPMENT

The great bulk of the toll service originates at subscriber stations and most of the remainder originates at local public telephones. The rest originates at special public telephones for toll service only. These are connected either directly to toll lines or may be switched thereto. Thus the local plant is in general used both for local and for toll service. This fact has a bearing on the design of the local plant, which must be suitable for both divisions of the service.

Calls for suburban toll and long-distance points are switched over toll trunk lines to those points. In all but very small central offices special switching equipment and means for its operation are provided for switching telephone lines and toll lines together. The requirements for toll switching increase with the size of the central office. In cities the toll switching equipment is usually separated from the local switching equipment and large cities having a multioffice local system are usually served by one large toll switching equipment located in the same building with one of the central offices. A separate toll switching equipment requires trunk lines to each of the central offices it serves as well as toll lines to the distant points. In very large cities the suburban toll lines and long-distance lines may be served by separate switching equipments.

Fig. 22.—*A toll switchboard*

The multiple toll line jacks may be seen along the middle face of the switchboard. The white lines indicate strips of paper in metal holders associated with each strip of jacks. These are marked to designate the trunk numbers and the connecting central offices. Each operator has a very small group of line lamps and answering jacks which also have designation strips

There are five common kinds of trunks used for establishing toll connections. These are known, respectively, as ring-down trunks, *A–B* toll trunks, tandem toll trunks, recording trunks, and toll switching trunks. The last two kinds are used where the toll equipment is separated from the local equipment, which is usually the case. In addition to the above kinds of toll trunks there are long-distance trunks which are composited and used for both telephone and telegraph service. This service is considered beyond the scope of this publication.

Ring-Down Trunks.—Ring-down trunks are commonly used for toll traffic in general. They are so named because the operators signal each other by ringing on the trunks. Ring-down trunks may be either long or short haul trunks. Long-haul trunks are operated with simple switching equipment on a magneto basis. Short-haul trunks may be operated with similar switching equipment, but when they terminate at local *A* operator's positions, as they frequently do, they may be equipped for common-battery supervision.

In central offices having equipment of the magneto type the line equipment is frequently the same as that for local lines. In many cases, however, special line drops and line jacks are used to improve the speech transmission. In the larger offices it is the usual practice to terminate all of the toll lines on one or more positions assigned for toll service. Incoming calls from toll points are received on the toll positions and calls for toll points received by the *A* operators are passed to a toll operator for completion.

In the central offices having equipment of the common-battery type the ring-down trunk lines are occasionally terminated on drops, but the usual practice is to provide line lamps. If drops are used they may be of the self-restoring type which are electrically restored to the normal position when an operator answers, or which are mechanically restored when a plug is inserted in the answering jack.

Line lamps are associated with their respective lines by line relays which respond to ringing current. When a line relay once operates it closes an electrical locking circuit. The lamp once lighted remains so until the locking circuit is opened as a result of answering on the part of an operator. On toll switchboards where multiple line jacks are required it is the usual practice to provide visual busy signals instead of the busy-test circuit which is used on local switchboards. These signals may be either very small electromagnetic devices or lamps with caps of a distinguishing color. They are always closely associated with the multiple jacks.

A–B Toll Trunks.—*A–B* toll trunks carry traffic in one direction only, are served by *A* and *B* operators, and calls are passed over a call circuit or order wire. The operation of such trunks does not materially differ from that of similar trunks used for local service.

A–B toll operation is most common for short-haul suburban toll service, but it has been extended in some instances to very considerable distances, in which case special switching equipment is required for signaling purposes. *A–B* toll trunks are very commonly used in connection with central offices having common-battery equipment where fast suburban service is desired and where a comparatively large traffic is to be handled.

Tandem Toll Trunks.—*A–B* toll trunks are also arranged to operate in tandem essentially the same as described for local trunks. The tandem-toll equipment is usually located on a separate toll switchboard. Tandem operation is frequently used for surburban service, in fact, more frequently it is thought than for local service.

Recording Trunks.—Toll calls as well as local calls originate at local *A* operators' positions. Where the toll lines are served by special toll operators the *A* operators must have facilities for passing toll calls to the toll operators for completion. In central offices having magneto equipment the *A* operator usually talks with the toll operator over an order wire and requests her to establish the desired connection. In offices having common-battery equipment special trunks known as recording trunks are provided for this purpose.

Recording trunks are equipped with jacks, usually multiplied, before the local *A* operators and terminate in the toll office on line signals and either answering jacks or answering keys. Very frequently the line signal is operated automatically when the *A* operator inserts a plug in an outgoing jack.

In small offices the regular toll operators answer calls on recording trunks, but in large offices special operators known as recording operators are assigned to receive calls on recording trunks. In some cases the *A* operators repeat the calls to toll or recording operators, but in most cases the line of the calling party is connected directly to the recording trunk, and the call is given directly to the toll or recording operator.

In general, recording trunks are not used as connecting trunks for the completion of toll connections. Special toll switching trunks are provided for this purpose. In a group of trunk lines connecting a local office with a toll office one or more of the trunk lines usually serve as recording trunks and all of the others as toll switching trunks.

Toll Switching Trunks.—Where the toll lines are served by special toll operators, facilities must be provided for connecting the toll lines with the local lines. In central offices having magneto equipment the usual interposition trunks serve for this purpose. In small offices having common-battery equipment the local lines are frequently provided with multiple jacks placed within reach of the toll operators, and in this case no switching trunks are required. For large offices having common-battery equipment it is the usual practice to provide special toll switching trunks from the toll switchboard to each local office that it serves.

Toll switching trunks are usually call-circuit trunks with switching equipment similar to that used for local *A–B* operation, but having a battery supply which furnishes a stronger talking current. Where multiple jacks are required at the toll board visual busy signals are usually provided also. In some cases multiple jacks are also provided for the recording operators. The incoming or local ends of toll switching trunks must be equipped for the classes of service they are to handle. Those used for public telephone service require coin collecting and returning equipment if the telephones are provided with the prepayment type of collector.

Recording Operator's Position Equipment.—In some cases recording operators handle toll connections as well as act as recording operators. In such cases no special equipment is required. Where special equipment is provided it is usually of a simple character and adapted to answering calls and holding the calling lines while information is being obtained in order to answer questions regarding rates and charges.

Sometimes answering keys are provided for each line, in which case no cords are required. In most cases answering jacks and switching cords are used to enable the recording operators to switch inquiry calls to operators having the records, and in some cases for connecting with toll switching trunks. The latter need obtains where the method of operation is such that the recording operator, instead of a toll line operator, secures connection with the calling party via a toll switching trunk.

Recording operators are provided with facilities for writing call details on memorandum tickets which are passed to toll line operators who establish the connections by means of the toll lines and toll switching trunks. In case the method of operation is such that the recording operator secures the calling party via a toll switching trunk, the call details on the tickets must include the trunk numbers for the information of the line operators. In a small office the tickets may be passed directly to the line operator or operators, but in a large office they must be distributed to operators handling lines to the required points. Messengers are frequently used for this purpose, and in some cases belt conveyors or pneumatic tubes have been provided.

When a recording operator disconnects from a recording trunk the *A* operator receives a disconnect signal. In many cases this signal is of a peremptory nature; that is, the disconnect lamp is caused to flash until disconnection is effected by the *A* operator. When a toll line operator takes up a toll switching trunk which is held by a recording operator the latter operator receives a disconnect signal.

Line Operator's Position Equipment.—In central offices having equipment of the magneto type the toll cord circuits may be similar to those used for local service, but it is the usual practice to provide them with special ring-off signals and repeating coils to improve the speech transmission.

In central offices having equipment of the common-battery type the toll cord circuits are usually provided with lamp supervisory signals similar to those used on local switchboards. On those positions used for switching together toll lines and toll switching trunks to common-battery offices the lamp associated with one cord of each pair is controlled by the telephone switch hook, and this cord is always connected to the toll switching trunk. The lamp associated with the other cord is controlled by ringing current in a manner similar to a toll line lamp, and once lighted remains so until the operator answers. This cord is always connected with a toll line. If the toll switchboard is also used for through switching of toll lines, as is usually the case in large offices, certain switching positions are assigned for this purpose, and the supervisory lamps associated with the switching cords are all arranged for ringing control.

Toll cord circuits usually differ from local cord circuits in that facilities for ringing are provided for both cords instead of for only one. It is also a usual practice to so arrange these circuits that the line operator can talk with the party on each cord without being heard by the party on the other cord, and in this way ascertain that both parties are ready to talk before connecting them together. Toll cord circuits are also so equipped that the operator can listen on them with a minimum of interference in order to supervise the connection.

Timing Equipment.—As toll charges always involve the duration of the connection, timing facilities are an important part of the switching equipment. All offices are provided with suitable clocks. As many clocks are provided as may be necessary, and they are so located as to make the line of vision for each operator as nearly as possible a perpendicular to the face of the clock, and thus to avoid errors in reading the time. The movement of these clocks is usually electrically controlled by a master clock.

Large offices are frequently provided also with small electric clocks for each operating position, or with special timing clocks for each two positions, by means of which the elapsed time can be directly stamped on the tickets which record the details of the connection. These clocks are usually mounted directly on the switchboard.

IV. TELEPHONE PLANT—EQUIPMENT OF AUTOMATIC SWITCHING SYSTEMS

Automatic switching is done by means of machines which are known as machine switches. Hence automatic switching systems are also known as machine switching systems. Automatic switching involves all the basic operations of manual switching, and it is frequently stated that the switching machines serve as operators. The machines do serve as operators, but in general with a more restricted range of operations. They also serve, however, as connecting equipment and thus replace the operator's position equipment of the manual system.

An operator in a manual central office can economically be given direct access to a large number of station line terminals (multiple jacks) and to many groups of many trunk line terminals, giving indirect access to an indefinite number of station line terminals in other offices. It is not found economical to give individual machines, which serve as connecting equipment, direct access to any such number of line terminals.

An operator makes a routing selection and then selects a particular line terminal by a procedure involving the preselection of subgroups of terminals each successively smaller than the preceding one, but this procedure is decreased in extent as the operator's familiarity with the locations increases. More than one machine, except in very small offices, is required to effect similar selections, and the number increases with the size of the office. Furthermore, each machine operates in a predetermined and, therefore, uniform manner.

The machine switches perform the operation of selecting the called line under more or less remote control. There are two systems of control. The most common system effects the selection by means of a so-called dial with which each telephone station is provided. The less common system effects the selection by means of so-called key sets which are provided for central office operators. Dial-control systems are usually known as automatic systems and operator-control systems as semiautomatic systems, but the reader should bear in mind that both systems are automatic switching systems. Practically all automatic-switching equipment is of the common-battery type.

As stated in the general introduction three types of automatic-switching systems will be considered. The one in most general use will be considered first. It is commonly known simply as the automatic system and will be so referred to. The semiautomatic system, known as the automanual system, will be considered next. The third system is known as the panel-type machine switching system. Both the first and the last systems are dial-controlled systems.

1. AUTOMATIC SYSTEM—LOCAL EQUIPMENT

Just as in the manual system an installed subscriber telephone is known as a subscriber station. An installed public telephone is known as a public station. Each telephone must have a telephone line by means of which connections can be established from one telephone to another. Each telephone line must terminate in a central office at which point switching facilities must be provided for connecting lines together. Also as in the manual system the local equipment is naturally divided into station equipment and central office equipment.

The automatic system is fully automatic in operation (no operators are required) for local subscriber service excepting message-rate party-line service and in most cases rural-line service.

Although extensive progress has been made toward automatic operation for rural service it will not be considered in this description. The automatic system is not usually fully automatic for local public telephone service. Where certain classes of service are excepted, calls for such service are handled on a manually operated switchboard which is so associated with the regular automatic switching equipment as to make much of the detail operation automatic.

In general automatic switching systems are installed to supersede manual switching systems. In the smaller communities where the local service is handled by a single central office the entire equipment can be readily changed at one time. In large communities where multioffice local systems are required it is the usual practice to replace one central office at a time. In such cases facilities must be provided for handling calls between stations in two very different systems. In order to properly cover this important practice it is necessary to include a description of equipment for handling calls between automatic-office stations and manual-office stations.

TELEPHONE STATION EQUIPMENT

Most of the telephone station equipment does not differ from that described for the manual system. Such equipment will be separately grouped.

Equipment Common to Manual Systems.—An automatic telephone set is similar to that of a manual system using common-battery equipment except that a device called a dial must be included. The central office is signaled as usual by means of the hook-switch. In this case, however, the first upward movement of the hook results in a preliminary switching operation instead of a response from an operator, and the first downward movement thereafter results in releasing all of the central office equipment which may have been previously operated and which is held under control of the calling party. The stations are signaled as usual by bells. As the harmonic system of selective ringing is standard in the automatic system, the harmonic type of bell is commonly used. The biased type of bell, however, may be used.

The transmitter, receiver, protector, and inside wiring details previously given apply also to the automatic system. The receiver commonly used is of the direct-current type in which the initial magnetization is furnished by means of the current which is normal to the line.

Extension bells and extension stations, with or without cut-out keys, also signs, booths, and supervisory switching equipment for public telephone stations, are provided as in the manual system. Coin collectors similar to those used in the manual system are very commonly used. These may be either single or multicoin collectors, but they are usually of the postpayment type.

Automatic Coin Collectors.—Coin collectors arranged to automatically collect single coins on calls to local automatic stations may be provided. They may be either single-coin or multicoin collectors, but if the latter are used the multicoin feature is for toll calls only. When used for calls to stations reached via operators, collections are handled manually.

Either the postpayment or prepayment type of single-coin collector may be provided. The postpayment type permits any call to be made in the usual manner, permits the calling party to hear the answer of the called party, but prevents the calling party talking to an automatic station until the required coin has been deposited. No collection operation is required. The prepayment type prevents any call being made until the required coin is deposited. On calls to automatic stations the coin is collected automatically when the called station answers, or it may be removed from the slot if the called station does not answer.

The multicoin collector is of the prepayment type. No call can be made until a coin has been deposited. On calls to automatic stations the coin is collected automatically when the calling party hangs up the receiver if the called party answers, otherwise it is returned to the calling party via a return chute similar to that used in the manual system.

The Dial.—The dial is the device by means of which the automatic switching equipment in the central office is controlled for the purpose of selecting the called line and the called station on a party line. The selecting operation includes the extension of the calling line to a terminal of the called line, but the connection thereto is not under dial control.

The appearance of a dial is clearly shown by the illustration of an automatic telephone. Its operation is so intimately associated with the devices it controls that the description will be given in that connection. A dial may be attached to any common-battery telephone, but new sets usually have the dial included as an integral part thereof.

FIG. 23.—*An automatic desk stand*

The illustration shows how a dial is placed on a desk stand. The finger-hole plate is the movable part of the dial. The finger stop may be seen to the right of the figure O

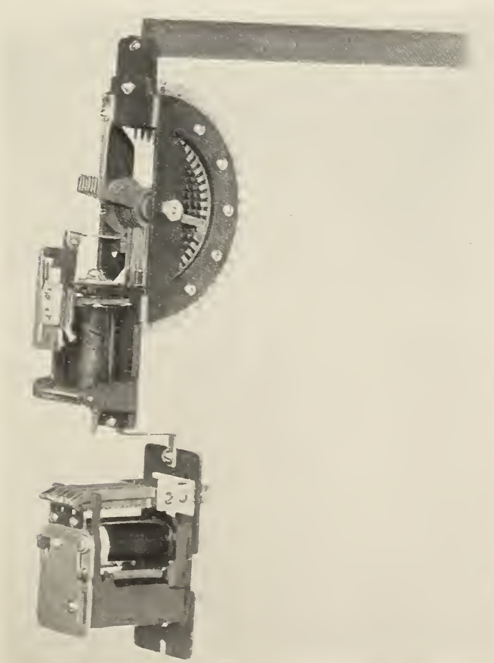

FIG. 24.—*A rotary line-switch*

The upper part of the illustration shows the semicircular trunk-bank, contact brushes, and motor magnet. The lower part of the illustration shows the two associated relays. (See page 69.)

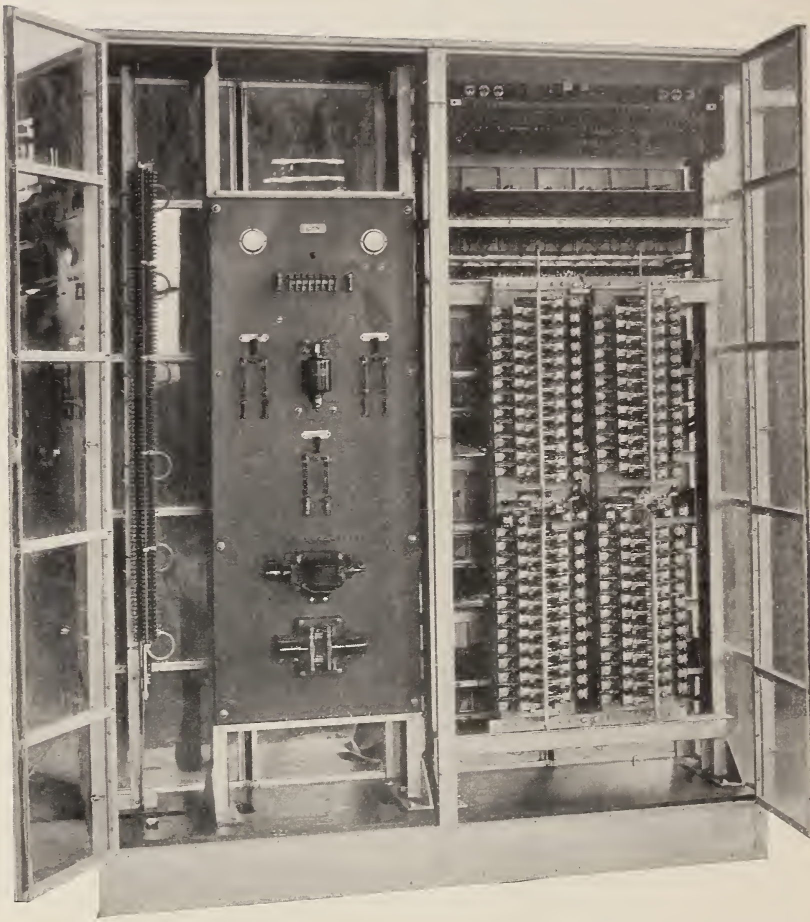

FIG. 25.—*A private automatic exchange switchboard*

The illustration shows a unit assembly for 100 lines and comprises a row of 100 protectors, a power panel, and a group of 100 line-switches of the plunger type. These may be noted from left to right in the order named. The power panel carries the necessary battery and ringing supply equipment. The line-switches are arranged in two vertical rows of 50 each with two groups of 25 in each row. A master switch, located at the middle of the row, and a 10-terminal trunk-bank are provided for each row of 50 switches. The connectors are placed on the rear of the line-switch frame

It is now the usual practice to provide a so-called dial tone which the calling party can hear shortly after the receiver is lifted from the hook when the preliminary switching operation in the central office has been completed. The dial tone notifies the calling party that the required apparatus is ready to receive a call.

Private Branch Exchange Equipment.—Private branch exchange service is rendered in connection with the automatic system just as it is in the manual system. Such service may be handled by manual switchboards, by an automatic switching equipment or by a combination of manual and automatic switching equipment.

If handled by a manual switchboard, dials are provided for each operator's position, and keys are usually provided for each cord circuit by means of which the dial may be associated with any calling cord for making outgoing calls. If handled by automatic equipment only, all calls are automatically switched. If handled by a combination of manual and automatic equipment the former is used for all incoming calls and may be used also for handling outgoing calls from certain restricted-service stations. The last two arrangements are known as private automatic exchanges. It is thought that the following description of automatic central office equipment will suffice for an understanding of private automatic exchange operation.

CENTRAL OFFICE EQUIPMENT

The introductory statements made under central office equipment in the description of the manual system also apply to the automatic system excepting those with regard to the type of equipment.

In the automatic system lines are terminated in exactly the same manner, and the practice with regard to protectors is the same as in the manual system except that the outside lines usually end on the terminal blocks and the inside lines on the protectors. It is also the usual practice to provide alarm equipment to notify attendants of the operation of the protecting devices.

The description of the switching equipment will be divided into two parts. The first part will cover automatic switching equipment as used without operators for rendering most of the service. The second part will cover manual and automatic switching equipment used in combination for rendering the service requiring operators.

Automatic Switching Equipment.—The number of a line is the basis for its automatic selection. The calling party must so operate a calling device that the central office apparatus will automatically connect the calling line to the line bearing the number desired and ring the desired station if that line serves more than one station. Thus there is an intimate relation between the number of a station and the method of selecting it out of a group of stations which may include 100 000 or more.

It is obviously impossible to bring all lines of a large system within the reach of a single mechanism for connecting purposes. In fact 100 lines have been selected as the basic group from which a single mechanism can select any line. Thus all lines are divided into groups of 100. The hundreds groups are grouped by thousands, and the thousands groups are grouped by ten thousands.

Each station line terminates on a device called a line-switch. Line-switches are of two types known respectively as the plunger type and the rotary type. The rotary type is the later type and is designed to give each line direct access to a larger number of selectors than can be obtained with the plunger-type line-switch.

Plunger-Type Line-Switches.—Each line-switch comprises two relays and a mechanism for connecting the associated line with any one of 10 outgoing trunk line terminals. One relay is a line relay and serves to start the operation. When the line relay is operated by a call it closes the circuit of the other relay which cuts off the line relay and causes an associated plunger to engage the one set of trunk-switching springs, out of a total of 10, with which it is in alignment. The 10 sets of switching springs are mounted in a horizontal row, arranged in a circular arc, and the assembly is known as a trunk bank. Each set of springs, when engaged by a plunger, connects the calling line with 1 of the 10 trunk line terminals.

Line-switches are mounted on unit-type frames having a capacity for 100 switches arranged in 2 vertical rows of 50 each. Each line switch has a trunk bank. The line switches of a 100-line group may or may not be divided into smaller groups, depending upon the traffic to be handled. If not so divided, the 10 trunk terminals are multipled through all of the trunk banks. If so divided, 10 trunk terminals are multipled through all of the trunk banks of each group. The number of trunk lines actually provided for any group or the number of line-switches per group of 10 trunks, however, depends upon the traffic requirements of the group. The trunk lines run to other devices which operate under control of the dials.

Each group of line-switches has a master switch. The function of the master switch is to so align each idle line-switch plunger with the switching springs of an idle trunk line that when a call is received the calling line will be immediately connected to an idle trunk. All idle plungers normally engage a vertical shaft which is a part of the associated master switch. When a plunger is operated it becomes disengaged from the master-switch shaft. Immediately after a line is connected to a trunk the master switch moves all idle plungers in the normal position so as to again align them with the switching springs of an idle trunk. In the course of these movements it picks up those idle plungers which were previously disengaged from the master-switch shaft in order to switch a call and which have been released on disconnection.

Message registers of the type used in the manual system are furnished when required for individual-line service. They may be mounted either on the line-switch frames or on separate frames used exclusively for that purpose. Each register is associated with the line at the line-switch trunk bank. When the line becomes connected to a trunk the register becomes associated with that trunk through a relay having a winding that is normally in the trunk circuit. This relay is inoperative with the line current in the normal direction.

When the called station answers the direction of the current in the calling-line circuit is reversed by another device. If an answer to a call is obtained the meter relay is operated and in turn operates the message register. The meter relay also disassociates its line winding from the talking circuit and is held operated by a second winding until the connection is released. Thus the register is operated once and remains in the operated position until released on disconnection.

Rotary-Type Line-Switches.—Each line-switch comprises two relays, a motor magnet, and a rotary switch for connecting the associated line with any one of 25 outgoing trunk line terminals. One relay is a line relay and serves to start the operation. The other relay is a combination cut-off and connecting relay. The rotary switch has a set of switching springs each of which is commonly known as a brush and also as a wiper. The term brush will be used in the description which follows.

The connecting brushes of the rotary switch are moved in a vertical plane by the motor magnet and make contact with flat metal pins which serve as terminals for the trunk lines. These terminal pins are assembled to form a semicircular bank. Rotary line-switches are mounted on a unit-type frame having a capacity for 100 switches arranged in 5 horizontal rows of 20 each.

Rotary line-switches differ radically from plunger-type line-switches in that each one is a complete operating mechanism. No master switches are required. After use the switch remains in the position in which it was last used. Thus it is normally in a position to connect its line with the trunk line last used.

When the line relay is operated by a call it closes the circuit of the other relay which immediately cuts off the line relay and connects the calling line to the trunk last used if that trunk is idle. If that trunk is busy the operation of the other relay is temporarily prevented and the operation of the line relay causes the motor magnet to be energized. The motor magnet rapidly rotates the switch until the position of an idle trunk is reached. When such a position is reached the other relay cuts off the line relay and connects the calling line through to the selected trunk line.

Message registers may be associated with line-switches of the rotary type as well as those of the plunger type. The operation in connection with a rotary-line switch does not differ from that described in connection with line-switches of the plunger type.

The Connector.—The device which can select for connection purposes any station line out of a group of 100 is called a connector. The lines are terminated on flat metal pins which are assembled into a bank of 10 horizontal rows of 10 each. Each row is arranged in a circular arc and is referred to as a level. When a telephone with a calling dial is switched through to a connector any one of 100 lines can be selected by two operations of the dial.

A dial bears the figures 1 to 9, and a zero, which is commonly called 0; it really represents the figure 10. To operate the dial, or to dial, as it is called, the calling party inserts a finger in a hole in the movable disk, which hole is directly over one of the figures, and pulls the disk around until the finger strikes a metal stop, and then lets go. The disk returns to its normal position and automatically opens and closes the line circuit a number of times equal to the number dialed. Thus the current which is normally on the telephone line may be interrupted any number of times

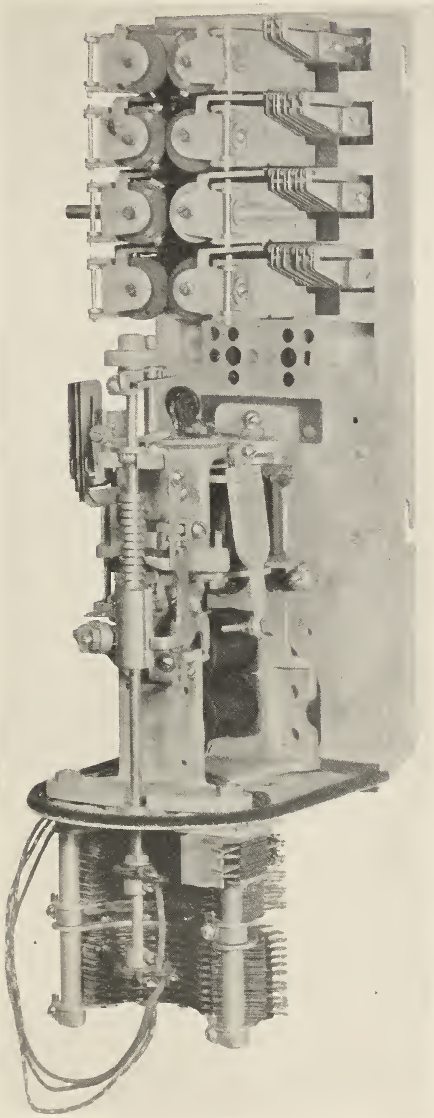

FIG. 26.—*An automatic connector*

Each connector comprises a group of relays, an electromechanical stepping mechanism, and a mounting plate. The line-bank with which the connector is associated is rigidly attached to the frame of the stepping mechanism. The vertical shaft in the foreground carries the contact brushes at its lower end and is lifted and then rotated, one step at a time, by the stepping mechanism under control of a dial. The illustration shows a connector in an operated position. On release the brushes are rotated to the left, until clear of the bank, by a spring attached to the shaft. The shaft and brushes then drop to their normal position where the brushes are one step below the first (lowest) bank level

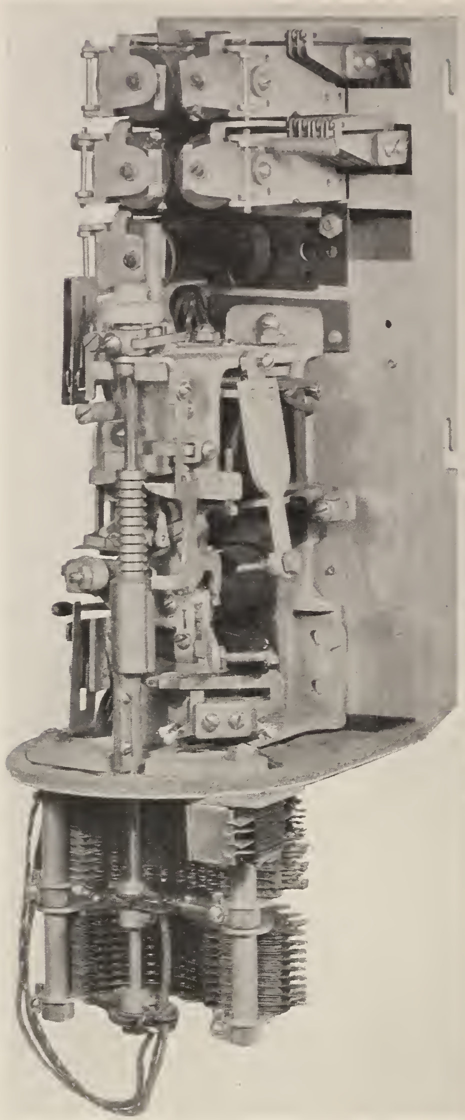

Fig. 27.—*An automatic selector*

The mechanism of a selector is very similar to that of a connector, but the electrical circuits are very different. Vertical stepping of the brushes to the required level is effected under control of a dial, but rotary stepping is an automatic operation. When the required level is reached the selector rotates its brushes until the terminal of an idle trunk is reached or, if there is no idle trunk on the level, until the brushes move off the right side of the bank. In the latter case a contact is mechanically closed for the purpose of signaling the calling party. The selector shown by this illustration has no talking-circuit equipment. Release is effected in a manner similar to that of a connector from 1 up to 10. The dial is provided with a governor which controls its operating speed and also with a mechanism which disassociates the talking circuit of the telephone from the line circuit during the movement of the dial.

The connector is so constructed that the first figure dialed steps its connecting brushes up a number of levels equal to the number dialed, and so that the second figure dialed moves its brushes horizontally along the level previously selected a number of steps equal to the second number dialed. As the brushes are rotated horizontally they make contact with the terminals of each line, but the mechanism of the connector holds the line connection open during this process. When the action stops the brushes will be in contact with the terminals of a particular line. The order of terminating the 100 lines is such that each can be selected by the above-described process. For example, line No. 62 would be on the second terminal of the sixth level.

In a system of only 100 lines each trunk from a group of line-switches runs direct to a connector, and as many connectors are furnished as there are trunks required to handle the calls. The lines of each particular hundred group are multipled to all of the banks of the connectors associated with the particular hundred lines so that each connector of a group has access to each line of that group. Because of the close association of line-switches and connectors the connectors are usually mounted on the rear of the frames which carry the line switches.

The Selector.—When a central office has many groups of 100 lines it is evident that before a particular line in any group can be selected the group itself must be selected. In an office having 1000 lines there would be 10 groups of 100 lines each and a choice of the required number of connectors for each group. The selection of a group is made by a device called a selector, and each trunk from a group of line-switches thus runs direct to a selector. The operation of a selector differs from that of a connector in that the level only is selected by the dial. After a level has been selected the selector automatically rotates its brushes until it finds the first idle trunk line on that level and then immediately connects the calling line through to a connector. If all of the trunk lines on a selected level are busy the selector will continue its rotation until the brushes clear the terminal of the last trunk line. When this position is reached a switch is operated mechanically. This switch opens the operating circuit and connects a busy-tone circuit to the calling line. This tone notifies the calling party of the busy condition.

Each level of a selector bank has a capacity for 10 lines, and thus the bank has a total capacity for 100 lines, exactly like a connector, but the connecting lines are always trunk lines. The trunk lines on the first level run to the connectors of the first 100-group, the trunk lines on the second level run to the connectors of the second hundred group, etc. Thus, if a telephone with a calling dial is connected to a selector, the first movement of the dial will select a row of trunk lines going to connectors of the selected 100-line group, and the selector will automatically select the first idle one and connect thereto before the calling party has time to dial again. The second and third movements of the dial will operate the selected connector as already stated. Thus any line out of a thousand can be selected by means of a selector and with a choice of the required number of trunk routes to each 100 lines.

To meet the average requirements of 10 simultaneous connections with each 100 lines there must be 10 selectors through which each group can be reached. Thus the 10 trunks from each line-switch group each go to 1 selector. As there would be 10 such groups, 100 selectors would be required to serve 1000 lines and each selector would be given one trunk line to each of 100 connectors.

A system of 10 000 lines would have 100 groups of 100 lines each. As the capacity of a selector is limited to 10 such groups (1000 lines) 2 sets of selectors are required. The line-switches connect with the first selectors, the first selectors select the second selectors, these select the connectors, and the connectors select the called lines. The first selectors select second selectors associated with particular thousands, and the second selectors select connectors associated with particular hundreds in the selected thousand. For 10 simultaneous connections for each 100 lines there would be required 1000 each of first and second selectors and 1000 connectors.

A system of 100 000 lines would have 1000 groups of 100 lines each, and 3 sets of selectors are required. The line-switches connect with the first selectors, the first selectors select the second selectors which are associated with particular ten thousands; the second selectors select the third selectors, which are associated with the particular thousands in the selected 10 000; the third selectors select the connectors which are associated with the particular hundreds in the selected thousand of the selected 10 000. For 10 simultaneous connections for each 100 lines there would be required 10 000 each of first, second, and third selectors, and 10 000 connectors.

It is the general practice to limit the line capacity of a central office to 10 000 lines, but from an automatic standpoint alone there is no necessity for so doing. Thus in a five-digit system, having an ultimate capacity for 100 000 lines, the first or ten-thousands digit selects the central office. When a small office is associated with such a system it is the practice to serve it through one of the larger offices by assigning to it a group of numbers which are a part of those of the larger office. All of the connectors for the assigned group and such selectors as are required for the selection of the connectors would then be located in the small office.

Order of Line Selection.—The connector alone will be considered first. When a line is connected through to a connector the dialing of the figure 1 steps the connector to the first level. Dialing the number 11 moves the connector to the first line terminal of the first level; dialing 12 moves the connector to the second line terminal of the first level, etc. Thus lines Nos. 11 to 19 are terminated consecutively on the first level, but line No. 10 is run to the tenth (and last) terminal of the first level. The entire arrangement of lines on the bank is given in the following table, which is arranged with the first level at the bottom to follow the order on the connector banks.

Level	Lines
0	01 to 09 and 00
9	91 to 99 and 90
8	81 to 89 and 80
7	71 to 79 and 70
6	61 to 69 and 60
5	51 to 59 and 50
4	41 to 49 and 40
3	31 to 39 and 30
2	21 to 29 and 20
1	11 to 19 and 10

It is evident that lines numbers 1 to 9 must be dialed as 01 to 09 and that the one-hundredth line must be dialed as 00, because a connector can only care for numbers with two digits; the number 100 can not be dialed on a connector alone. Numerically speaking, then, the lines of a connector run from 00 to 99. Still speaking numerically, lines 00 to 09 are the first 10 of the hundred, lines 10 to 19 are the second 10, etc., but the order of arrangement for dialing is such that lines 10 to 19 are referred to as the first 10, and lines 00 to 09 as the tenth 10.

In a system that has more than 100 lines each connector is always associated with a particular hundred and is controlled by the last two digits of the line number. Thus all of the bank position numbers of a connector become a part of higher line numbers, and in so far as the connectors are concerned, no line number begins with 0. For example, in dialing the number 6600 the first digit controls a first selector, the second digit a second selector, and the line 6600 is actually found on the tenth position of the tenth level on a connector associated with the sixth hundred group of the sixth thousand group.

In a 1000-line system there are 10 groups of 100 lines each. The trunks of the first selector level run to connectors serving the first hundred group, and according to the dialing requirements the lines in this group are numbers 100 to 199. The trunks of the second level run to connectors serving lines 200 to 299. The trunks of the tenth level run to connectors for lines 000 to 099, that is, the lines of the tenth hundred. Thus a 1000-line system has line numbers 000 to 999.

In a 10 000-line system there are 10 groups of 1000 lines each, and in each 1000-line group there are 10 groups of 100 lines each. The first thousand numbers are 1000 to 1999, and the tenth thousand numbers are 0000 to 0999. Thus a 10 000-line system has line numbers 0000 to 9999. Similarly a 100 000-line system has line numbers 00 000 to 99 999.

A 100-line system is referred to as a two-digit system. A 1000-line system is referred to as a three-digit system. Similarly a 10 000-line system is a four-digit system, and a 100 000-line system is a five-digit system. Because of the fact, however, that numbers of more than one digit beginning with 0 are considered undesirable from a dialing standpoint, 10 per cent of the numbers in any system are not available for station lines.

These are numbers 00 to 09 in a 100-line system, numbers 000 to 099 in a 1000-line system, numbers 0000 to 0999 in a 10 000-line system, and numbers 00 000 to 09 999 in a 100 000-line system. In each case the line-switches, selectors, or connectors which would be required for the numbers in the tenth hundred thousand or tenth thousand, as the case may be, are not furnished when such numbers are not used. It will be readily apparent that only the tenth level of the selecting devices which are controlled by the

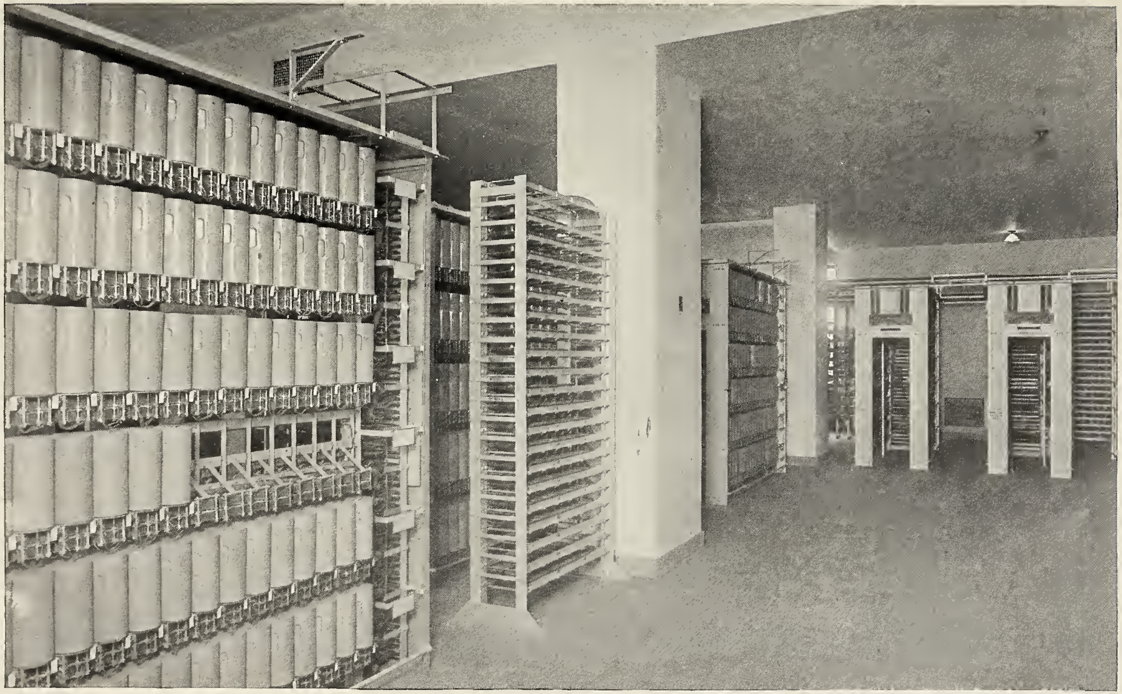

FIG. 28.—*Automatic switching equipment*

Attention is directed to the method of mounting selectors on steel frames known as trunk boards. It will be noted that each selector is inclosed by a metal dust-proof cover. These may be easily removed to give access to the mechanism. The line-banks require no covering because the dust is wiped off by the movement of the brushes. It will also be noted that one shelf is only partly equipped with selectors but fully equipped with line-banks. All line-banks are permanently wired to terminals located on one end of the frame. Additional selectors may readily be placed for the spare line-banks

first digit of the line numbers is made unavailable for selecting station lines.

The tenth level of the first selectors is thus made available for special line numbers, and it is the common practice to use this level for dialing the toll switchboard or an assistance operator. The switching equipment is so arranged that dialing one 0 only connects the calling line direct to the toll board or an assistance operator via the tenth level of the first selector.

The use of the figure 1 as the first digit of an automatic station call number is not desirable because a single movement of the hook switch at the telephone may have the same result as dialing 1, and because calling parties occasionally jiggle the hook before beginning to dial. The first level of first selectors is therefore commonly used for trunking to operators via a special train of selectors only. By this means code numbers having only a few digits may be used for calling operators where they are required.

Additional Functions of a Connector.—When the called line has been selected the connector will make electrical connection between the calling and called line if the latter is idle, but this it can not do if the line is busy. If the called line is busy, the connector reports the fact to the calling party by connecting his line to an interrupted electric circuit which causes the receiver at the calling station to emit a succession of buzzing sounds.

If the called line is idle, the connector proceeds to ring the called station and in so doing makes a simultaneous connection with the calling line whereby the calling party is enabled to hear a ringing tone each time the called station is rung. The ringing is stopped when the called party removes his receiver from the hook, and then the connector connects the calling and called lines together so that the two parties can talk.

The connector furnishes talking current for the called party except in some cases when it is associated with a toll switching trunk. The connector furnishes talking current for the calling party except when used on interoffice calls. The connector also reverses the direction of the current in the calling-line circuit when the called party answers for the purpose of operating registers, coin collectors, and operator's supervisory signals.

Party-line stations are usually provided with harmonic bells which are rung selectively. Party-line service therefore involves both the selection of the desired line and the desired station on the line. Each station is given a number which is a combination of its line number and its party number. As four-party line selective ringing service is the usual practice, that alone will be considered.

In each connector there is a ringing relay which on operation connects the ringing current to the called line. These relays have no selective functions. The ringing relays of all connectors ringing only individual-line stations are permanently provided with ringing current having the one frequency required. The ringing relays of all connectors ringing party-line stations must necessarily be provided with ringing current of the proper frequency to ring the desired station. The party digit is used to control the ringing frequency selection.

One method of effecting the ringing frequency selection is to assign selector groups for this purpose. Each group of 100 party lines is multipled as usual through all of the associated connectors, but the connectors are divided into 4 groups. The ringing relays of each group are permanently provided with current to ring a particular station on each line. The four groups of connectors are reached by trunks from four successive levels of the associated selectors. Thus when the calling party dials the ringing selection digit the selector selects an idle trunk to a connector from the level dialed; that is, a connector which will ring the desired station when the proper time for ringing arrives, which is after the last two digits have been dialed and the called line found idle. With this method the party digit appears in the station number as the third from the last.

Another method of effecting the ringing selection is to provide each connector with a rotary switch called a frequency selecting relay which is operated by the dialing of the ringing selection digit. The frequency selecting relay steps from position to position under control of the dial. In each operated position it connects ringing current of a particular frequency to the ringing relay and thus the final position reached determines the frequency of the ringing current which the ringing relay will connect to the called line. With this method the party digit may be either the last or the third from the last digit of the station number. The frequency selecting relay remains in the operated position until the entire connector is released.

Holding, Guarding, and Releasing Equipment.—To establish, hold, guard, and release a connection requires a very considerable amount of apparatus associated with the several switching devices. In the modern automatic system, as used for local service and excepting certain cases for rural service, the selection operation is controlled by the dial over the two-wire line circuit which is also used for speech transmission. During the selection process apparatus may be freely associated with the line circuit for selection purposes, but after a connection is established all apparatus except that actually required for the transmission of speech is disassociated from the talking circuit.

Each two-wire line is extended through central office cables to a line-switch. At its line-switch each line is associated with a third wire which serves for cutting off the line relay and for busy-test purposes in a manner which is similar to the use of the third wire in the manual system on multiple switchboards. The third wire of each line has a bank terminal on each connector on which its associated line has a terminal.

Each office trunk is a three-wire trunk and the third wire of each trunk has a bank terminal associated with each multiple terminal of its trunk. When a line-switch seizes a trunk to a first selector the third wire is cut through, and the selector closes the third-wire circuit. Thus the line relay of the calling line is cut off, the line-switch is held, and a guarding potential is placed on every multiple terminal of the calling line and of the trunk so that no other switch can seize either of these busy lines.

As each switch is seized in succession the third wire is cut through, and each switch holds those back toward the calling party until the next switch assumes the holding function, and as each trunk is put into service it is guarded against seizure by other switches. As the connector is the last switch, it finally holds the connection and thus controls the release. When the connector seizes the called line it closes the third-wire circuit of that line and thus places the guarding potential on all multiple terminals of that line. The closing of the third-wire circuit of the called line is done in such a manner that while its cut-off relay opens its line-relay circuit, it does not cause the seizure of a trunk.

The connector furnishes current to both the calling and called lines through relays which serve for transmission purposes and also to hold the connection. When the calling party hangs up, his third-wire circuit is opened by the connector, and his line, line-switch, and all selectors are simultaneously released, but the connector is not released until the called party hangs up also. When the connector is released it releases the called line and the line-switch of the called line also.

Repeaters.—In a multioffice system trunk circuits are required from office to office. For transmission reasons it is desirable to feed talking current to each office end of an interoffice connection if the two offices are separated by a considerable distance. Furthermore, it is undesirable, for several reasons, to carry the third wire, which is associated with each trunk, through the outside-line system. It is the usual practice in this case to introduce into each outside trunk line at the outgoing end a device known as a repeater. It is thus located between the first and second selectors. A repeater responds to dial interruptions of the calling line and causes corresponding interruptions of the trunk circuit.

A repeater also furnishes current to the calling party for speech transmission and for holding the connection, instead of the connector, which is of course located in the office of the called line. The connector in this case furnishes talking current for the called line only. It does, however, furnish current to the trunk line and repeater for holding purposes and reverses the direction of this current as usual when the called party answers. The reversal of this current causes the repeater to reverse the current in the calling-line circuit.

Primary and Secondary Line-Switches.—In large offices having heavy traffic loads it is the usual practice to provide a double group of plunger-type line-switches. Those on which the station lines terminate are known as primary line-switches. These trunk to the other group. The line-switches of this group are known as secondary line-switches, and they trunk to the first selectors. The first selectors are divided into groups of 100 each, and each such group of 100 serves 10 groups of secondary line-switches with 10 trunks to each group. Each secondary line-switch of a group connects with a different primary line-switch group, and thus each calling line may be connected through to any one of 10 secondary groups which have access to a total of 100 selectors. The result is that a very large number of lines is given access to one group of trunks to first selectors, and the saving in first selectors materially outweighs the extra expense for line-switches. The efficiency of trunk groups upon which this practice is based will be considered in the section on traffic.

Secondary line-switches are also used in large multioffice systems at the outgoing ends of interoffice trunks. They are interposed between the first selectors and the repeaters in such a manner that all of the station lines have access to all of the trunks in each group. By this means material economies may be effected in the number of trunks required to carry the load.

Rotary Connectors.—It is a very common practice for a single subscriber to have several central office lines. This is particularly the case for private branch exchange service. In all cases it is the practice to assign consecutive numbers to such a group of lines, but only the first one is usually listed in the directory and called. As in the manual system, it is necessary to connect with the first idle trunk of such a group. In the automatic system a rotary connector has been devised for this service. Such a connector is actually a combination of a connector and a selector. The first line of the group is selected in the usual manner, but if it is busy the connector automatically rotates its brushes to the first idle trunk or to the last line of the group if all are busy. The busy tone is not given to the calling party unless all lines of the group are busy.

Group Connectors.—In certain cases of private branch exchange service subscribers require more than 10 central office lines; that is, more than a single level of a connector can accommodate. A special connector known as a group or one-digit connector is used in this case. Such a connector can select an idle line out of a group as large as 100. This connector operates automatically as soon as the level has been dialed. It tests the lines in groups of 10—that is, level by level—and rotates in on the first level on which there is an idle trunk.

Reverting-Call Equipment.—The regular system of selectors and connectors handles calls to stations on all lines excepting to other stations on the calling line. A call for a station on the same line is known as a reverting call and is handled by a special reverting-call switch. Each station on a party line is provided with a list of numbers for calling the other stations on the same line. The calling party dials the proper number and then hangs up. When such a number is dialed the line is connected to a reverting-call switch, which operates like a connector as far as selection is concerned, but when it stops its brushes on the position selected they meet ringing-control circuits, which cause the bells of both the calling and called stations to ring as soon as the calling party hangs up. When the called party answers both bells stop ringing, and thus the calling party is notified to again remove the receiver for talking purposes. If the called party does not answer, the calling party stops the ringing of both bells by again removing the receiver from the hook and the final replacement of the receiver effects the disconnection.

Supervisory Equipment.—There are many operations of the automatic switching mechanisms which are guarded by supervisory signaling equipment in the form of lamps and bells, which are associated with the various mechanisms through relays. Each group of switches has its own signals, and master signals are provided which are associated with all groups. A master signal serves to locate the group, and the group signals to locate the device that has failed to function properly.

Traffic Registers.—Automatic registers may be readily associated with individual switches or with groups of switches, so that both the total traffic and its distribution can be exactly determined.

Manual and Automatic Switching Equipment Used in Combination.—Manually operated switchboards are provided for handling local calls from public telephones having coin collectors which are not operated automatically, message-rate calls from stations on party lines for which charge tickets must be written, and for handling calls to and from rural stations. These switchboards are placed as sections of one continuous switchboard which also usually includes sections for handling all or a part of the toll service.

Manually operated equipment is also provided for handling information calls, so-called intercepted calls, and assistance calls. This equipment may or may not be installed as sections of the switchboard referred to above.

Equipment for Public Telephones and Message-Rate Party-Line Service.—Each public-telephone line and each message-rate party line has a line lamp and an answering jack at the manual switchboard. All originating calls are handled by operators. Each such line is also provided with multiple terminals on regular connector banks so that any station can be called automatically. When connection is made to a line at either a switchboard or connector-bank terminal all other terminals are made to test busy.

The operator's position equipment differs from that used for the same purpose in the manual system. Answering cords are provided, but the usual calling cords are replaced by first selectors. Each answering cord and associated selector is provided with a listening key, a dialing key, a connecting key, a ringing key, and three supervisory lamps. If prepayment coin collectors are used, coin-collecting and coin-returning keys are also provided. Each operator's position is equipped with a dial.

A dialing key is used to connect the dial with the associated selector for calling purposes. A connecting key is used to connect the cord to the selector, and to thus connect the calling line to the called line. This key is operated when the called station answers, and in the case of public-telephone service when the required amount has been deposited. The ringing keys are for recalling purposes.

One supervisory lamp is associated with the answering cord and is controlled by the calling party in the usual manner. Another supervisory lamp is associated with the trunk to the selector by means of a relay which operates when the line current is reversed by a connector, and releases when the line current is subsequently reversed to its normal direction. This lamp is thus controlled by the called party. The third supervisory lamp is known as the connecting lamp. It lights when the called party answers as a notification to connect, and remains lighted until the connecting key is operated.

Equipment for Rural-Line Service.—Rural lines have terminals only on the manual switchboard. Both calls from and calls to rural lines are handled manually. The line signals may be either drops or lamps controlled by relays operated by ringing current. Each line has an answering jack and may have multiple jacks with busy signals of a toll-board type if required.

Calls from one rural station to another are directly switched by the operator, as she has jacks of all such lines within her reach. Calls from a rural station to an automatic station require special outgoing trunk lines from the rural switchboard to the automatic switching equipment. Such lines are commonly known as dialing lines. These are equipped with jacks, multipled with busy signals, if necessary, at the rural switchboard and terminate on selectors.

Calls from automatic stations for rural stations are made by dialing a special code number which causes the selection of a special line terminating on a lamp signal and an answering jack at the rural switchboard. Each of these lines is also provided with a message-register key if message-rate individual-line service is rendered. The operation of a message-register key causes the current furnished to the calling line to be reversed in direction and hence the operation of the associated message register. On all calls to and from automatic stations an established connection is held by the operator as well as by the calling party.

The operator's position equipment is arranged for connecting rural lines having magneto station equipment with automatic lines having common-battery station equipment, and reached via automatic switching equipment. Each operator's position is equipped with a dial, and the usual listening keys are provided for each pair of cords.

One cord of each pair has a ringing key and a supervisory lamp controlled by a relay which is operated by ringing current from rural stations. When the lamp is lighted it continues to burn until the operator answers with the listening key. No line current is furnished. This cord is used for answering rural-station calls and for calling rural stations on calls from automatic stations.

The other cord of each pair is used for calling automatic stations via dialing lines to selectors, for answering calls from automatic stations via selectors only, and for calling rural stations when the calls are from rural stations. Each of these cords has a ringing key for use on rural lines only, a dialing key for use on dialing lines only, and a supervisory lamp, which is operative in connection with automatic stations only. The lines to selectors are provided with equipment which enables the called station to control the supervisory lamp via the connector by means of current reversals. The lines from selector banks are provided with equipment which furnishes talking current and enables the calling station to control the supervisory lamp by means of relays only.

Equipment for Information Service.—In small offices an information operator may be placed at a position on the manual switchboard. In large offices the equipment may be mounted on special desks the same as in manual systems. The information operation differs from manual practice in that the information required is not given to another operator. The calling party uses the information obtained to make a new call. Information operators are called by dialing a special code number. Connections to information operators are made via selectors only. Hence there is no reversal of the calling-line current, and hence no operation of message registers.

Equipment for Intercepting Service.—Intercepting operator's equipment is also known as dead-number equipment. Calls for idle numbers, including those that have been recently changed or discontinued, are automatically switched to a special switchboard served by an operator who is provided with records similar to those of a multiple-marking operator in the manual system. The operations for automatically switching such calls not only care for individual-line-station calls but for calls for any station on a party line as well.

Intercepting operators inform each calling party that a wrong number has been used, what the correct or changed number is, or that the number called has been discontinued, as the case may be. Intercepting operator's equipment may also be used for intercepting calls from stations of subscribers who have been denied service. Although intercepting operators are reached via connectors the current in the calling-line circuit is not reversed, and hence no message register is operated. The answering equipment is arranged to prevent this operation on the part of the connector.

Equipment for Assistance Service.—Assistance operator's equipment is also known as complaint equipment. Parties having difficulty with the operation of the equipment, or who are unable for any reason to establish connection with the desired party, may secure assistance by calling an assistance operator. At the present time a special code number having more than one digit is commonly used for this purpose, but the numeral 0 is also used.

Assistance operators may or may not be provided with equipment for verifying "don't answer" or "busy" reports, but if not, other operators are provided for this purpose. Assistance operators may be provided with equipment for completing connections with which a calling party has had difficulty. Assistance operators are reached via selectors only, and no message register is operated except by the operator in case she completes a call.

SPECIAL EQUIPMENT FOR HANDLING CALLS BETWEEN AUTOMATIC-OFFICE AND MANUAL-OFFICE STATIONS

Special equipment may or may not be used for handling calls from automatic-office stations to manual-office stations. Special equipment in manual offices is always required for handling calls from manual stations to automatic stations. Separate trunks and trunking equipments are always provided for handling calls in each direction. The design of the equipment is greatly dependent upon the need for maintaining uniform operating methods.

Equipment for Calls from Automatic to Manual Stations.—In general, it is desirable that an automatic station shall obtain connection with any other station in the same local area by the single method of dialing the call number of the station regardless of whether all the stations in the area are automatic stations or whether a part of those stations are manual stations, but a uniform method has not always been found practicable. There are two methods to be considered.

Direct Operator Trunk Equipment.—By the first and also the older method of handling calls from an automatic station to a manual station the calling party dials a special code number to reach an operator in the office of the called station and gives the station number to the answering operator, who completes the connection. The incoming trunk lines may be terminated on regular line equipment at an *A* operator's position or on special line equipment at a *B* operator's position. In neither case are multiple jacks provided, as such lines can only be used for one-way traffic.

As incoming calls from another local office are usually handled by *B* operators, it is in some cases found more desirable to provide special equipment for these lines at a *B* position than to use regular equipment at an *A* position. As *B* positions are usually equipped for machine ringing, both the operating labor and ringing time may thereby be reduced. In some cases automatic listening equipment is provided to further reduce the operating labor and to make the operation conform more closely to regular *B* operation.

Call-Indicator Trunk Equipment.—By the second and later method of handling calls from an automatic station to a manual station the calling party dials the number of the desired station. The number which is dialed is displayed before an operator in the called office on a device known as a call indicator. The appearance of a call indicator is shown by the illustration (Fig. 41) associated with the description of the panel-type system.

It is evident that where the call-indicator system is used both the automatic and manual station numbers must be similarly arranged with respect to the office designation. With the automatic system in a multioffice local area having not more than eight central offices, the first digit of the call numbers controls the selection of a trunk to a particular office. If there are more than 8 and less than 80 offices in the local area, the first two digits control the office-trunk selection. In the manual system each office is known by a name.

When an automatic office replaces a manual office in a multioffice local area, two methods may be used for making the office designations similar. Either the manual offices may be designated by numerals prefixed to the station numbers, or the automatic office may be named. The latter method has been adopted for local areas having more than eight central offices. When names are used for all offices, automatic stations are provided with dials which bear letters as well as figures, and any station is called by dialing the first two letters of the office name and then the number. As the letters on the dial are associated with the figures, the dialing of a letter has the same result as dialing its associated number.

As has been previously explained, automatic party-line stations have individual numbers. They are not identified by letters, as is the usual practice for manual party-line stations. It follows that the dials provided for automatic stations routing calls to manual party-line stations designated by letters must bear letters in addition to the figures. If the dials used require letters for office designations, certain of the letters may also be used for station designations; otherwise special dials having party-line letters only may be used.

A call indicator has as many groups of numbers from 0 to 9 as there are numerical digits to be registered and in addition a set of party-line letters if required. Normally all figures and letters appear very faintly, if at all. A small lamp is placed beneath each figure and each letter. The lighting of a lamp brightly illuminates the associated figure or letter. When a number is displayed a figure in each group appears and also the party letter if one has been dialed.

The called numbers are received on registers. The registers are operated by the dials. A group of registers is associated with each call indicator. The number of registers per group is made sufficient to handle the maximum number of simultaneous or accumulated calls. Each incoming trunk line is provided with a register selector similar to a rotary-type line-switch. When a trunk is selected the calling-line circuit is closed through to the register selector via a repeater in the automatic office. The register selector immediately selects and connects the line circuit to an idle register.

A register includes a rotary switch for each digit to be displayed. Each such switch has a normal position, and 10 bank terminals connected to correspondingly numbered or lettered lamps in the digit group with which it is associated. When the first-digit switch has been moved a number of steps equal to the number dialed, and while the calling party is again rotating the dial the second-digit switch is associated with the calling line. The other digits are successively registered in a like manner.

When all digits have been registered an indicator signal lamp on the operator's keyboard is lighted. A so-called display key is operated to cause the number to be displayed. A signal lamp associated with the calling trunk line also lights and thus identifies the trunk cord to be used. The operator establishes the connection as usual in the manual system. When the plug is inserted in a jack of the called line the register is released and automatically restored to normal. Thus the lights are extinguished and the indicator is left free to handle another call.

The above arrangement may be varied by having a signal lamp and an assignment key associated with each cord. In this case the lamp associated with the trunk cord is lighted first, and the number wanted for that trunk is displayed when the associated assignment key is operated.

Manual Office Equipment for Calls to Automatic Stations.—As a manual station has no automatic equipment the calling party always gives the desired number to an operator. The *A* operators are provided with equipment for calling automatic stations as well as manual stations. Two methods are used for calling automatic stations. Which will be used depends largely upon the space available for mounting the equipment and upon which method is the more economical for handling the traffic.

Position Equipment Having Dialing Cords.—Each *A* operator's position is equipped with a dial and a dialing cord. Each outgoing trunk line to an automatic office is provided with two jacks at each multiple, one for the plug of the dialing cord and one for the plug of a regular switching cord. When handling a call, the operator inserts the plug of the calling cord in the regular trunk jack and the plug of the dialing cord in the associated dialing jack. She then operates the dial in the usual manner. The equipment may or may not be arranged for automatic listening. When the called party answers, the dialing cord is disconnected; it is then available for another call.

Position Equipment Having Dialing Keys.—Each operator's position is equipped with a dial, and each calling cord is provided with a dialing key which on operation connects the dial to the associated cord. The automatic stations are dialed in the usual manner.

Where space is not available for dialing keys special listening keys having an extra pair of contact springs and also an extra relay may be provided for each cord circuit for associating the dial with the calling cords. Once connected to a cord the dial remains so until the calling party answers or until the operator releases it by means of a special master key.

Trunk-Selecting Equipment.—Where a large number of trunk lines to an automatic office are required, either of two methods may be used to assist operators in selecting idle trunks. Either method may be used with either dialing cords or dialing keys.

One method is to provide each section of the switchboard with a sufficient number of nonmultipled lines to handle the maximum number of simultaneous calls. Each line is terminated on a selector of the rotary-switch type. When a plug is inserted in a jack the rotary switch automatically selects an idle trunk to the automatic office.

The other method which may be used is to provide a group-busy tone or group-busy lamps associated with the multiple trunk jacks. These jacks are usually mounted 20 to the strip. With the tone method, if all of the first 10 lines are busy the operator will receive a busy tone when she tests the first jack, and if all of the last 10 lamps are busy the operator will receive a busy tone when she tests the eleventh jack. The tone informs the operator that the next nine lines are all busy, and she skips them in her search. With the lamp method one lamp may be provided for each five trunk jacks which lights when the associated five trunks are busy. The operator tests only those jacks with which no lighted lamp is associated.

2. AUTOMATIC SYSTEM—TOLL EQUIPMENT

While toll service is rendered with a manually operated switchboard, this equipment is so associated with the local switching equipment as to utilize automatic switching devices to a large extent. At the present time toll calls originating at automatic stations are usually received by recording operators over recording trunks which are selected when the calling party dials 0.

In some cases, however, toll lines to near-by points are served by local toll operators who are reached by dialing a special code number. In this case a calling line is connected directly to the toll line.

A large number of offices are now being planned in which all toll operators will usually be called by dialing a special code number. The number 0 will be reserved for the assistance operator's call. In those cases, however, where the number of operators required is very small all operators may be called by dialing 0.

In those cases where the toll switchboard is located in the automatic central office building it is usual to assemble the toll switching sections with the other manual switching sections, thus making one manual switchboard. In those cases where long-distance toll lines are served by a centrally located toll switchboard only the toll lines to near-by points are served directly at the manual switchboard in an automatic central office.

At the present time only ring-down trunks, recording trunks, and toll switching trunks are commonly used. It is probable that *A–B* toll trunks and tandem toll trunks will be included in the future.

Ring-Down Trunks.—The equipment for ring-down trunks is usually similar to that of the manual system. In some cases special automatic equipment is provided to enable the calling toll operator to call the stations connecting with the called office, but this is not as yet the usual practice.

Recording Trunks.—Recording trunks are used for the same purpose as in the manual system. Recording operators are called from automatic stations by either dialing 0 or a special code number. These operators receive the calls, write memorandum tickets, and pass the tickets to toll line operators. Recording-operator trunks are always reached via selectors only, therefore the calling-line current is not reversed, and message registers are not operated when a recording operator answers. The equipment is usually arranged, however, so that an established connection is held by both the calling party and the operator. Both must disconnect to effect a release.

Toll Switching Trunks.—Toll switching trunks are used for the same purpose as in the manual system. Manual toll switching trunks are provided to rural operators and automatic toll switching trunks for calls to automatic stations.

Automatic toll switching trunks terminate on outgoing jacks at the toll board and on a special toll selector in the automatic central office. A special system of toll selectors and toll connectors is provided for selecting the desired line terminal and ringing the called station.

The equipment is so arranged that a toll operator can call a line terminal and hold the called line until she is ready to ring the station and so that should a busy line be called the connector will not only report that fact as usual but will seize and hold the called line as soon as it becomes idle. When the line becomes idle the connector also reports that fact to the operator by causing the operation of a supervisory signal. The release of the connection is controlled by the operator. Talking current for the called party may be furnished by either the connector or the last selector, depending whether the old or new method is used.

A number of toll connectors are associated with each group of local lines as well as a number of regular connectors. The toll connectors are so designed that they can also serve as regular connectors and are reached by trunks from both toll and regular selectors. The order of selection for local calls is so arranged that the toll connectors are only chosen when all regular connectors are busy. The order of selection of toll connectors for toll calls is the reverse of that used in selecting connectors for local calls. Hence toll connectors are to a certain degree reserved for toll connections.

Recording Operator's Position Equipment.—The recording operator's work is essentially the same as in the manual system, and she is provided with corresponding position equipment.

Line Operator's Position Equipment.—The position equipment for a line operator is similar to that provided for a manually operated switchboard. In addition, however, a dial is provided for each position and a dialing key is usually provided for each calling cord used for connection to a toll switching trunk. The calling supervisory signals are so associated with the toll switching trunks as to notify the operator when a busy line is seized, and when it becomes idle as well as when the called party answers.

Timing Equipment.—The timing equipment does not differ from that provided for manually operated switchboards.

3. AUTOMANUAL SYSTEM

The equipment of the automanual switching system includes a large amount which is the same as that used in the manual system and a large amount which is quite similar to that used in the automatic system.

Equipment Common to Other Systems.—The subject of equipment for the automanual system is naturally divisible into local and toll equipments, but inasmuch as the present practice is to manually switch all calls received at a toll board no detailed description of the toll equipment seems necessary. Toll operators are as usual provided with toll switching trunks to the local central office, and each of these is provided with automatic switching equipment. These trunks are, however, also associated with the local operators just as local lines are. The toll operator passes calls to the local operators who are provided with controlling equipment necessary for establishing the connections.

The subject of local equipment is, as usual, divisible into station and central office equipments, but reiteration may be avoided by stating that the station equipment may be the same as that of any manual system using common-battery equipment. The central office equipment also has its regular subdivisions, but the line-terminal equipment, protectors, and information equipment all conform to the usual manual practice. Traffic registers and manual switching equipments for special service are provided as in the automatic system, but in this case special equipment is provided for handling reverting calls.

The automanual switching equipment includes selectors and connectors, and the functions of these devices are similar to those of the automatic system, but the detail operations differ because of the radically different method of control. In addition the automanual system includes equipment for the preselection of an operator.

Automanual Switching Equipment.—With automanual equipment the calling party lifts his receiver from the hook and asks for the desired number in the manner which is usual in connection with all manual common-battery equipment. The calling party may, however, be served by any operator in the central office, as no particular group of lines is served by any one operator. The incoming calls are usually distributed automatically to the first operator of a series who is ready to receive calls.

Line Equipment.—Each line is provided with a line relay and a cut-off relay, as is usual for all common-battery systems. The line relay controls the signaling of an operator, and the cut-off relay has its usual function in automatic systems of cutting off the line relay when the calling line has been extended to the first switch.

Also, as is usual in automatic switching systems, each line has 10 multiple branches to be used in the selection of an idle trunk to a first selector, but in this system each of these branches runs to a contact on a relay. The 10 relays are each associated with a particular trunk. These trunks in this system are known as primary trunks. The third wire from the cut-off relay of each

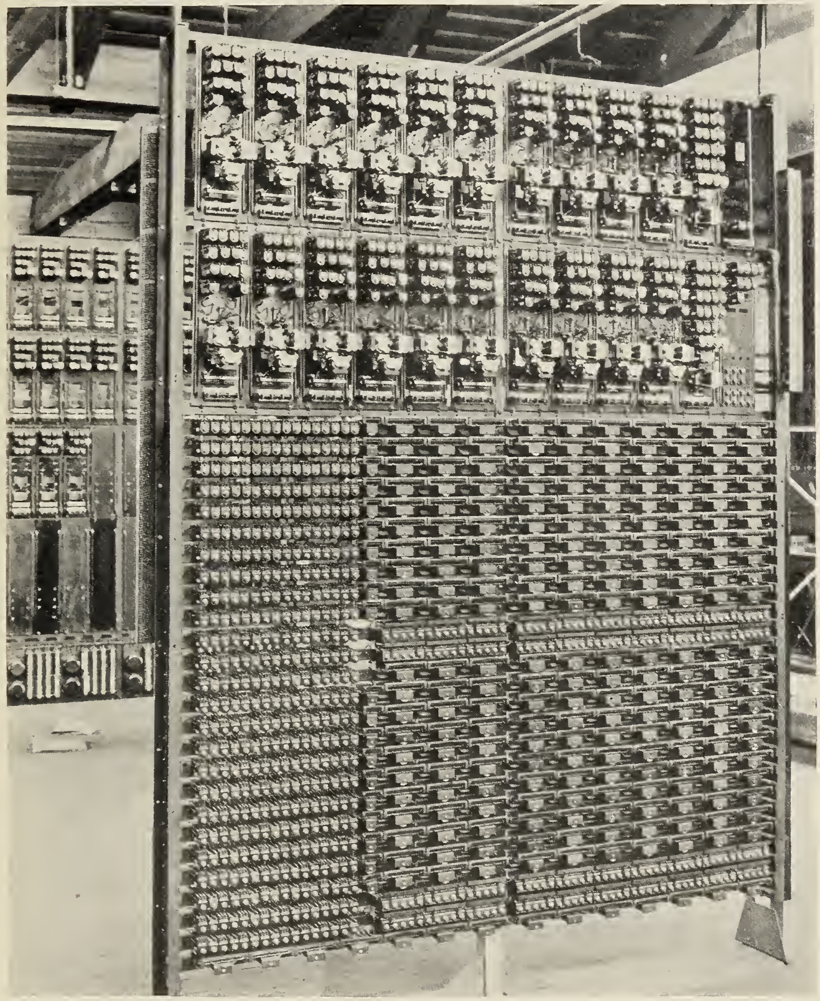

FIG. 29.—*Automatic switching equipment—automanual system*

The illustration shows a unit assembly of line equipment for 200 station lines, one group of 10 first selectors for each group of 100 lines, and the switching relays required to establish 10 simultaneous connections to first selectors for each group of 100 lines. Similar groups of switching relays are associated with the selector trunks for the purpose of selecting an idle operator and to enable the selected operators to control the selectors. These, however, are held busy only during the time required to establish a connection between the calling and called lines

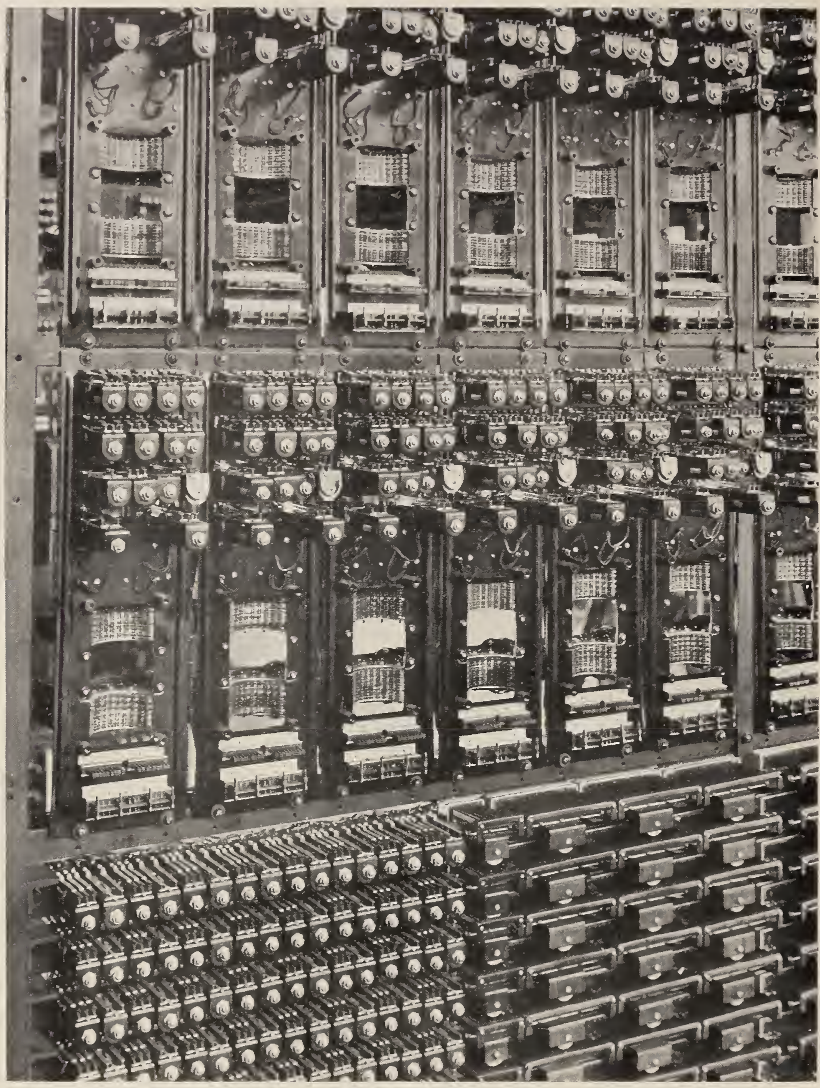

FIG. 30.—*Automatic switching equipment—automanual system*

This is a close-up view of a part of the equipment shown by Fig. 29. The relays in the lower left corner are line and cut-off relays arranged in pairs as usual. The relays to the right are multiple-contact switching relays. First selectors are shown above ,but the stepping mechanisms have been removed to permit a view of the banks. These selectors furnish talking current to the calling party and thus control release line is also run to contacts on each relay so that it is cut through to a first selector at the same time as the line. Each line also has the usual multiple branches (three-wire) to each connector through which calls may be received.

Each line relay has three contacts which are wired to a primary master control consisting of a system of relays and a rotary distributing switch. This control is common to a group of lines, usually 100, and determines to which idle primary trunk a calling line will be connected. It handles the calls in succession and in the order in which they are received up to the limit of its speed, beyond which it determines the order of preference. If, because of some defect in operation, connection of the calling line to a primary trunk in the regular order of selection is not effected within a predetermined time, the calling line is connected to the next idle trunk.

It has been stated that each line is multiple wired to contacts on 10 relays, each relay being associated with 1 of the 10 primary trunks to first selectors. To provide for direct connection between each line and each trunk by means of one relay would require an impractical number of relays. A multiple-contact relay for 10 lines has been developed for this purpose. Each relay has 30 contacts, that is, 3 for each line.

Each line of a numerical group of 10 runs to one set (three) of contacts on each of ten 30-contact relays. The operation of any relay of the 10 connects all 10 lines to a set of 10 intermediate wires called links. A trunk is multiple wired to 10 relays. Each of these relays is a three-contact relay, and the operation of any one connects the associated trunk to a link. By means of these relays each trunk may be connected to any one of its associated 10 links.

Thus to connect a line to a trunk requires the operation of two selector relays. The operation of the one associated with the lines connects individually the 10 lines in a particular tens group with 10 links associated with a particular trunk. The operation of one of the relays associated with a trunk connects one of the links to the trunk.

Each line of a hundred has, numerically speaking, a particular unit position in a particular tens group. The master control is such that when a call is received an idle trunk is selected, and that trunk is connected to the calling line through a 3-contact relay and link having a units position corresponding to that of the line relay of the calling line and through a 30-contact relay, having a tens position corresponding to that of the line relay of the calling line.

Operator Selection.—At each first selector the associated primary trunk branches, one branch going to the selector brushes and the other to an operator through an operator-selection system of apparatus and trunks. A large office (10 000 lines) requires the extension of the primary trunk via a secondary trunk and a tertiary trunk. For each 100 primary trunks 10 secondary trunks are provided. For a 10 000-line office with 10 per cent trunking 1000 primary trunks (and first selectors) are required. With 10 secondary trunks per 100 primary trunks there would be a total of 100 secondary trunks. Each tertiary trunk terminates on a lamp signal before an operator, and any secondary trunk may be extended to an operator by any tertiary trunk.

The extension of a primary trunk by a secondary trunk is effected through a secondary master control common to 100 primary trunks. Each primary trunk has a relay associated with a secondary control, and this relay operates like a line relay when the primary trunk is seized. The operation of this relay causes the control system to connect an idle secondary trunk to the primary trunk just as described for a primary control.

The extension of a secondary trunk by a tertiary trunk is effected through a tertiary control common to all secondary trunks. Each secondary trunk has a relay associated with the tertiary control, and this relay operates like a line relay when the secondary trunk is seized. The operation of this relay causes the control system to connect an idle tertiary trunk to the secondary trunk, but in this case the control also involves the selection of not only an idle tertiary trunk but one to an operator who is ready to handle the call.

Each operator is provided with a small desk as shown by the illustration. Each desk has three sets of equipment for handling calls. Each set has a group of three signal lamps and a group of keys both of which are associated with one tertiary trunk. One lamp of each set is a line signal lamp, and the other two act as operating signals. All of the keys in each set excepting two are arranged in a manner similar to those of an adding machine and are for the purpose of registering the called number. One of the other two keys is for answering and one for starting the switching operations. A set of lamps and keys is usually referred to as a key set.

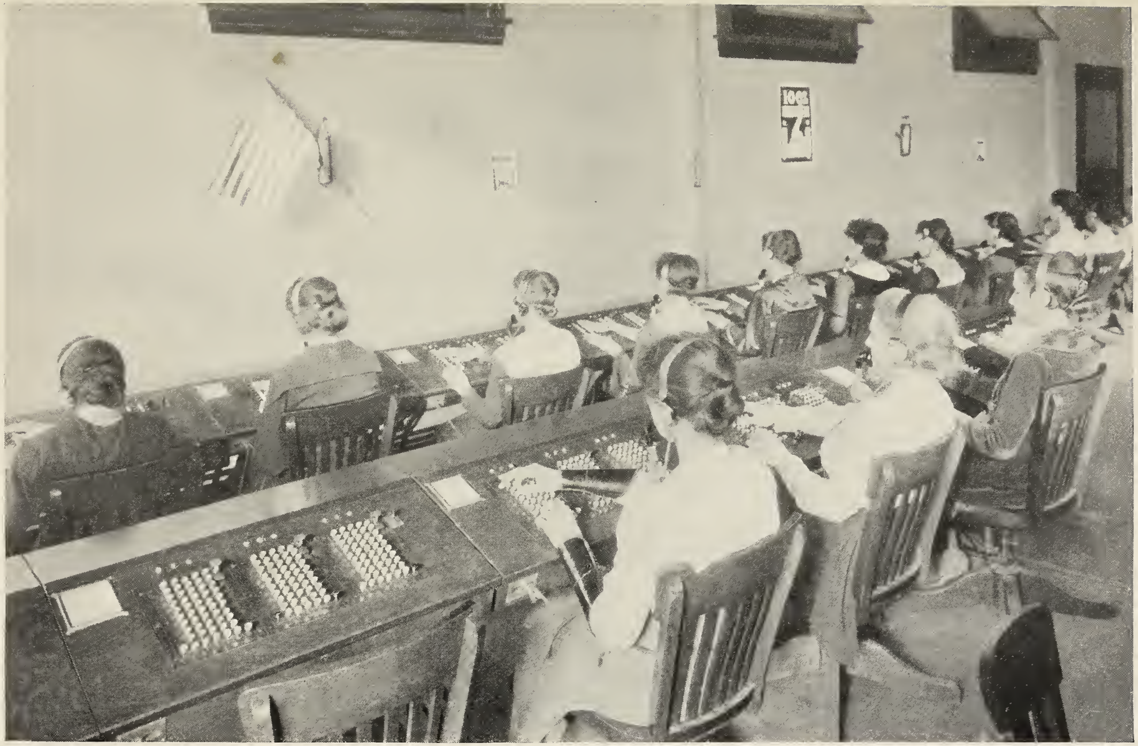

FIG. 31.—*Operating room—automanual system*

Each operator is provided with a small desk. Each desk has three call-handling equipments. Each of these comprises three signal lamps, an answering key, five rows of call-register keys, one for each digit, and a starting key. A call-handling equipment is held busy only during the time required to establish a connection between the calling and called lines

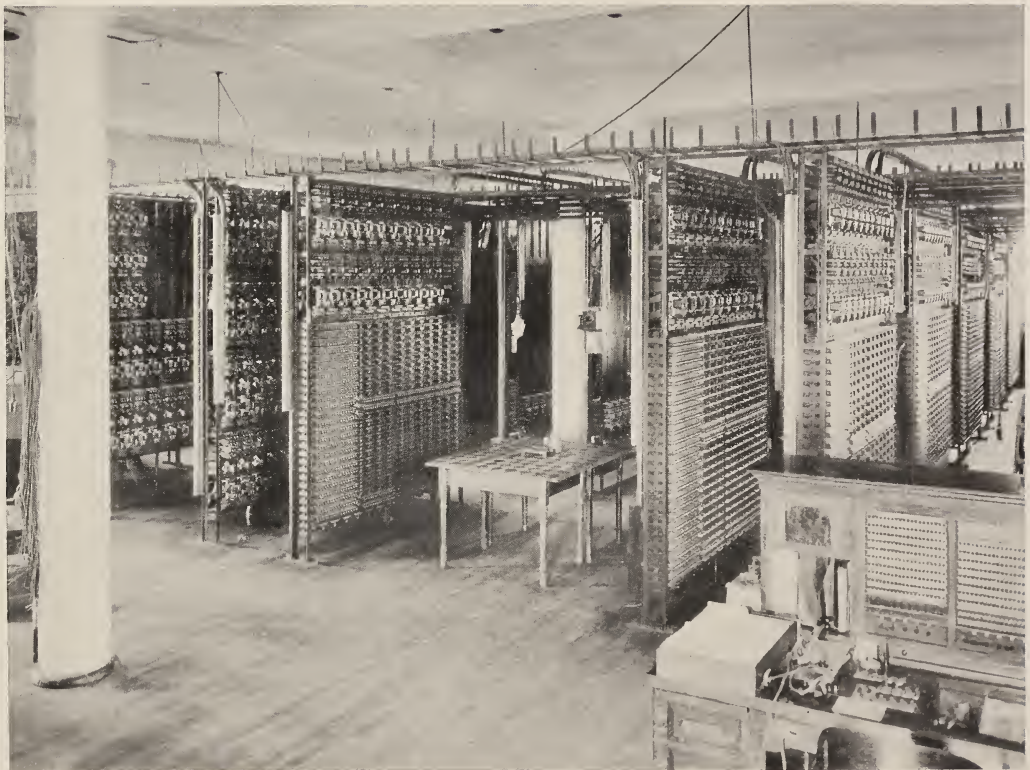

FIG. 32.—*Switch room—automanual system*

This illustration shows the general arrangement of the automatic switching equipment. The frames in the rear carry selectors and connectors only. The desk in the foreground is used for supervisory purposes and for testing

A set of selection relays is associated with each key set, and the relays in each set are so interconnected with those of all other sets and with the tertiary master control that a particular idle trunk will be selected. The selection is usually so effected that normally a call will be received by the first operator. Any position having a lighted line lamp is made busy to all calls, and the receipt of a call on such a position results in automatically switching the next call to the next position. Thus each call is received on the first position that has no waiting call.

Operators answer calls by operating an answering key associated with the lighted lamp. This operation opens the lamp circuit, connects the operator's telephone to the calling line, and leaves the position free to receive a new call on its first (in order) idle key set. Thus a call may await an answer for a very short time while the operator is handling a previous call. It requires a few seconds for the apparatus to complete a connection after the operator's work is done, and the key set is held busy until the connection is established. A fast operator may therefore have all three sets busy at one time, but this is unusual.

Manual Operation.—The answering operation has already been described. The operator obtains the desired number from the calling party in the usual way and then registers that number on the keys of the busy set exactly as a number is registered on the keys of an adding machine. Each key locks in the operated position and remains locked until another key in the same row is operated. Vertical rows of keys are provided for each digit of the numbers, for the party-line designation, and for other central office designations. After the operator registers the called number she operates the starting key and watches the other two lamps until both lights are out.

When a call is received two lamps light; the second lamp is known as a guard lamp. This lamp circuit is opened as well as the line-lamp circuit when the operator answers, but this operation causes the third or answering lamp to light. The operation of the starting key again lights the guard lamp and opens the answering-lamp circuit. The guard lamp remains lighted as long as the key set is busy. Thus a key set in use is always identified by a light, and the operating stages are indicated by the several lamps.

Automatic Operation.—A so-called sending system of relays and two rotary distributing switches is associated with each key set. It, together with the operated keys, controls the operation of the selectors and connectors and the disconnection of the operator's entire switching control from the primary trunk.

When the calling line is connected through to a key set the circuit of a temporary holding relay at the first selector is closed. This relay opens the line circuit to the brushes and connects an operating relay of the selector to one side of the line to the sender. Thus the selector is made ready to receive current impulses for selection purposes.

The impulse-sending system has a so-called revertive impulse control which is radically different from the control effected by a dial. The starting key closes a circuit which starts a train of operations. Each time the first selector circuit is closed at the sender the selector makes one step and simultaneously a rotary switch associated with the sender makes one step. After the selector has made a step it opens the line circuit which releases its motor magnet and also that of the rotary switch at the sender. The release of the motor magnet at the selector again closes the line circuit. Each step is made in the same manner and is registered at the sender.

The rotary switch of the sender above referred to has its controls wired to the number keys in such a manner that when the number of steps equals the first digit of the called number the line circuit is opened for a short interval during which period the first selector automatically seizes an idle trunk to a second selector, and the sender shifts the control to the second digit of the called number and continues the rotation of the rotary switch until the normal position is again reached. The above operation is repeated for each digit of the called number, thus operating each selector and finally the connector.

After the operations required by the last digit of the called number have been completed the sender continues to the normal position, opens the circuit of the guard lamp and releases the key set, tertiary and secondary trunks.

While the operation of the selectors and connectors differs in detail from that previously described for similar devices the operating principles do not differ. One conspicuous difference however may be noted. The first operation is a rotary one instead of vertical. Thus the trunks on the selector banks are grouped in vertical rows and on the connector banks the lines are terminated so that the ten groups are in vertical rows and the units of the tens groups in horizontal rows.

Holding, Guarding, and Releasing Equipment.—When a primary trunk is selected the calling line is connected thereto by the primary selection relays. The third-wire circuit is also closed through to the first selector and serves for holding and releasing purposes, but only with respect to the calling line equipment.

Battery current for the calling line is furnished through a relay of the first selector. This relay is thus held operated by the calling party, and it controls the holding and release of the primary trunk and first selector. It also has exclusive control of the holding and release of the secondary and tertiary trunks until the call has been switched through to an operator's key set. The holding and releasing of the secondary and tertiary trunks is effected by means of individual third wires and associated relays.

When the call is switched through to a key set, control of the release of the secondary and tertiary trunks is given to the associated sender. Thus the sender is enabled to release these trunks at the proper time, which is when the sender has returned to its normal position. When released these trunks become entirely disconnected from the connection they have just served to establish and are therefore freed for similar service on other calls.

The holding of the calling-line equipment, the primary trunk, and first selector is not successively transferred to the second selector and finally to the connector as previously described for the automatic system. The first selector controls the holding and release of the second selector and the second selector has similar control over the connector, but only up to the time the called party answers. These controls are effected as usual by means of third wires associated with the respective trunks. The connector furnishes battery current to the called line through a relay which controls the release of the connector.

The guarding operations with respect to the calling line, second selector trunks, connector trunks, and the called line are, as usual, for automatic switching. When a connection is made to each third wire a guarding potential is placed thereon which prevents seizure at any multiple terminal. The primary, secondary, and tertiary trunks are directly selected through their respective controls and the selection circuit in each case is open with respect to all busy trunks.

Supervisory Equipment.—Important operations of this equipment, as with other automatic equipment, are guarded by supervisory signals in the form of lamps and bells. In addition a special supervisory switchboard is provided for the chief operator. This board is equipped with signal lamps which are duplicates of those of the operator's key sets. By this means all of the operations can be supervised.

4. PANEL-TYPE MACHINE SWITCHING SYSTEM—LOCAL EQUIPMENT

The local equipment is fully automatic in operation for the classes of service usually required in a large city. These include message-rate two-party line service and public telephone service handled with the prepayment type of coin collector.

Rural line service, when required, is handled on a manual switchboard associated with the machine switching equipment. In those cases where only a small amount of public telephone service is to be rendered with prepayment coin collectors it may be handled on the manual switchboard. Should public telephone service be rendered with postpayment coin collectors or should message-rate four-party line service be required these also are handled on the manual switchboard.

This system is designed for extensive use in large multioffice areas where it is impracticable to convert all offices from manual to machine switching equipment at one time or in many cases even in a short period of time. Hence in most cases equipment must be provided for handling calls between machine-office and manual-office stations.

TELEPHONE STATION EQUIPMENT

Most of the telephone station equipment does not differ from that of the replaced manual system. Dials are provided for each station having machine-switching service.

EQUIPMENT COMMON TO MANUAL SYSTEM.—The descriptions previously given of permanent magnet receivers, transmitters, biased bells, and inside wiring apply to this system. The carbon-block air-gaps to earth included in the protector differ in detail from those of the manual system. One carbon block of each pair is much smaller than the other and is cemented in a slot at the center of a porcelain block which maintains the required separation of the two carbon blocks. The heat produced by the passage of a strong current will melt the cement and the small carbon block is then driven into contact with its mate by spring pressure. Extension bells and extension stations, with or without keys, also signs, booths and supervisory equipment for public telephone stations, are all provided as in the manual system.

FIG. 33.—*The dial—panel-type system*

Each finger-hole, excepting the first and last, is designated by three letters in addition to a figure. The first two or three letters of the called-office name are dialed before the station number

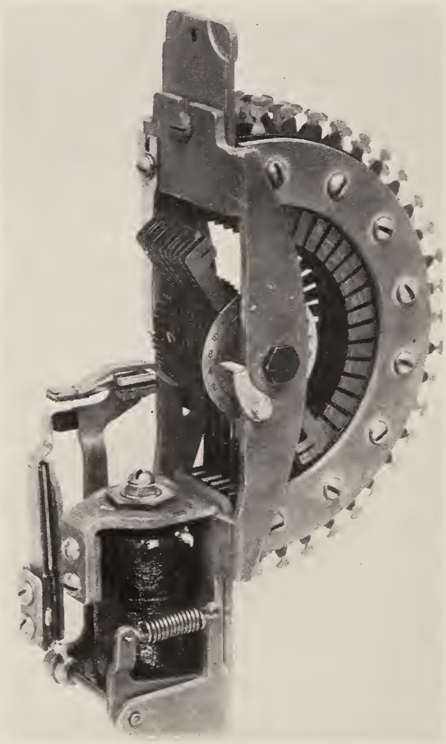

FIG. 34.—*A rotary switch—panel-type system*

The semicircular bank carries terminals for 22 lines and has 6 contact pins per terminal. The 6 brushes are moved simultaneously from terminal to terminal by the motor magnet. A position-indicating disk is attached to the brush shaft and a pointer is attached to the frame. (See page 102.)

Coin-collecting devices identical with those used in the manual system and of either the postpayment or prepayment type may be used but the latter is considered as the standard. Coins are automatically collected or returned with prepayment collectors on a call to any station reached by dialing the station number depending upon whether or not the called station answers. The collector is operated when the calling party hangs up the receiver.

The Dial.—The appearance of the dial is shown by the illustration. It bears 24 letters and 10 figures. Three letters are associated with each of the figures 2 to 9 inclusive. The dialing of a letter is equivalent to dialing its associated figure. The call numbers are listed in the directory together with the office designation as in the manual system except that either the first two or first three letters of the office designation are printed in capitals and are to be dialed first. An example is COLumbus 4739 which is really equivalent to 2 654 739 but is more easily remembered. In the smaller systems two letters and in the larger systems three letters are capitalized.

A dial tone is furnished by the central office equipment when the necessary preliminary switching operations, caused by lifting the receiver from the hook, are completed. The calling party waits until this tone is heard and then begins to dial. The operation of the dial causes the called number to be registered on certain central office equipment which then assumes control of the required selection processes. In the case of a call for a manual office station an operator in the called office is signaled. When she answers the called number is automatically passed to her and is shown by means of illuminated figures on a call indicator. In the case of a call for a station reached via an operator in the machine switching office or in a toll central office a special code number is used for routing the call and signaling an operator.

Private Branch Exchange Equipment.—This system of machine switching is so designed that it will operate in connection with the previously described automatic system and equipment of that type is used for private branch exchanges when automatic switching equipment is required. The two systems may be so arranged that the private branch exchange stations may be called from machine stations without the aid of an operator.

Large cities usually have extensive private branch exchange developments. These include some large and many small installations where manual operation may be desirable. Manual switchboards used in connection with this system are provided with dials and dialing keys. In some cases the stations also may have dials and the cord circuit equipment of the switchboard is then so arranged that the dialing for outward calls may be done at the calling stations.

CENTRAL OFFICE EQUIPMENT

All outside lines are terminated on vertically arranged protectors and all inside lines are terminated on horizontally arranged terminal blocks. Both protectors and terminal blocks are mounted on a main distributing frame and cross-connecting wires are run as in the manual system. The inside lines for machine stations terminate on equipment for switching such lines to selectors which handle originating calls and on multiple banks associated with selectors which handle terminating calls. The inside lines for manual stations, if any, terminate on signals and jacks on the manual switchboard and, excepting rural lines, may also have bank terminals for terminating calls.

Machine Switching Equipment.—As in any other machine switching system the number of a line or station is the basis for its automatic selection. The number in this case includes the letters. The letters determine the selection of a multiple terminal of a trunk line to the desired central office and the figures determine the selection of a multiple terminal of the desired line in the selected central office.

The multiple line terminals are assembled in banks with the terminals arranged in straight lines in both the vertical and the horizontal direction. The banks are mounted on steel frames one above another and appear as panels of the frames. The frames which carry the banks also carry the selectors. Each selector frame has five banks and a number of selectors. The selectors travel only in a vertical direction. Each bank has terminals for 100 trunk or station lines multipled before all of the selectors on the frame. By means of five sets of brushes each selector has access to multiple terminals for 500 lines.

The code letters representing the name of the called central office are equivalent to a number, but this number has no decimal relation to the number of the called line and no fixed relation to the location of the multiple terminals of the trunk lines to the called office. In this system the equivalent number which is registered must not only determine the routing but the class of call to be handled as well, because calls of different classes must be

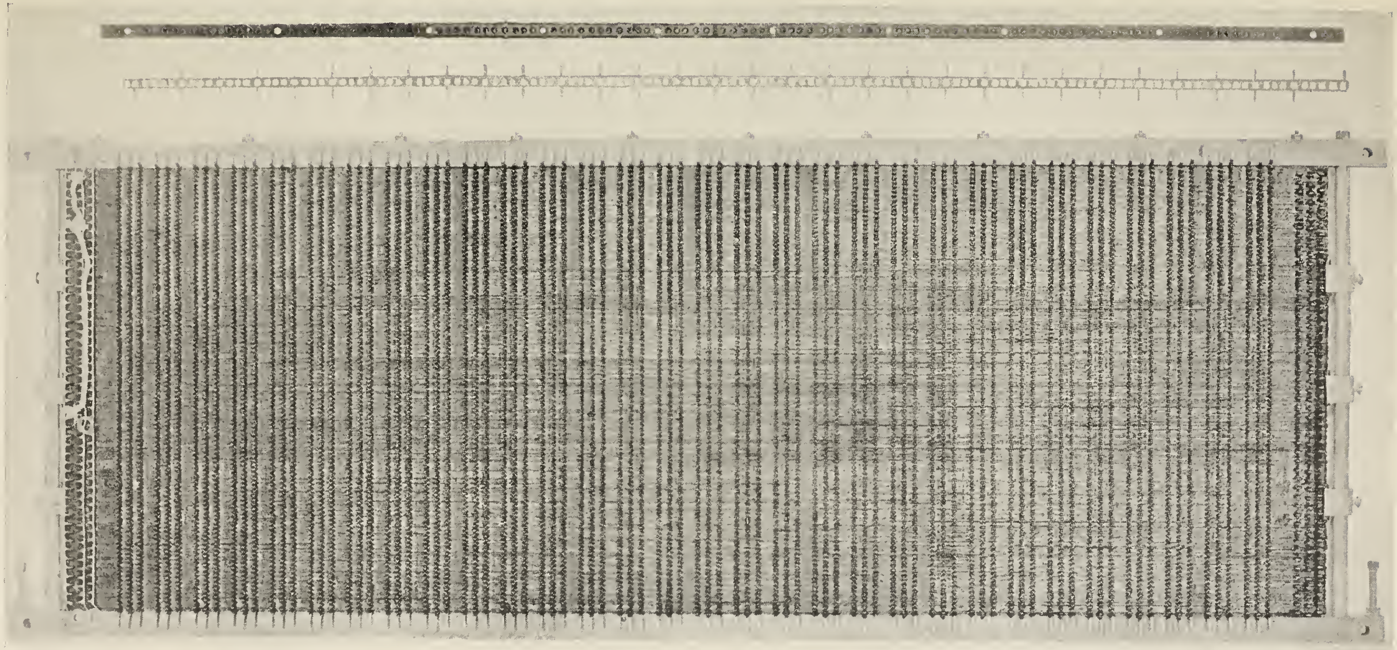

FIG. 35.—*A selector bank—panel-type system*

The illustration shows: One side of a completely assembled bank for 100 lines; one of the metal strips having 30 contact pins and one wiring pin on each edge; and one insulating strip. Three metal strips, separated by insulating strips, are provided for each line, and the pins are horizontally spaced to provide 30 sets of 3 pins each on each side of the bank. Thus each line has 30 multiple 3-pin terminals arranged horizontally on each side of the bank. The terminals for 100 lines are separated by insulating strips and assembled in vertical alignment. The entire bank contains 300 metal strips, 6000 terminals, and 18 000 contact pins

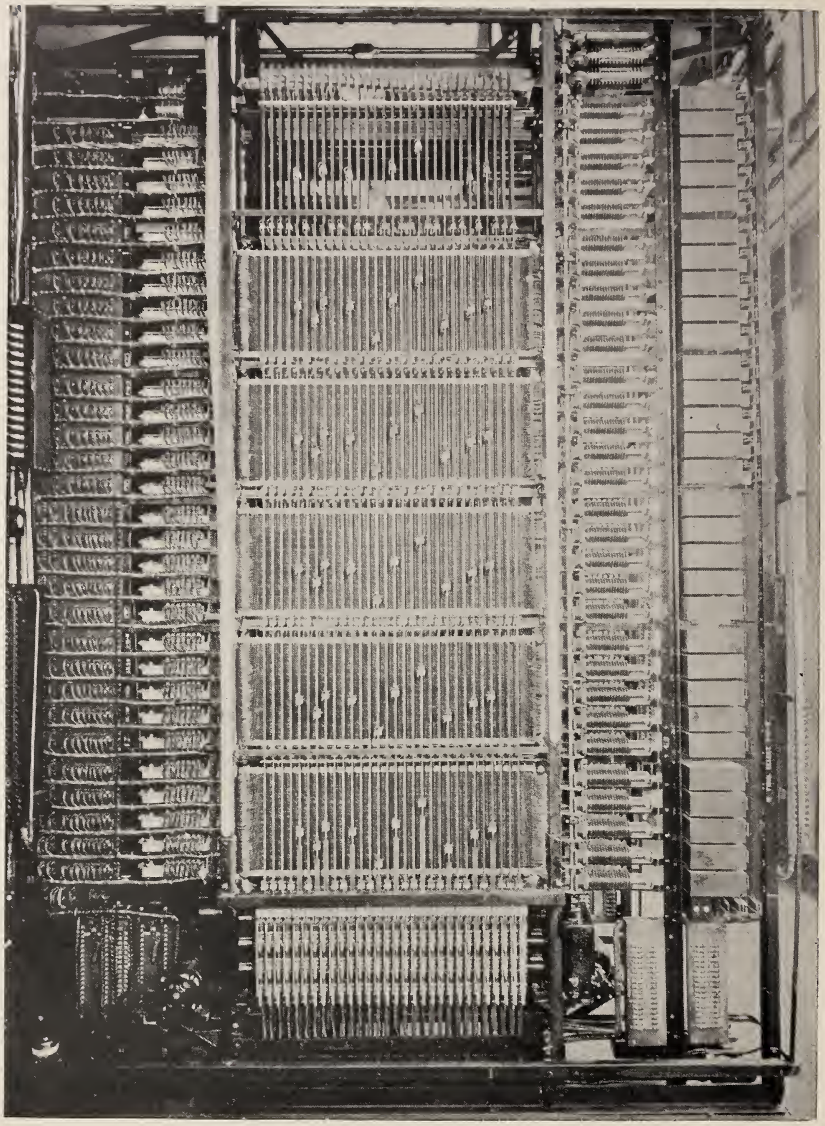

FIG. 36.—*A selector frame—panel-type system*

This frame carries five 100-line banks in vertical alignment, and 30 selectors on each side. Each of the 60 selectors has access to one vertical set of multiple terminals for 500 lines by means of sets of brushes associated with each bank. All five sets of brushes on a selector rod move simultaneously, the movement being limited to the height of one bank. Only one set of brushes can make contact at a time, the required set being preselected. The driving rolls and clutches are located below the banks. The commutators are located above the banks. The sequence switches are to the right of the banks. The relays are to the right of the sequence switches and inclosed by metal covers handled differently. A translating device is therefore provided which furnishes both controls required for each combination of letters which may be registered.

The number of a line has a fixed relation to the location of its multiple terminals, but in this system the station line terminals are divided into groups of 500 each as well as into groups of 100 each. Thus the selection of a multiple station line terminal involves the selection of a 500-line group in the called 1000 line group before the 100-line group is selected. The selection of the 100-line group is followed by the selection of a 10-line group, and then a terminal of the called line as in other systems.

Each station line is associated with a switching device. The main operating function of this device is to connect a calling line to an idle selector. In a few cases a rotary line-switch is provided for each line. A line-switch has access to a group of selectors. It selects a trunk line to an idle selector, and connects the calling line thereto. In other cases a switching device called a line finder is provided for each trunk line to a selector. A line finder has access to a group of station lines. A line finder selects or finds the calling line and connects the selector thereto.

Those selectors which have occasion to select an idle trunk from a group of trunks do so automatically, but all other selection operations are effected under the control of a device called a sender. A group of senders is associated with a group of first selectors via a single rotary switch called a sender selector. The entire selection system is so dependent upon the arrangement of the bank terminals and upon the design and operation of the selectors that these will be considered first.

Panel-Type Banks and Selectors.—A set of 3 flat metal pins is provided for each line terminal. Sixty such terminals are provided for each line. These are arranged horizontally with 30 on each side of the bank and are multipled together; in fact, corresponding pins are merely projections on a flat metal strip. The wiring terminals are on the ends of the metal strips. Thus both sides of the bank are accessible for selection purposes.

The 3 pins of a set are actually on slightly different levels for assembly reasons, but essentially the 30 sets on each side of the bank constitute a bank level. Each selector bank has 100 such levels. As shown by the illustration of a selector bank, the sets of pins on each level are so spaced that each face of the bank has 30 groups of multiple terminals for the same 100 lines arranged in vertical order.

Five such banks are mounted on each selector frame with the terminal pins in vertical alignment. One selector may be placed in front of and have access to each group of terminals for 500 lines which are in vertical alignment on the 5 banks. Hence 60 selectors with vertical motion only may have access to the same 500 lines. This arrangement is shown by the illustration of a selector frame. Thirty selectors of the 60 are, of course, not shown, as they are on the other side of the frame.

Each selector has 5 sets of line brushes, a brush-support rod, a rack for driving and centering, an up-drive clutch, a down-drive clutch, a set of 5 brush tripping fingers attached to a trip-rod, a trip magnet, a set of commutators and commutator brushes, one or more relays, and a sequence switch. Each 30 selectors on one side of a frame has a set of 2 power-driven friction rolls, which are kept in motion at the proper speed and in opposite directions, for driving the selector brush-support rod up or down as determined by the clutch energized.

Both the line brushes and the commutator brushes are attached to the brush-support rod. The movement of this rod is limited to a distance somewhat greater than the height of one bank. The five sets of line brushes are respectively associated with the five banks. The commutator brushes are all attached to the upper end of the brush-support rod and the commutators are mounted upon the frame directly above the banks. The commutator brushes make electrical contact with their respective commutators when the line brushes align with the bank levels involved in the respective processes. Thus certain control circuits are opened and closed as required by the position of the line brushes.

The five sets of line brushes are multiple wired and connected to the stationary equipment via commutators which close the connections at the proper time. Each set of brushes has a cam which, in the normal position, holds the brushes so that they can not contact with the bank terminal pins. A set of brushes is brought into the contacting position when a trigger on the cam is moved downward by a tripping finger. Normally, all the line brushes are six preliminary steps below the first levels of their respective banks. The five tripping fingers are placed on the trip rod at different elevations with respect to the associated brushes. The first set of brushes must be elevated one step to align with the trip finger, the second set of brushes must be elevated two steps, etc.

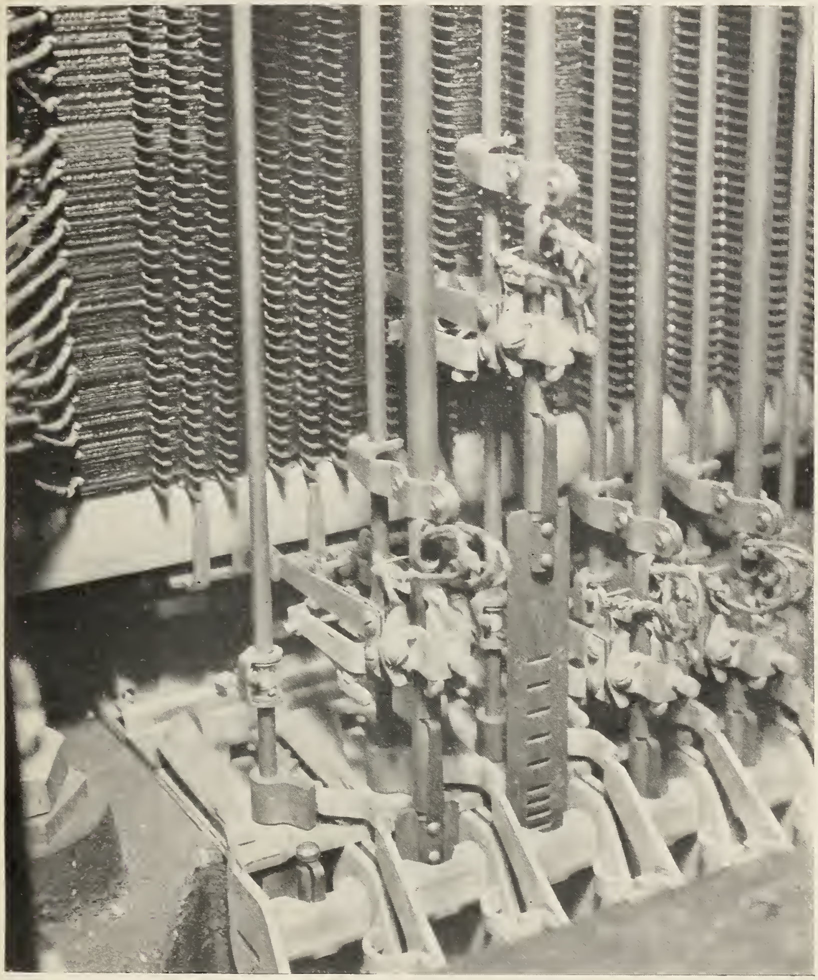

FIG. 37.—*Selector mechanism—panel-type system*

This is a close-up view of the brush mechanism of a selector and of the upper end of the rack which drives the brush-support rod up and down. Each set of brushes is normally held by means of a movable cam in a position to clear the bank pins. The cam is moved to permit contact by means of a tripping finger carried by a trip rod having rotary motion only. One of these rods is shown by itself at the left of the illustration. Each trip rod has five tripping fingers to engage the five sets of brushes, but the fingers are at five different elevations with respect to the normal positions of the five sets of brushes. A set of brushes must be elevated a number of steps equal to the brush number to align with its tripping finger. The trip rod is then rotated, and on the next upward movement of the brush rod the brushes are moved into the contacting position. The tripping operation is always completed before the brushes reach the first bank level

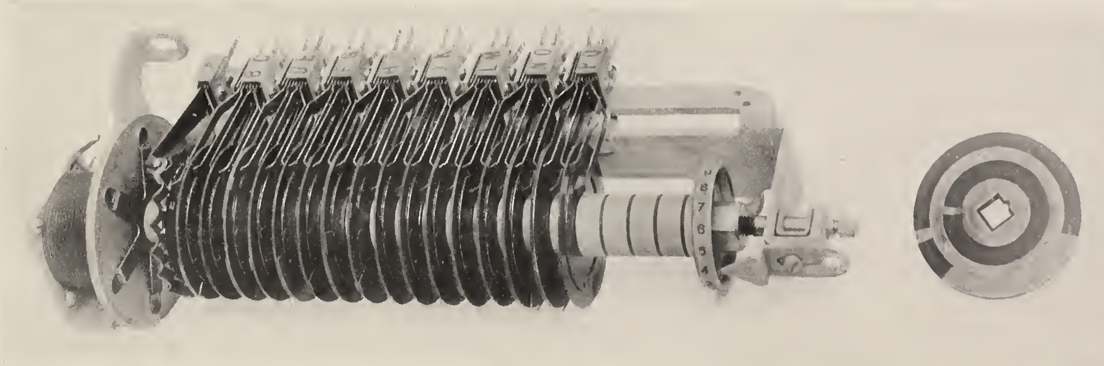

FIG. 38.—*A sequence switch—panel-type system*

The illustration shows a completely assembled sequence switch and one of the disks known as a cam. Space is provided on the shaft for 20 of these cams. Two brushes are provided for each side of each of these cams. A sequence switch has 18 stop positions which are indicated by the index wheel and pointer. Each cam comprises an insulating disk with metal rings on each side riveted together. The rings are cut with inner and outer segments to make contact, respectively, with the two brushes for those positions during which contact is desired. The switch is driven by means of the magnetic clutch at the left end and a vertical shaft which is kept rotating continuously. (See Fig. 36.) A sequence switch enables the establishment of a large number of circuit arrangements in a predetermined order

Thus the selection of a group of 100 lines is a brush-selection process. The set of brushes that will be tripped corresponds to the number of preliminary steps all the brushes are elevated. The spacing of the preliminary steps is determined by a commutator. The trip magnet swings the trip fingers so that the one in alignment with a trigger can engage the trigger and trip the set of brushes on the next upward movement and before the brushes reach the first level of a bank. The brushes are restored to normal by engagement with a horizontal plate when the support rod is driven to the normal position.

As shown by the illustration, the sequence switch is a rotary switch having a number of nonconducting disks bearing metal rings on each side. The rings on the two sides of a disk are electrically connected and each is notched or cut out to form segments. Two brushes are associated with each ring. A particular ring may have segments on its inner edge, on its outer edge, or on both edges. One brush contacts with the segments on the outer edge or with the entire ring if there are no segments on the outer edge. The other brush contacts with the segments on the inner edge or with the entire ring if there are no segments on the inner edge. A sequence switch has a magnetic clutch. When energized a metal disk engages a similar disk attached to a continuously driven shaft and thus the switch is rotated.

The sequence switch is used to switch the circuits of the selector as required by the different selection processes and as required for the operations individual to the different selectors. Each sequence switch has 18 stop positions, one of which is a normal position. Sequence switches can not be driven backward. Once moved out of the normal position a sequence switch must pass through all positions to reach the normal regardless of whether a call has or has not been abandoned.

The multiple line terminals on each bank are always divided into groups, but there is no corresponding spacing on the banks. The grouping is determined by means of a commutator. The brush selecting operation is followed by a group selecting operation which causes the selected brushes to move to the first line terminal of the group. Both brush and group selections are effected under control of a sender.

All selectors except those which connect with station line terminals automatically select the first idle trunk in the preselected group when the first line of the group is found busy.

These are known as trunk-hunting selectors. Each group of multiple bank terminals which serves a particular group of trunks is given one extra level of multiple terminals known as the overflow level. When all trunks of a group are found busy the selector brushes stop on the overflow level. By means of a commutator a differential operation is obtained which causes a busy tone report.

The groups of multiple terminals on the banks of those selectors which select station line terminals each serve 10 lines. Both the tens and units selection processes are controlled by a sender. These selectors automatically select the first idle line of private branch exchange groups when such an operation is required. A commutator is provided for each of these selection processes.

The line circuit to the selector brushes is always open while the brushes are being moved so that interference with other lines is avoided. The releasing of a selector involves moving the brush-support rod to the normal position where the brushes are reset, advancing the sequence switch to its normal position and guarding the selector against seizure during the releasing operations.

Rotary-Type Line-Switches.—Each line-switch has two relays, a motor magnet and a rotary switch which has a normal position and 22 connecting positions. The rotary switch and motor magnet are shown by the illustration. One relay is a line relay and starts the operation. The other relay is a combination cut-off and connecting relay. Each trunk line to a selector has four wires, two for dialing, talking, and holding the selector, one for holding the line-switch and one test wire which tests busy when the associated selector is busy.

When a call is originated the motor magnet is connected to the test wire of each trunk in succession until an idle one is found. The calling line is then connected through to the selector, the selector sequence switch is advanced to the first operating position, the line relay is cut off and both the third wire of the calling line and the test wire of the trunk are made to test busy. The test connections are such that if the calling line is any one of a group of private branch exchange lines excepting the last, a comparatively weak busy test will result. Thus such busy lines are differentiated from all other busy lines.

On an originating call the line-switch is held in the operated position by the first selector. When a terminating call is received only the cut-off relay is operated by the selector making the line

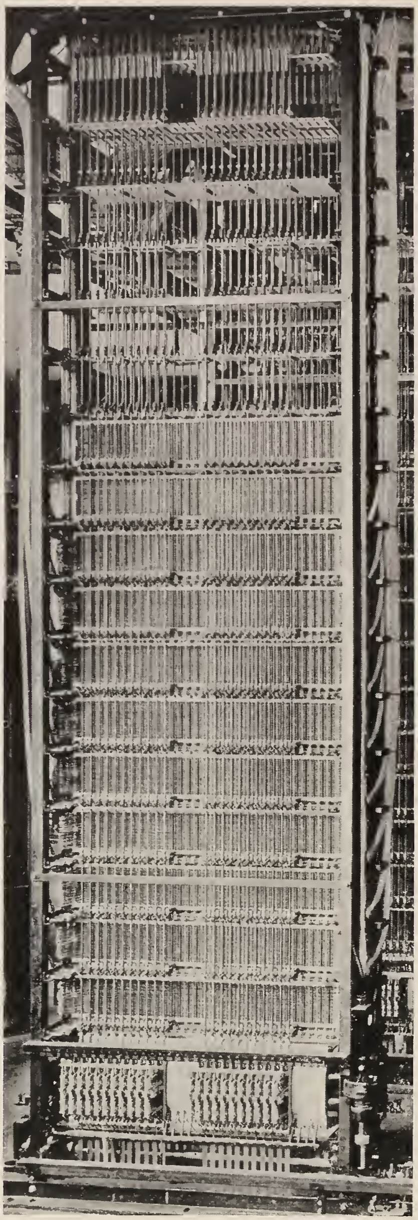

FIG. 39.—*A line-finder frame—panel-type system*

A line finder is essentially a selector having the function of finding a multiple answering terminal of a line of a group with which it is associated, when a call is originated on that line, and connecting a first selector and a sender thereto. A comparatively large number of lines may be served by a comparatively small number of line finders. The structural arrangement of a line-finder frame is similar to that of a selector frame. Each bank has multiple answering terminals for only 20 lines but a fully equipped frame carries 15 such banks. Each line finder has as many sets of brushes as there are banks on the frame, and therefore may have access to as many as 300 lines connection. In this case the operation of the cut-off relay merely cuts off the line relay.

Message registers for individual and two-party-line service may be associated with the line-switches. These are operated automatically by the first selectors on completed calls to all stations reached by dialing a station number. These stations include manual office stations. The two-party-line registers are so associated with the lines that the proper register is operated.

Line Finders.—The mechanism of a line finder is similar to that of a panel-type selector. A group of line finders serves a group of station lines. Each station line has a line and a cut-off relay as usual, a four-wire circuit and multiple bank terminals on a line-finder frame for answering purposes. The operation of the line relay closes a battery connection to the multiple bank terminals of the fourth wire which serves to identify those terminals for the associated line finders. The operation of a line relay also closes a start-control circuit which causes only one line finder to make connection with the calling line.

The construction of a line-finder bank is similar to that of a selector bank but each bank has multiple terminal levels for only 20 lines. Furthermore the multiple terminals for each such group of station lines and the finders that serve them are divided into two equal subgroups. One subgroup of line terminals count upward and are normally served by one subgroup of finders. The other subgroup of line terminals count downward and are normally served by the other subgroup of finders. When all finders in one subgroup are busy those in the other subgroup are available for either subgroup of lines. With this arrangement the average time required to find a line is somewhat more than would be required to find 1 line in a group of 10.

The illustration shows a partly equipped line-finder frame. Such a finder frame usually carries 15 banks; therefore a line finder has 15 sets of brushes. A group of line finders is so associated with a group of station lines that calls are usually handled in succession. Brush-tripping equipment is therefore provided for each bank having terminals for the same 20 lines and common to the associated brushes of all the associated finders. The 2 tripping rods required for each such bank are placed horizontally, one on each side, just below the bank and are operated simultaneously.

Calls may accumulate, and equipment is therefore provided for determining the order in which they will be handled. Two calls may be handled simultaneously only when the calling lines have terminals on the same bank and are in different subgroups and when there is an idle finder in each subgroup. Equipment is also provided for distributing calls among all the finders in each subgroup.

When a line finder is started the sender selector is also started and seeks an idle sender unless it is associated with one at the time. The line connection from the finder to the first selector is opened during the time required for finding the calling line and an idle sender. When the terminal of the calling line is reached by the brushes, the finder is stopped, the line relay is cut off, thereby disassociating the line and the finder start-control equipment, and the third wire of the calling line is made to test busy as described for a line-switch. When both the calling line and an idle sender have been found the calling line is connected through to the sender and the sequence switch of the first selector is advanced to the first operating position.

On an originating call the line finder remains in the operated position until the first selector releases it by establishing a disconnecting circuit. When a terminating call is received the cut-off relay is operated by the selector making the line connection. In this case the operation of the cut-off relay merely cuts off the line relay. Message registers may be associated with individual and two-party lines and operated as described for line-switches.

Order of Line Selection.—There are four kinds of selectors associated with panel-type line banks. These are known as district, office, incoming, and final selectors and they are here given in the order in which they are chosen for selection purposes. Thus the first selector is called a district selector and handles originating calls only. Final selectors connect with station lines and handle terminating calls only. The selector frames are known by the name of the associated selectors. The bank terminals on a final frame are known simply as final terminals.

Each district selector must have access to groups of trunk lines leading to all points which a calling party may have occasion to reach. These points include all local and toll offices serving the local area, assistance or other operators in the same central office and information operators who may or may not be in the same central office. The trunk lines to other local offices may be either machine switching trunks or call indicator trunks, depending upon whether the other offices of the area are machine or manual offices.

If the total number of trunks required can be accommodated on the five banks of a district selector, the office trunk selection is made by district selectors only. If not, some or all of the group of trunks from the banks of district selectors are run to groups of office selectors, each having access to trunks to a particular group of offices. Hence the office trunk selection may or may not involve two selectors.

The size of the outgoing trunk groups for district and office selectors is not limited to the number of multiple bank terminals per group as determined by the group selection commutator. A group of multiple bank terminals may be readily combined with the group above by making the overflow level permanently test busy. Trunk groups may be thus varied in size from 5 or 10 to 90 trunks.

Each trunk to a machine switching office ends on an incoming selector and the trunks from the banks of incoming selectors run to final selectors which select the called line. Each machine switching office requires district or district and office selectors for handling originating calls and incoming and final selectors for handling terminating calls.

Each incoming selector must have access via final selectors to final terminals of all station lines of the office. In a unit size office having 10 000 terminals 20 groups of final selectors are required as each has access to the final terminals of 500 lines. Hence the multiple terminals on the 5 banks of each incoming frame are divided into 20 groups. As the groups are made equal in size each bank has multiple terminals for 4 groups. Allowing 4 levels per bank for overflow purposes results in a maximum of 24 trunks per group.

The 20 groups of trunks to final selectors are terminated on the incoming frame banks in numerical order according to the numbers of the final terminals with which they are associated via the final selectors. Hence the brush selection involves the selection of a group of 2000 lines, and the group selection involves the selection of a group of 500 lines in a preselected 2000-line group.

Final terminals are numbered in straight numerical order counting from the lowest level on each frame. The figure 0, although dialed as a 10, is considered as 1 from a terminal location standpoint. Thus both the groups of 100 and the individual terminals of each group are arranged in numerical order according to the decimal system. The brush selection involves the selection of a 100-line group in a preselected 500-line group. The group selection involves the selection of a tens group in a preselected 100-line group. The unit selection involves the selection of a particular terminal in a preselected tens group.

With this arrangement of incoming and final selector banks a fixed system of translating the thousands and hundreds digits of call numbers is required for incoming brush, incoming group, and final brush selections. This is because incoming brush selection involves a choice of thousands by pairs, each comprising an even thousand and the next odd thousand, because incoming group selection involves a choice of the first or second 500 in either an even or the next odd thousand, and because final brush selection involves a choice of one of the first five hundreds or one out of the second five hundreds of final terminals.

A party line has a final terminal for each station for selective or semiselective ringing purposes. Thus each station on a party line has an individual final terminal number. The final terminals of each party line are on adjacent final frames and each final frame has final terminals for like stations only; that is, stations rung in the same manner. The line wire reversals required for selectively or semiselectively ringing certain stations are made on a distributing frame from which the individual final terminals are wired.

Private branch exchange trunk lines may be terminated on any bank of any final frame having terminals for individual lines. All such lines of a particular group must be on consecutive terminals of the same bank if selected by a single call number.

District Selectors.—District selectors have four selection processes. These are the usual brush, group, and automatic trunk hunting processes and in addition a talk-selection process. These selectors furnish current to calling lines for talking and holding purposes on calls to other stations and current for holding during a brief period on calls to assistance operators. These selectors may also furnish different types of transmission equipment for differently routed calls. The switching required is done by the sequence switch.

After the brush and group selections have been effected under control of a sender the selected brushes are in contact with the first trunk terminal of the selected group. If the first trunk is idle the selector immediately connects the sender thereto, but if busy the selector automatically seeks the first idle trunk in the group and then connects the sender thereto. Thus the sender is enabled to continue the required operations. These differ for differently routed calls. The third wire of the selected trunk is immediately made to test busy. The trunks to office selectors and to assistance operators have three wires and the third wire is used for holding and guarding. The trunks to other offices have only two through wires and the locally multipled third wires are used only for guarding.

When all of the trunks in a group are found busy the selector brushes stop on the overflow level, the sender is immediately released and the sequence switch is advanced to its overflow position where a busy-tone circuit is connected to the calling line. When the calling party hangs up the receiver the district selector is immediately released and it releases the calling line-switch or line finder.

When the required final terminal has been selected by a final selector the sequence switch of the district selector is advanced under control of the sender to the position required by the routing of the call and the calling line is thus connected through to an incoming selector, a manual office, an assistance operator or another operator as the case may be. In the first two cases the ringing is started and in the last two cases the operator is signaled. On calls to assistance operators the sequence switch is again advanced to a special talking position when the operator answers. The calling line is given direct control of the release of all selectors and the sender is released when the talk-selection operation is completed. On calls to assistance operators, however, the release control is shared by the operator after she answers.

If the calling station has flat-rate service, the district selector is released when the receiver is hung on the hook. If the calling station has message-rate service, the act of hanging up the receiver causes the sequence switch to advance to a charge position. If the call was not routed to an operator, and if the called party answered, the message register is operated before the selector is released. If the call was routed to an assistance operator, both the operation of the message register and the release of the selector are under her control.

Special district selectors and senders are used for public telephone service handled with prepayment coin collectors. When the calling party hangs up the receiver, the sequence switch is advanced to its charge position and the selector is again connected to a sender. If a charge is to be made the sender causes the collection, otherwise it causes the return of the deposited coin.

The district selector always releases its hold on all other selectors when it is released by the calling party regardless of whether or not its restoration to normal is delayed by the making of a charge. Hence no other selectors are held up during a charge operation.

Office selectors.—An office selector is first operated when the district selector makes its third wire test busy. The sequence switch is immediately advanced to its brush selection position. After the brush and group selections have been effected under control of the sender, the office selector automatically selects the first idle trunk of the group if the first trunk is busy and connects the trunk circuit through to an incoming selector, a manual office, an assistance operator or another operator as the case may be. The sender and subsequently the district selector are thus enabled to continue operations. The third wire of the selected trunk is immediately made to test busy.

When all trunks in a group are found busy the selector brushes stop on the overflow level and the sequence switch is advanced to its overflow position. The sender is then operated in a special manner. It causes the sequence switch of the district selector to be advanced to its overflow position where the busy tone circuit is connected to the calling line. The district selector releases the sender and office selector and is itself released when the calling party hangs up the receiver.

Office selectors always connect all three wires of the trunk from a district selector bank to the corresponding wires of the selected trunk or assistance operator's line. The office selector guards the selected trunk or operator's line until the through connection is established and after release by the district selector until released by the office selector. The through connection of the third wire enables the district selector to guard the selected trunk or operator's line while the through connection is maintained by the office selector and similarly enables an assistance operator to hold the selectors against release by the calling party.

Incoming Selectors.—An incoming selector is usually both operated and held over a two-wire trunk line. It furnishes current for these purposes and also to the called station for both talking and signaling.

Incoming selectors have the additional important function of ringing the called station and furnishing the ringing tone to the calling party. The operation of selectively or semiselectively ringing a four-party-line station involves a choice of ringing currents. A special commutator is provided which makes a contact with its brush when the selector brushes are in alignment with any terminals of the second and fourth trunk groups of a bank. By this means a control is provided for determining the ringing current connection required for selectively or semiselectively ringing two of the four stations on a four-party line.

The advance of the sequence switch to its first operating position is made under control of the sender. After the brush and group selections have been effected the incoming selector automatically selects the first idle trunk of the group if the first trunk is busy and connects one wire of the trunk circuit through so that the sender can control the final selector. The second wire is used to stop the further operation of the incoming selector until the final selection has been completed. The third wire is immediately made to test busy.

When all trunks in a group are found busy the selector brushes stop on the overflow level and the sequence switch is advanced to the equivalent of an overflow position. The sender is then operated in a special manner and causes the district selector to furnish the busy tone to the calling party and to release the sender as usual. The office and incoming selectors are released when the district selector is released by the calling party.

When the final selection has been completed the final selector removes the stop on the incoming selector. The incoming selector causes the sender to proceed with the talk-selection process. When the district selector connects the calling line through to the incoming selector the incoming sequence switch is advanced to the position for ringing stations on individual lines, stations on two-party lines and two of the stations on four-party lines. If either of the other two stations on a four-party line are to be rung the commutator connection temporarily prevents ringing and causes the sequence switch to advance to a second ringing position where the normal ringing current connection is changed to that required. Selective ringing requires a ringing current having an opposite direction. Semiselective ringing requires a ringing current interrupted twice per ringing cycle instead of once. The party-line station that will be rung in either ringing position depends upon the final terminal selected.

When the called party answers, the incoming selector opens the ringing circuit, completes the talking connection from the calling to the called party, and reverses the direction of the line current to the district selector. This reversal causes the operation of the charge relay of the district selector. This operation enables the district selector to control the making of a charge on release.

Final selectors.—Before a connection is established through to a called station the calling party has control of the release of the final selector via the incoming selector. After a called station answers, the control of the release is so shared that release will be effected by the party who last hangs up the receiver.

The first advance of the sequence switch, the brush selection, the tens group selection, and the units selection are made under control of the sender. If the called line is idle its third wire is immediately caused to test busy, the stop on the incoming selector is removed, and the connection is completed by the district and incoming selectors.

If the called line is busy, and if it is not the first one of a group of private branch exchange trunks (differentiated by a weak busy test), the stop on the incoming selector is removed and the sequence switch is advanced to a busy position, where the busy tone circuit is connected to the trunk from the incoming selector. The final selector brushes are immediately driven to the normal position. When the calling-line circuit is closed through to the incoming selector by the district selector the incoming selector operates as usual but the ringing circuit is immediately opened and the incoming selector closes the calling-line circuit through to the busy tone circuit of the final selector.

If the called line is busy and is the first one of a group of private branch exchange trunks a weak busy test is found. As a result the sequence switch is advanced to its trunk hunting position. If an idle trunk is found connection is then established as for any other line. If an idle trunk is not found the selector brushes are stopped in contact with the last trunk terminal where a strong busy test is found. The resulting operations are then the same as for a busy station line.

Senders.—The detail design and equipment of a sender depends upon the class or classes of calls it is to handle. A sender handling calls having three-letter office designations differs from one that handles calls having two-letter office designations. A sender handling calls to both machine and manual offices requires more equipment than one that handles calls for machine offices only. Similarly a sender handling calls involving the operation of coin collectors requires more equipment than one that handles noncoin calls only. Other examples of senders will be referred to later in connection with the handling of calls from manual stations.

One common form of sender is that designed to handle calls for other mechanical stations in a multioffice area, calls for an assistance operator, calls for other operators, calls for manual stations reached via one operator and calls for manual stations reached via a tandem operator. Such a sender arranged to handle calls having two-letter office designations comprises some fifty relays, a set of rotary switches for registering call numbers, a single rotary switch serving as an office code translator, and at least three sequence switches. A sender used for collecting and returning coins has an extra sequence switch and a few additional relays. The following description applies to these two forms of sender only.

The sender is connected to the district selector (via a sender selector) by six wires which may be considered as divided into three for incoming control and three for outgoing control. The equipment of a sender handling noncoin calls may be considered as divided into five parts which will be referred to as the register equipment, the translator equipment, the class equipment, mechanical selection equipment, and equipment for manual office calls only. When coin collectors are to be operated, a sender equipment has a sixth part for this purpose. The register equipment comprises the set of rotary switches and a group of relays. The class, mechanical selection and manual office call equipments each comprise a sequence switch and a group of relays. The translator equipment comprises one rotary switch and a few relays.

When a connection to a sender is made, the class sequence switch is advanced to its first operating position where the calling line is associated with the registers, the dial-tone circuit is connected with the calling line and provision is made for guarding the sender until restored to normal. One register is provided for each digit of all called numbers possible. These are successively associated with the calling line. The association is switched from one register to another during the intervals between digits when the calling party is rotating the dial. The switching is done via an extra rotary switch known as the control register.

When all of the office letters have been registered, the control register starts the translator. The translator stops in a position which is determined by the letter registers. Each stop position of the translator establishes a number of control connections for subsequent use. When the translator is stopped, the class sequence switch is advanced and then stopped in a position for handling the class of call involved. The position in which it is stopped is determined by one of the translator connections which controls the class setting as it is called.

A sender is always required to control the brush, group, and talk selection processes of a district selector. It also has to control the similar processes of an office selector if the required trunk terminals are on the banks of office selectors. On a call to another machine station it also has to control the brush and group selection processes of an incoming selector and the brush, group, and unit selection processes of a final selector. On a call to a manual office station reached via one operator, it also has to signal the operator and pass the called number. On a call to a manual office station reached via a tandem operator, it also has to signal the operator and to pass both the called office code letters and the called number.

The group of relays associated with the equipment for mechanical selection includes a fundamental subgroup known as counting relays. These are used for each selection process to determine the number of steps a selector is to be permitted to elevate its brushes. There are 10 pairs of counting relays arranged in numerical order and 1 extra relay associated with the No. 1 pair. There are 10 terminals respectively associated with the 10 individual pairs of relays. If a selector control circuit is associated with the first terminal the selector is permitted to advance 1 step. If the control circuit is associated with the second terminal the selector is permitted to advance 2 steps, etc. Each vertical step of a selector causes the operation of a pair of counting relays which switch the control circuit association to the next pair having a lower number. The operation of the No. 1 pair causes the opening of the control circuit and thus prevents further operation.

The outgoing control circuit is extended to each selector in succession by the selector previously operated. The sender always starts a selector by advancing the sequence switch one position but it can not do so until the sequence switch has been made ready by the completion of the previous operation. The advance of the sequence switch closes the up-drive clutch circuit. The up drive continues until the sender opens the control circuit thereby causing another advance of the selector sequence switch which opens the up-drive clutch circuit.

The outgoing control circuit is associated with the counting relays via the sequence switch of the mechanical selection equipment and via the translator, the numerical registers or the class equipment. The translator furnishes the counting relay connections for district brush, district group, office brush, and office group selections. If office selections are to be omitted the translator causes these to be passed. The numerical registers furnish the counting relay connections for incoming brush, incoming group, final brush, final tens and final units selections. The class equipment furnishes the counting relay connections for talk selection and controls the omission of incoming and final selection processes when not required.

The sequence switch of the mechanical selection equipment is advanced after each selection process is completed to make ready for the next one, but these advances are subject to temporary stops depending upon the stage of operations. The counting relays lock in the operated position and are released by the next advance of the sequence switch. They are thus made available for the next selection operation.

On calls to manual office stations the called numbers are passed to the manual office by means of current pulses which cause the number to be displayed on a call indicator. Each digit of a number, including the office code on tandem calls, and including a station letter if there is one, is sent in succession. A particular digit is sent in each case by a four period combination of strong or weak current pulses in particular directions and during certain periods. Ten different combinations for the 10 digits are, of course, required.

The combinations required for each digit of a particular call number are determined by the sequence switch of the manual call equipment and the registers. The sequence switch does the required switching and cares for the constants of the various combinations. The registers determine only the variables. The manual office operator is signaled when the sender is connected through by a district or an office selector. When the operator answers, the sequence switch is caused to rotate continuously until the entire call has been passed to the call indicator. This operation is immediately followed by the talk-selection process which results in connecting the calling line through to the manual office.

When a sender used for operating coin collectors is selected for this purpose, only the class equipment and the coin collector equipment are operated. The class sequence switch is advanced to its first operating position and remains there until the coin has been returned or collected. The collector sequence switch is then advanced to the collect or return position. The position it will stop on is controlled by the district selectors and in turn depends upon whether or not the called station has answered.

The release of the sender is effected via the class equipment which also controls the restoration of the entire sender to normal. The registers are reset and each sequence switch advanced to normal in turn. When the class sequence switch makes its last advance the sender is made available for handling another call.

Sender Monitor Equipment.—Each sender has a monitor equipment which includes a rotary switch, a group of relays, two jacks and a signal lamp. The jacks and lamps are mounted on an attendant's switchboard which serves all senders. Two power-driven interrupters also serve all monitor equipments in common. One interrupter is used for timing operations and the other to flash the signal lamp in certain cases.

The monitor equipment is associated with the other sender equipment by a control circuit. When this circuit is closed the monitor operation is started. After a predetermined time the lamp circuit is closed and the operation is stopped automatically if the control circuit is held closed for that length of time. If the control circuit is opened before the time limit expires, the operation is immediately stopped. The opening of the control circuit always causes immediate restoration to the normal position.

The starting circuit is closed and opened several times during the handling of a call, so that the operation of the monitor equipment may cover several operating stages of the sender. Equipment is provided for causing the signal lamp to be flashed, to burn brightly and to burn dimly and to thus indicate the nature of a delay or failure.

By means of one of the jacks and suitable position equipment the attendant can at any time connect his telephone to a calling line and hold the sender equipment in its operated condition for the purpose of ascertaining the cause of an irregular operation. The other jack is used to make the sender test busy to all calls in case of trouble.

The sender monitor equipments associated with senders which operate coin collectors have another signal lamp which is lighted when the collecting or returning operation fails to move the coin.

During the movement of the sequence switch the timing equipment is associated therewith, but the time limit is made much less than for other monitor operations. The signal lamp flashes if the time limit is exceeded.

Selector and Line Finder Supervisory Equipment.—Time limit signal equipments are provided for district selectors to cover delay in releasing on the part of the calling party, for final selectors to cover delay in releasing on the part of the called party, for selectors and line finders to cover delay in releasing in case the brushes are driven beyond the last bank level and for line finders to cover delay in handling calls. An audible alarm is given when the time limit is exceeded.

Traffic Registers.—Each selector group is provided with a register to count the number of calls handled by the group. Each group of trunks having terminals on district, office, or incoming selectors have a register associated with their multipled overflow levels to count the number of times all trunks in each group are found busy. All district selector groups and all senders groups are provided with register equipment for counting the number of times the respective groups are all busy. Line finders are provided with a register for each group which counts the number of calls that originate on the associated lines when all of the finders of the group are busy.

Manual and Machine Switching Equipment Used in Combination.—A comparatively small *A* operator's switchboard is a regular part of a machine switching central office equipment. Such a switchboard is always required for handling assistance calls and intercepted calls. It may be used for handling calls originating at public telephones and at stations having message-rate service on four-party-lines, and for handling calls which originate and terminate on rural lines.

The line equipment provided is always of the manual type required by the class of service rendered and may or may not be associated with machine switching equipment. Certain operators are provided with manual position equipment and others may be provided with either manual or semimechanical position equipment.

The switchboard usually includes sections for handling toll calls to suburban points, though not necessarily to suburban points exclusively. This equipment is mentioned here because of its association with the local service equipment and because the traffic handled by the switchboard as a whole largely determines which type of position equipment will be used for local service.

An incoming trunk switchboard arranged for *B* operators is provided in machine switching central offices for handling calls from manual central offices in the same local area and from toll offices when the local or toll offices are not provided with equipment for controlling machine switches, and for handling calls from intercepting operators. These *B* operators have special equipment for controlling machine switches in their own offices.

Information and other special service operators are usually provided with special desks, as in the manual system. These operators are reached by district or district and office selectors when a special code number is called.

Line Equipment.—Public telephone lines and message-rate four-party lines have equipment similar to that of the manual system for handling originating calls. These lines also have final terminals, reached by final selectors, for handling terminating calls. The equipment at the switchboard is arranged to associate four number plates with each party line answering jack. Dialing lines to district selectors are provided for completing calls if the position equipment is of the manual type.

Rural lines are provided with equipment of the manual type arranged for handling both originating and terminating calls. Dialing lines to district selectors are provided for handling calls to other than rural stations. On calls for rural stations from other than rural stations the operators are reached by lines from final selector banks, which are selected when rural line numbers are called.

Intercepting operators have intercepting lines from final terminals of station lines whose terminating calls are to be transferred or temporarily denied and from vacant final terminals which may be called in error. Station lines denied originating service are connected directly to intercepting lines. Intercepting lines may also be connected to vacant incoming selector bank terminals which may be selected as a result of dialing error.

Intercepting operators also have lines from final terminals for receiving calls from other operators and lines to *B* operators' positions for verifying reports. The latter lines enable the establishment of a connection to any final terminal whether or not the called line is busy. Dialing lines to district selectors are provided for completing calls via other central offices.

Assistance operators have lines for receiving calls from parties having difficulty in establishing a connection and for completing reverting calls on machine station lines. These lines are reached by district or district and office selectors when a special code number, usually 0, is called. Assistance operators may complete calls to any station either directly or via an intercepting operator.

A Operators' Manual Position Equipment.—The manual position equipment provided is very similar to that used for *A* operators' positions in the manual system except that each position is equipped with a dial and each calling cord is provided with a dialing key. Those positions handling prepayment coin collectors are provided with coin-collecting and coin-returning keys. The answering supervisory lamps may be equipped to furnish flashing recall signals.

Manual position equipment is always provided for rural operators, for intercepting operators and usually for assistance operators. Rural operators may be provided with equipment for causing the operation of message registers.

A Operators' Semimechanical Position Equipment.—A semimechanical position equipment comprises a number of individual machine switching equipments for lines to district selectors and certain equipment which is used in common for all lines. This latter equipment includes a set of register keys used for selecting purposes and a set of master keys.

Each switching line terminates on a single cord and plug used for answering calls. Three supervisory lamps, a listening key and a monitoring key are associated with each cord. Coin-collect keys also may be provided.

Although called listening keys, these keys connect both the operator's telephone and the common equipment with the associated switching lines. The equipment is so arranged, however, that this connection is made automatically when the operator plugs into a jack to answer a call and so that any previous connection is opened. When the operator's services are required on a previously established connection the listening key is used.

Each position has one busy-test cord and plug as the switching cords can not be used for this purpose. The set of master keys comprises a coin-return key, party-line ringing keys, a key for temporarily disconnecting a calling party and a key for disconnecting the operator's telephone and all common equipment from the switching line to which it is connected at the time. The supervisory lamps have the usual manual functions but in addition they indicate the progress made in establishing desired connections, which includes the indication of erroneous operations.

The register keys comprise four groups. These keys are of the push-button type and lock in the operated position. The grouping is indicated by markings on the buttons. The first group of keys are for routing calls. If the called office is reached directly the depression of the proper routing key causes the selection of a trunk to the desired office. If the called office is reached via a tandem office the depression of the proper routing key causes the selection of a trunk to the tandem office. The second group of keys are for registering the code letters of the called office. These keys cause the office code to be passed when the called office is not reached by direct trunks. The third group of keys are for registering the number of the called station and cause its selection. The fourth group of keys includes four party-line keys, each of which acts as a starting key when depressed. One key is provided for starting operations on calls for individual line stations. All keys are released when operation is started and then becomes available for handling another call.

B Operators' Equipment.—Each incoming trunk terminates on an incoming selector and has two supervisory lamps and two keys on a *B* operator's position. No cords are used. Each operator's position is provided with a set of register keys, but these are not at any time associated with the operator's telephone. The general arrangement of a *B* operator's position, but not the exact arrangement as now used, is shown by the illustration.

One of each pair of keys is called an assignment key and the other a disconnect key. The assignment key causes the register keys and an idle sender to become connected to the trunk and incoming selector with which the operated key is associated. The register connection is made via a trunk line finder and the sender connection is made via a sender selector. The disconnect key causes the disconnection of the register and the sender.

The called number is always that of a station served by the *B* operator's office and only four digits have to be registered on each call. The selection process is started immediately after the units digit has been registered. An extra key is provided for handling calls from intercepting operators when connection is not to be prevented by a busy test. All register keys lock in the operated position and are released by the sender.

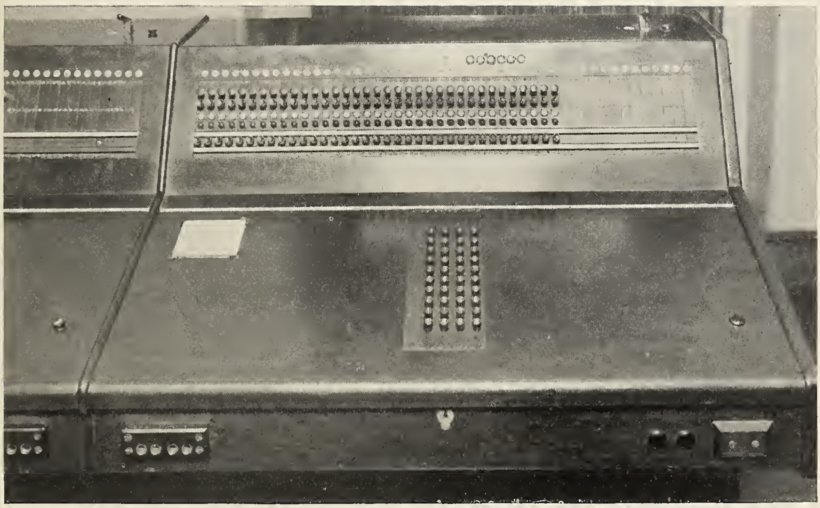

FIG. 40.—*B operator's position equipment—panel-type system*

The *B* operators handle incoming calls from local manual offices and from toll offices which are always manually operated. *B* operators receive calls over order-wire circuits and require incoming-line equipment for assignment, supervisory, and release purposes, and equipment for controlling selectors in their own office only. Coin-collect and coin-return keys are also provided when required. Each operator is provided with a small desk-like switchboard position having an inclined face and a keyboard. The line equipment is mounted on the inclined face and a set of keys for controlling the selectors is mounted on the keyboard. When a called number is received it is registered on these keys as a number would be registered on an adding machine. The register keys are held busy for a very short time and then released for handling another call

FIG. 41—*A call indicator—panel-type system*

The illustration shows a call indicator as it appears on the keyboard of a *B* operator located in a manual office and handling calls from machine stations. A called number is indicated by the illumination of one figure in each group. A station designation is indicated by the illumination of one of the letters in the letter group

The supervisory lamps have the usual manual functions and in addition they indicate the progress made in establishing desired connections which includes the indication of erroneous operations.

SPECIAL EQUIPMENT IN MANUAL OFFICES FOR HANDLING MACHINE-STATION CALLS

Certain special equipment is usually provided in manual offices for handling calls from machine stations. Special equipment may or may not be provided for handling calls to machine stations.

EQUIPMENT FOR CALLS FROM MACHINE STATIONS.—There are three methods which may be used for handling calls from machine stations. Such calls may be handled via direct trunks to regular manual line equipment arranged for *A* operation, via direct trunks to call indicator equipment arranged for *B* operation, or via tandem trunks to call indicator equipment arranged for tandem operation. The first method is not used except in those comparatively few cases where the traffic does not warrant the provision of call indicator equipment which enables calls to be passed without talking to an operator.

Direct Call-Indicator Trunk Equipment.—The appearance of a call indicator is shown by the illustration. The figures 0 and 1 at the left of the indicator respectively indicate that the call is for an individual line in the first ten thousand or in the first thousand of the second ten thousand. The next four groups of figures represent the thousands, hundreds, tens, and units digits of the called number. The row of letters represents the station designations. The illustration shows the number 4259 displayed by the lighted lamps beneath the respective figures.

Each trunk line terminates at a *B* operator's position on a cord and plug. Each trunk line also has a small group of relays, two supervisory lamps, and a key. One lamp is known as an assignment lamp. This lamp lights when the district or office selector in the calling office connects the sender through to the call indicator office. The lighting of this lamp indicates that a call is to be handled on the associated trunk line. The key is known as the assignment key. The operation of this key causes the associated trunk line to be connected to the call indicator equipment and causes the sender to pass the called number.

The lighting of the lamps is effected by means of some thirty relays associated with the call indicator. Three of these are master relays which operate under control of the sender. Each group of lamps has four lamp relays. The lamp lighted in a given case depends upon which relays are operated and which are not operated. The lamp relays for the station digit also control the 0 and 1 lamps on the left of the indicator and the trunk ringing equipment so that the required station will be rung. The groups of lamp relays are successively associated with two of the master relays via a group of relays which control the sequence. These relays are controlled by the third master relay. The sender furnishes the current pulses required for controlling the sequence as well as those required for selecting the individual lamps.

The assignment lamp begins to flash when the assignment key is operated. The operator notes the called number and establishes the connection in the usual manner. The assignment lamp continues to flash until the plug is inserted in a jack. It will also act as a guard signal by lighting again should the operator inadvertently remove the plug before the trunk line is released.

The call indicator is released when the plug is inserted in a jack. Ringing is started when the district selector closes the line connection after the talk-selection operation. If the operator plugs into a busy-tone jack the ringing operation is prevented and the calling party is enabled to hear the busy tone. When the called party answers the trunk line current is reversed in direction to operate the charge relay of the district selector. When the calling party hangs up the receiver the district selector releases the trunk line and the other supervisory lamp lights as a signal to disconnect.

Tandem Call-Indicator Trunk Equipment.—The call indicator used on a tandem position includes groups of lamps for indicating the office called. The office lamps light first so that the operator may select the called office immediately. She does this as usual by means of an order-wire key but in this case the operation of the key does not include the cutting off of an incoming call circuit to the operator's telephone because no such circuit is required.

The outgoing completing trunk to the called office is assigned as usual by the *B* operator in that office. The tandem operator connects the call indicator trunk to the assigned completing trunk and when the called station answers the trunk relays cause the operation of the charge relay of the district selector as usual. If the called station is busy the *B* operator connects the completing trunk to one of her busy-tone jacks.

Equipment for Calls to Machine Stations.—There are three methods of handling calls to machine switching offices. Calls may be handled via a *B* operator in the machine office, in which case no special equipment is required in the manual office.

In some cases dialing equipment may be provided for all *A* operators. In other cases special machine switching equipment known as key-indicator equipment may be provided. The method adopted is dependent upon how long the manual office will probably be kept in service and upon the traffic to be handled.

Dialing Equipment.—In some cases each *A* operator's position may be equipped with a dial and each calling cord may be provided with a dialing key. Either separate dialing keys or combination listening and dialing keys may be used. The method of operation is essentially the same as previously described for the automatic system. The trunk lines run direct to incoming selectors in the machine switching offices. Each incoming selector used for calls from a manual office has an associated sender. These senders handle only one class of call and control only incoming and final selectors.

Key-Indicator Equipment.—When key-indicator equipment is used each *A* operator's position is provided with a trunk indicator, a set of 10 numerical register keys, and a release key in addition to the regular position equipment. The location of this additional equipment is shown by the illustration.

When the operator receives a call for a machine station she selects the call-circuit key bearing the name of the called office and operates this key as usual. In this case, however, she is not connected to a *B* operator's call circuit; the key is therefore known as an office key. The operation of an office key starts a rotary switch known as an allotter. The allotter selects an idle group of three rotary switches which are interconnected to form a single link. One of these finds the trunk indicator and numerical keys on the calling position, one selects an idle trunk line to the called office and one selects an idle sender. The number of the selected trunk is immediately displayed on the trunk indicator.

The trunk indicator has a group of lamps for each digit of the trunk numbers. The illustration shows three groups of lamps, but only an 0 lamp and a 1 lamp for the hundreds group. Lamps for trunk number 36 are shown lighted. The one lamp at the left end of the lower row lights when the office key is operated and remains lighted until an idle trunk is found and its number indicated or until a release key is operated. While lighted it indicates that no trunk is yet available.

The register keys are numbered 0 to 9 and do not lock in the operated position. When a key is operated its number is immediately registered by the selected sender. The key first operated causes a registration for the thousands digit, the next key operated for the hundreds digit, the next for the tens digit, and the last for the units digit. Thus the keys must be operated in the correct order as determined by the called number. Should there be no idle link or sender available the operator is so informed by a signal.

After the called number has been registered by means of four of the numerical keys the operator completes the cord connec-

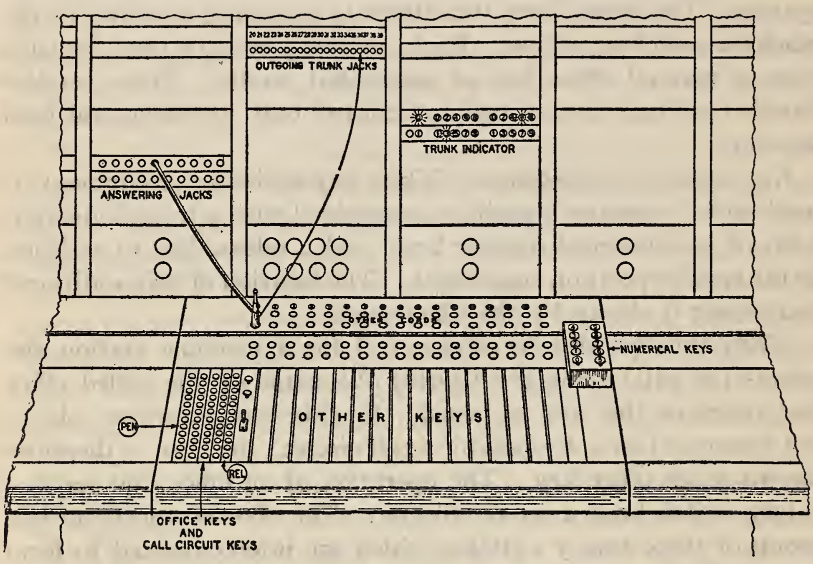

FIG. 42.—*Key-indicator position equipment—panel-type system*

tion to the trunk line jack bearing the displayed trunk number. From this point on regular manual supervision is obtained.

The sender handles only one class of call and controls incoming and final selectors only. The called number is registered on a group of relays. A simple rotary switch controls the operating sequence. The sender establishes the connection over the selected trunk line to the final terminal of the called line. The incoming selector causes the ringing of the called station in the usual manner, but the ringing can not be started until the operator has inserted the plug in the trunk jack. When the operator disconnects, all machine switching equipment held during the connection is automatically released.

5. PANEL-TYPE MACHINE SWITCHING SYSTEM—SPECIAL TOLL EQUIPMENT

All toll calls are handled by operators. Toll operators are in some cases provided with manual switching equipment and in other cases with combined manual and machine switching equipment. In a few cases tandem offices may be provided with machine switching equipment only.

Toll switching equipment is always provided in machine switching offices for handling calls to and from those points which are comparatively near by and with which there is a comparatively large traffic. This service is usually handled on an *A–B* toll basis. *A* operator's equipment is provided for handling outgoing calls and *B* operator's equipment is provided for handling incoming calls. In those cases where incoming ring-down trunks are used calls over such lines are handled by *A* operators only. Each office has its toll equipment on the manual switchboard used for local service.

All toll points not reached by direct trunks from machine switching offices are reached via one or more separate toll offices. One of these is always a long-distance toll office. Calls for long-distance points which originate at a machine station are routed as usual to a recording operator. The recording operator is reached via district or district and office selectors when a special code number is called.

In very large cities it is the usual practice to provide one or more toll offices which are not only separate from the local offices but are also separate from the usual long-distance office. Long-distance offices usually handle calls on a particular person basis but these other toll offices handle calls for particular numbers. Thus they serve those toll points which it is desirable to handle on a two-number basis and to which the distances are too great or the traffic too small to justify direct trunks from each local office.

The machine switching system provides facilities for handling all originating two-number toll calls via the *A* operators, but in some cases calls for points reached via a two-number toll switchboard may not be handled by *A* operators. In such cases a recording operator at that switchboard is reached by a special code number.

When all originating two-number toll calls are handled by *A* operators some points are reached by direct trunks and other points are reached via one or more two-number toll switchboards. These are usually of the manual type, but tandem machine switching equipment, with or without operators, may be used in some cases.

Outgoing-Toll-Call Equipment in Machine Offices.—The *A* operators handling outgoing toll calls are reached by lines from district or district and office selectors when a special code number is called. These lines terminate on equipment of the manual type.

The toll lines usually carry outgoing calls only and the line equipment depends upon whether the position equipment is of the manual or semimechanical type. Either type of equipment may be used. The type adopted depends upon the traffic to be handled and upon whether or not the connecting offices have the necessary equipment for machine operation. If manual position equipment is used the outgoing toll line equipment is also of the manual type. If semimechanical position equipment is used the toll lines are reached via district selectors having access to toll lines.

Holding jacks are provided with semimechanical position equipment to enable the operator to split connections. When a plug is inserted in a holding jack a connection to a called toll point may be established via the district selector. The calling party may be held on another cord as usual. When the called party answers the plug may be transferred from the holding jack to the answering jack and the connection thus established.

A so-called checking multiple may be provided for these operators. A checking multiple comprises a metal pin for the third wire of each station line mounted within reach of the operator. These pins are assembled in strips like multiple jacks, but require only half the space. When a call is received and the calling-line number given, the operator touches the tip of a plug to the pin corresponding to the line number given and hears a distinctive tone if the correct number has been given.

When some calls are to be routed via a two-number toll switchboard they may be handled by either of two methods. In some cases each *A* operator's position is provided with a few cords known as final terminal cords. Each of these is connected to a final terminal of the local office. The operator passes a call over a recording trunk to a toll operator in the other office and gives also the number of one of her idle final terminals. The cord is then connected with the calling line. An operator in the other office obtains connection with the calling line by calling the assigned final terminal number and thus assumes control of the connection. In other cases combination recording and connecting trunks are provided which enable the *A* operator to retain control of the connection.

INCOMING-TOLL-CALL EQUIPMENT IN MACHINE OFFICES.—The *B* operator's equipment for toll switching trunks does not differ essentially from that required for local service. It is usual, however, to provide a stronger talking battery for toll service than for local service. Where prepayment coin collectors are used the trunk equipments include coin-collecting and coin-returning keys. In very large cities the *B* operators may serve toll switching trunks from both long-distance toll offices and two-number toll offices.

TOLL OPERATORS' EQUIPMENT IN TOLL CENTRAL OFFICES.—The same three methods of handling calls to machine switching offices as used in local manual offices are available for use in a toll office having manual equipment. Calls may be handled over manually equipped trunk lines to a local *B* operator, over similar trunk lines with dialing equipment, or over key-indicator trunks with the required machine switching equipment. The method of handling calls adopted in a given case depends upon the same conditions as for a local office. In the case of a toll office, however, the use of key-indicator equipment is more likely to be justified.

In a very large city a tandem toll office handling two-number toll calls may be provided with machine switching equipment. One such office is now in service for handling calls to and from manual offices only. Calls from the manual offices are received over call circuits as usual and are handled by tandem operators provided with register keys for controlling the machine switches. Calls are received in the manual offices on call indicators.

Such a tandem office may also be arranged for handling calls to and from machine switching offices. Calls from machine offices having *A* operators' position equipment of the manual type are handled by tandem operators in the same manner as calls from a manual office. When routed to machine offices the calls are automatically switched at both the tandem and receiving offices. When routed to manual offices the calls are received on call indicators. Calls from machine offices having *A* operators' position equipment of the semimechanical type are handled at the tandem office by machine switches only. When routed to other machine offices the calls are there switched automatically. When routed to manual offices the calls are received on call indicators.

V. TELEPHONE PLANT—OUTSIDE LINE CONSTRUCTION

The construction of local line (also known as exchange line) plants and the construction of toll line plants are similar in many respects. Both include aerial wire, aerial cable, underground cable, and submarine cable. The toll line plant, however, includes a number of special features, and it is therefore thought best to consider local and toll construction separately.

1. LOCAL LINE CONSTRUCTION

The outside line plant consists mainly of the wire lines and their supports, connecting the central office and the telephone station. Owing to the great number of wires involved, the necessity for installation in a permanent and secure manner and the necessity for accessibility for repairs, renewals, and extensions, this construction has become highly developed and systematized. The practical considerations incident to the installation of a large number of wires compel the grouping of the wires into cables as described under "Development of the art." The amount of cable used in any community, therefore, naturally increases with the size of the community. The line wires always leave the central office in cables. These cables are placed underground in large cities and are generally carried on poles in small cities and villages. Underground cables may terminate on the inside or the outside of buildings, on back fences, on block poles, or on highway poles. Underground cable lines may be continued by cables within buildings, called house cables, by block cables on fences, buildings, or poles, by aerial cables, or by open (bare) wires on highway poles. Aerial cable lines may also be continued by open wires on poles.

Cable Terminals.—Cable wires must be terminated in a permanent manner and so that no moisture can enter the cable itself or affect the permanency of the terminal connections. At the central office end the wires are terminated on long rows of protectors or on long rows of terminal blocks mounted on the main distributing frame. The sheath of each cable necessarily ends at the first terminal of the row to which the wires are con-

FIG. 43.—*Underground cables in a manhole*

The lead-covered cable, in sections approximately equal to the distance between manholes, is drawn into the ducts, and the sections are spliced together in the manholes. The illustration shows the ends of the ducts, the method of distributing the cables in a manhole, the lead-sleeve-covered splices, and the manner in which the cables are supported on the side walls of the manhole nected. The paper-insulated cable wires are not run directly to the terminals. It is the usual practice to splice a short length of special terminal cable to each outside line cable. The wires in terminal cables are covered with cotton and silk or with wool. The splice is more or less filled with wax compound which seals the outside line cable and is covered with a lead sleeve which is soldered (wiped joints) to the respective cable sheaths.

The outer end of each cable is terminated inside of a terminal box. If the terminal box is inside a building the line cable is continued in essentially the same manner as at the central office end and the continuing wires are attached to substantial metal terminals.

If the terminal box is located on the outside of a building, on a fence or on a pole, the cable wires are either continued to the metal terminals by pairs of wires which are insulated with a rubber compound or are connected directly to the metal terminals. In the first case the lead sleeve which encloses the splice is soldered at one end to the cable sheath, is then entirely filled with wax compound and forms a so-called pot-head. In the second case the connections are made to terminals inside a chamber which is subsequently filled with wax compound.

Underground Cables.—Underground cables are continuously supported in ducts, also known as conduits, usually of vitrified clay, creosoted wood, or iron pipe, laid in sections which are joined in proper alignment. The ducts are placed on the bottom of a trench and protected by concrete or creosoted plank. The trench is filled with compactly tamped earth. Access to the ducts is had through manholes. Manholes are brick or concrete chambers (vaults), usually at street intersections, built with drainage connection and capped by iron castings with more or less water-tight covers, set flush with the surface of the street. The distance between manholes is, in general, determined by the length of cable which can be drawn in, 500 feet being about an average distance. The ducts, together with their associated manholes, are known as a subway. The cable, in sections, is drawn into the ducts via the manholes and the sections are spliced together. Both the splice and the slack of each section are supported by brackets attached to the side walls of the manhole.

In large cities the underground cable wires from the central office are frequently continued with wires in house cables, block cables, and aerial cables on highway poles before the station connections are reached. The junction with such continuing cables is usually made by terminating both cables in the same terminal box and cross-connecting the respective wires. In many cases, however, the underground cable wires are carried directly to a terminal box from which the station connections are run.

The large cables which leave the central offices are in some cases terminated as a whole, but are usually spliced to smaller cables in the manholes and the smaller cables are run to the terminal boxes. A cable from a subway to a building terminal, block terminal, or pole terminal is supported by a single duct, known as a subsidiary or lateral duct. The duct is run as far as may be necessary to properly support and protect the cable.

In small cities the underground cable wires from the central office are also extended by other cables; but they are very frequently carried directly to distributing terminal boxes, located on buildings, and on block or highway poles. Underground cables may also be extended by open wires on pole lines.

House Cables.—House cables are run from the underground cable terminal, which is usually located in the basement, via vertical riser shafts to small terminal boxes located on the several floors. The conductors of the building cable are divided into groups. Certain conductor groups are terminated only in certain boxes and other conductor groups are terminated in several boxes in order to meet existing local requirements, and to provide a reasonable degree of flexibility for future needs.

Block Cables.—In the sections of cities which are closely built up, block cables are usually attached to building walls, are carried by alley or rear property pole lines, or may, depending upon the locality involved, be attached to rear property fences. Block cables are run from an underground cable terminal box or are directly spliced to the underground cable. The conductors are divided into groups, the same as for house cables, and terminated in small terminal boxes which are distributed throughout the block so as to best meet the distribution needs.

Aerial Cables.—Aerial cables are supported by suspension cables known as messengers. Attachment to the messenger is made at frequent intervals, usually by metal hangers but in some cases by marlin lashings. The messenger consists of an number of galvanized steel wires twisted together and it has great tensile strength. It is attached to each pole by a substantial clamp

FIG. 44.—*Block cable on poles*

This is a very common form of block distribution. The poles carry electric light wires at the top and the telephone cable below. An iron terminal box may be seen below the cable on the first pole

FIG. 45.—*An aerial wire line*

This illustration shows the standard cross-arms having 10 pins for 5 metallic circuits. The pole in the foreground is side guyed and head guyed to strengthen it for lateral and longitudinal strains. respectively. Strain insulators are shown at their usual locations in the guy wires. These have a tensile strength equal to that of the guy wires and serve to insulate those portions of the guy wires within reach of a person on the ground bracket. The pole lines which support only aerial cables are usually low, fairly sightly, and can be so located as to permit a minimum interference with and from foliage.

Aerial cables may run directly from the central office or from underground cable terminals. The conductors are divided into groups the same as for house or block cables, and terminated in small terminal boxes which are attached to the poles and distributed along the cable run.

Pole Lines.—Pole lines in general are so constructed that the poles bear all of the vertical load and some of the side or longitudinal strain. Side strains are caused by wind, curves and nonsymmetrical construction. Such strains may be met by providing lateral guys. Longitudinal strains are caused chiefly by abrupt changes in contour of the earth, by curves, by dead-ending lines, and by occasional line breaks. Such strains may be met by providing longitudinal guys.

Particular pole lines are so constructed as to meet the local conditions imposed by the nature of particular rights of way which have been acquired. These include sightliness, clearing obstructions, safety considerations with respect to highways, railroads and electric light and power wires, difficult pole setting in rocky or marshy ground, and unusual exposure to the elements, especially fire, wind, and sleet.

Bare open wires on pole lines are carried on glass insulators attached to cross-arms by pins. The cross-arms are set in shallow slots called gains, which are cut into the poles, and attached to the poles with through bolts. In order that the poles may be economically spaced the wires must have a very considerable tensile strength to stand the strain. These wires may be of hard copper or of galvanized iron or steel. Hard copper must be so handled as to avoid cracking or nicking the surface, and for this reason all joints in such wires are made by means of soft copper sleeves. A copper sleeve has the form of a double tube, through which the two wires to be connected are passed. The joint is made by twisting the tube with special tools after the wires have been inserted. Similar sleeves, made of tinned iron, are commonly used with iron and steel wires because a much more durable joint can be so made than by twisting the wire ends together. Joints with hard copper wire, as for branch lines, are frequently made with copper bolt connectors.

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When the terminals of cables are connected to open wires on pole lines such connections are made with wire which is insulated with rubber compound because the wires must be brought close together in entering the terminal box. These wires are carried by rings, knobs, or cleats to the several bare wires. Such wire is called bridle wire, is always of soft copper and the two wires of each pair are always twisted together.

STATION CONNECTIONS.—Stations served by building cables are connected by running the inside wires direct to the cable terminals. Stations served direct from underground cable terminals on buildings or fences, and stations served by block cables on buildings or fences, are connected with bridle wire which is run from the cable terminals to the terminals of the inside wires, which terminals are located inside of the building. The wires are carried by galvanized iron rings or porcelain knobs which are attached at frequent intervals to the buildings or fences. The rings are of the split type and the wire may be slipped in from the side without being passed through. They are made in several sizes so that a single ring run may carry a varying number of wires.

Stations served direct from underground cable terminals on poles, by aerial cables on block or highway poles, and by open wire are connected by means of drop wires. Drop wires are usually run from the cable terminals or from the open wires through rings to a porcelain knob carried by a bracket which is attached to the pole, messenger, or cross-arm, then aerially with or without additional supports to a knob which is attached to the building, and then through other rings or on knobs to the terminals of the inside wires, which terminals are located inside of the building.

Drop wires are usually insulated with a rubber compound, and as this wire has to span considerable distances it must have adequate tensile strength to stand the strain. Furthermore, the insulators which support the spans must have considerable mechanical strength and have a secure attachment. Drop wires are usually made of copper-clad steel and the two wires of each pair are twisted together. However, in passing around insulators in case of great strain, they must be untwisted to avoid cutting the insulation.

The outside wires enter the building through holes which usually slope upward, but if such sloping is impractical, drip loops are made in the entering wires at the point of entrance. If the line wiring is of an exposed character the entering wires are carried through insulating tubes and all attachments to the buildings in the entire run to the protector are made with insulators.

There is one other method of making station connections from block terminals which is not considered as satisfactory as those previously referred to but which is still used to some extent. It is known as the ring-pole method of distribution. The terminal box for the underground cable is placed at the top of a fairly high and centrally located pole. Below the terminal box a flat metal ring which may be as much as 3 feet in diameter surrounds and is attached to the pole by iron braces. This ring carries insulating knobs on its underside and the drop wires are attached to the knobs and may radiate in all directions from the pole. The drop wires are connected to the cable wire terminals by bridle wire which is run from the knobs to the pole, up the pole and into the terminal box.

PROTECTORS.—Open-wire pole lines in general are subject to more electrical hazards than any other form of construction, among which hazards lightning is the chief because it can not be entirely avoided. While electric currents seldom damage an open-wire line, the wires thereof are excellent conductors and carry the currents to points where serious damage could result unless guarded against. Such points are the station telephones and the junctions with cables. These are always protected by fuses, grounding devices, or both, when connected to open line wires.

Cable pole lines are also subject to electrical hazards. The cable sheaths are good conductors and may be melted by the action of strong currents. Telephone stations served by aerial cables are generally protected by both fuses and grounding devices, and junctions between aerial and underground cables are always equipped with fuses at least, except in the case of short underground dips in aerial cable lines.

WATER CROSSINGS.—While water courses are in many cases crossed with aerial wires or with cables supported by special construction, many such crossings are made with submarine cable. Which type of construction is used in a particular case depends upon the local conditions and the number of wires involved. In some cases the land structures required might be very costly or altogether impractical because of the width of the stream, and in some cases submarine cables could not be sufficiently protected.

Submarine telephone cables were formerly constructed with rubber insulated wires, but the modern submarine telephone cable has its wires insulated with dry paper and protected by the usual lead sheathing in a manner similar to the wires of underground cables. Submarine cables, however, are always armored with one or more layers of heavy galvanized iron wire. Several layers of jute yarn, saturated with a preservative compound, are placed between the lead sheath and the armor, between the layers, and over the outer layer of iron wire.

Submarine cables are laid directly on the bed of the water course, into which they sink if the bed is soft, and the two ends of each cable are terminated in special terminal boxes or houses near the water's edge. The landing ends frequently require special covering or housing for additional protection.

RURAL LINES.—A very large number of rural lines of this country are owned by individual farmers or by farmers' mutual associations. All possible methods and grades of line construction are found in use for rural service. Probably most of the privately owned lines are single iron wire lines which use the earth as the other side of the line circuit. Such use of the earth for telephone purposes may give satisfactory service if the ground connections are well made, if there are no electric light, electric railway or other power lines in the immediate vicinity, and if the insulation of the lines is properly maintained. The rural service field is one in which standardization of line construction and general maintenance will greatly improve the grade of service and also, in the long run, appreciably reduce the cost.

2. TOLL-LINE CONSTRUCTION

GENERAL CONSTRUCTION.—In general the aerial wire construction is similar to that used for local lines, but the wires are in some cases larger, and along main routes the supporting pole lines are usually more substantially built. Iron wires are rarely used unless for short distances. On account of the greater distances involved and the variety of electrical disturbances to which toll lines are subject, great care is taken to preserve the line balance by electrically symmetrical construction. The lines may be transposed according to a standard system or according to the nature of the exposure to electrical disturbance. The elimination of such disturbance may also involve changes in the construction of foreign circuits causing such disturbance.

PHANTOMED TOLL LINES.—Toll lines are now very generally phantomed, as previously described under "Development of the art." A phantom circuit gives much better transmission than

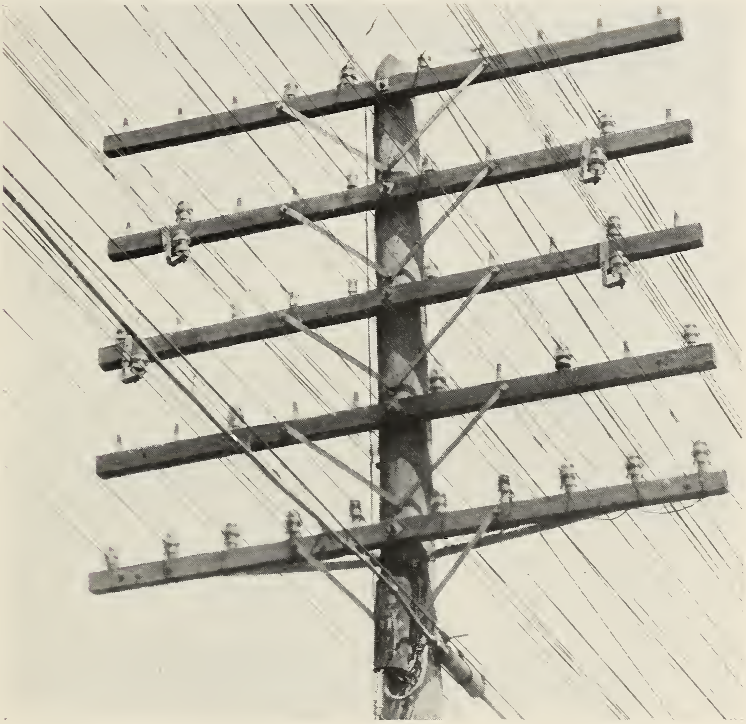

FIG. 46.—*Pole-line construction for both aerial cable and aerial wire*

The cable is in its usual location just below the lowest cross-arm. A terminal box of the can type is close to the cable. A short piece of cable connects the terminals in the box to the line cable; it enters the box from below and has the form of a drip loop. The method of supporting the cable is clearly shown. The iron drop-brackets and double insulators are for phantom-circuit transpositions. By this means the two wires of one side circuit are crossed over those of the other side circuit for the purpose of exchanging their respective locations on the pins

Fig. 47.—*Loading-coil pots in a manhole*

The coils used for loading purposes are placed in iron pots, filled with insulating compound, and closed with water-tight covers. The illustration shows five of these pots in a manhole and the manner of connecting the coils into underground cable circuits by means of short lengths of cable, making water-tight joints with the covers of the pots. Very large pots may be used in a manhole either of its side circuits. This is primarily because of the fact that its conductivity is twice that of either side circuit.

LOADED TOLL LINES.—Besides having resistance, all paired conductors have a property called capacity. Resistance and capacity together cause both attenuation and distortion of the speech currents in telephone lines. The degree of attenuation and distortion increases with the length of the line, increases with a decrease in the space between the wires, and decreases with an increase in the size of the wires. Paired cable conductors, which are much smaller and closer together than open wires, have these detrimental properties in a large degree as compared with open wires. In both cases it has been very common practice to minimize the detrimental line properties by using larger wires for toll lines than for local lines.

Both attenuation and distortion may also, to a certain extent, be counterbalanced by the use of loading coils which are inserted in the lines as briefly described under "Development of the art." There are three degrees of loading most commonly used in practice, known as light, medium, and heavy. All three are applied to cables, although the medium and heavy are more commonly used. As applied to aerial open wires heavy loading is generally used.

Loading coils are mounted in iron cases called pots; the pots are filled with an insulating compound and the covers are made water-tight. For underground cable lines the pots are located in the subway manholes or in auxiliary manholes near the regular manholes. For aerial cable lines the pots are either buried at the base of the poles or preferably mounted on fixtures attached to the poles a short distance below the point of attachment of the aerial cable.

TOLL LINES LOADED AND PHANTOMED.—Loaded circuits may also be phantomed, but in such cases both the side circuits and the phantom circuits require special loading coils. The side circuit coils are wound in such a manner that when the current passes in opposite directions through the two sides of the line, as is the case when talking over a side circuit, the loading coils act effectively, but when the current passes through the two sides of the line in the same direction, as is the case when talking over the phantom circuit, the loading coils have no effect. The phantom circuit coils are wound in a manner essentially opposite to those of the side circuits. They are thus effective only with respect to the phantom circuits.

Toll Lines with Repeating Amplifiers.—While loading coils tend to equalize the attenuation of the elements of speech currents throughout the effective frequency range and also reduce the attenuation as a whole, the attenuation can never be entirely eliminated because electrical energy losses always occur in the line and in the loading coils themselves. To extend the range of transmission beyond the limit fixed by the minimum attenuation economically obtainable by the aid of loading coils, either large conductors for both cables and aerial wire lines or else some type of amplifier must be used.

Repeating amplifiers, which were described under "Development of the art," are being introduced in toll lines to a great extent. They are so arranged that they are energized automatically when the containing circuit is put into service. Since the operation of these devices introduces practically no distortion, the transmission current may be repeated and amplified as many times as necessary to meet all present commercial requirements.

VI. TELEPHONE TRAFFIC

Telephone traffic is defined as an aggregate number of calls for connections and, from the operating point of view, comprises all calls handled.

Telephone traffic, being the result of service demands is, in a general way, representative of those demands, but the traffic in any given case greatly exceeds the number of completed regular calls made by the public because it includes calls for busy lines, stations that do not answer, wrong stations and stations in trouble, extra calls caused by lack of facilities, operating calls incidental to particular methods of handling, information and complaint calls, company service calls, etc. Telephone traffic is, therefore, numerically representative of the total service which is rendered by the plant and operators. The most important general divisions of the subject of traffic are handling the traffic and the provision of the necessary plant facilities and operators.

The broad definition of traffic given above meets the numerous applications of the term. While it is frequently applied in a general way, it is much more frequently applied in a specific way. An aggregate number of calls is usually considered with reference to a particular period. The period of reference depends upon the use to which the count is to be applied.

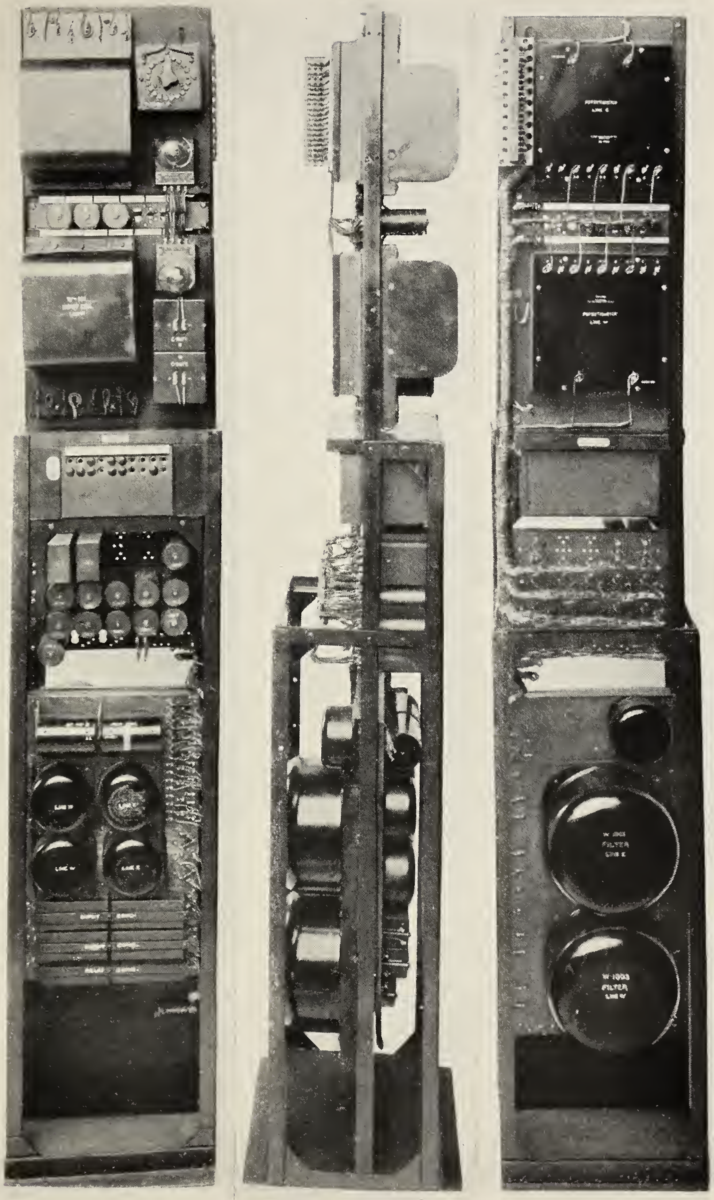

FIG. 48.—*A repeater unit*

Apparatus is mounted on both sides of a steel frame and three views of the same unit are shown. Two repeating amplifier bulbs are located on the right near the top of the left view. These are associated with the line wires through an equipment network. A description of this equipment would necessarily be of a very technical character and is unnecessary to the attainment of the object of this circular

The traffic handled by each central office is always classified the same as the service it represents is classified because the different classes of service are handled differently. Particular calls very commonly represent a combination of service classes, therefore traffic is also classified according to the type of call. This classification naturally includes all irregular and special types of calls, such as mentioned above.

The consideration of plant facilities for handling traffic involves also the type of call to be handled, but such considerations are usually limited to a particular portion of the plant, and each specific problem involves the facilities required for handling the traffic that will probably be routed via those facilities. As a result of such considerations traffic is divided into many sectional groups which are appropriately designated. Examples are: Originating, outgoing, incoming, call circuit, ring down, long haul and short haul traffic.

The discussion which follows is based on present day practice. The discussion under each heading which involves both manual and automatic switching equipment will include both. As present-day practice is mostly manual this practice will always be considered first.

1. TRAFFIC VARIATIONS

Telephone traffic as a whole is subject to wide variation with respect to both locality and time. This follows from the fact that the telephonic needs of the users vary in the same respects.

Average Variation.—The time when any individual user in any particular locality will originate a call is impossible to predict; it depends upon combinations of many causes. The demands of a group of subscribers are the result of the combined demands of the individuals of that group. The usual demands of any user have a general relation to those of all other users, and a close relation to those having corresponding business or social interests. The larger the group the more nearly uniform is the distribution with respect to time of demands of the group. This results from the fact that the effect on the calling rate of each of the many causes influencing the origination of a call is so averaged that the aggregate calling rate may be said to follow a definite law of distribution for a given group of subscribers.

If the users are grouped according to their interests the average service demands of each group will be found to follow the degree of activity of the interest. The total originating traffic of any central office district comprises, of course, the traffic associated with all of the interests combined, and the variations as a whole generally follow the activity of the predominating interests.

While toll traffic varies with respect to time in a manner similar to local traffic, it is dependent in all cases upon the mutual interests of two localities. The degree of mutual interest is dependent, in turn, upon many factors, but the nature of the localities, the distance and the transportation facilities between them are probably the most important.

Variation Throughout the Day.—Traffic varies throughout the day in all localities and each day has its maximum and minimum. On account of the usual preponderance of business traffic the daily variations in a general way follow the business needs during the morning and early afternoon. During the late afternoon the business needs usually decrease and the social needs increase. During the evening the social needs are usually a maximum and frequently determine the traffic variation.

Traffic after midnight is small and is usually least between 2 and 4 o'clock. It increases as commercial activities are resumed, and reaches a maximum when these activities are at a maximum. It decreases somewhat during the midday meal period and increases again in the afternoon to a maximum which is usually less than the morning maximum, and then decreases rapidly to the evening meal period, after which it usually again increases, though it may not, depending upon the locality. The evening decrease is usually fairly gradual and follows the decrease in social activities through to the midnight hours.

The periods of night minimum, morning maximum, luncheon decrease, afternoon maximum, and evening maximum vary with the locality, as does also the rate of variation, but every locality has its busiest hour, during which the traffic is a maximum. It is of interest to note that, in a busy city, more than 10 per cent of the total daily calls may originate during the busy hour.

Variation from Day to Day.—Traffic normally varies but slightly from day to day during the week, except with respect to Saturday and Sunday. On these days the variation as compared to those on other days may be very great and they differ in different localities. In cities where Saturday is a half holiday the morning maximum is frequently greater than for any other morning, and the afternoon maximum is much smaller. In many cases the Saturday evening increase is very pronounced. Traffic is generally

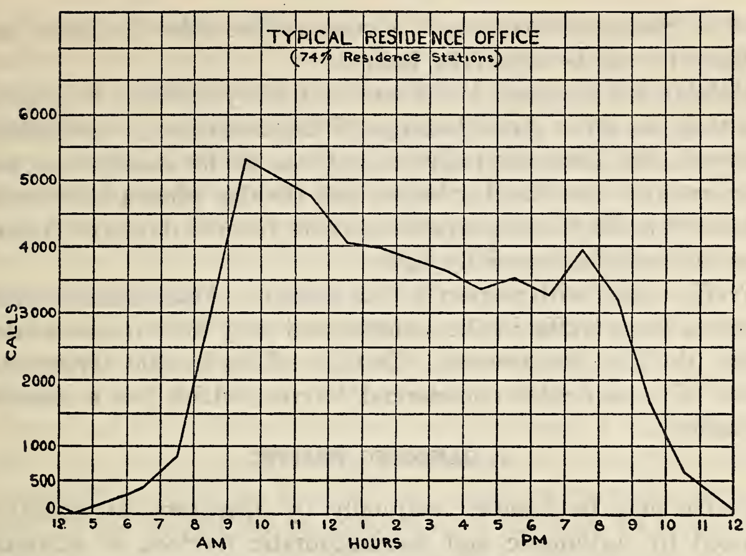

FIG. 49.—*Typical load curve for a residence central office*

The total number of calls handled during any given hour is plotted for the middle of the hour except for the period from midnight to 5 a. m. when few calls were handled. The maximum number of calls per hour—approximately 5300—were handled between 9 and 10 a. m. This was the busy hour. The load gradually decreased during the afternoon but increased again to an evening maximum of approximately 3900 between 7 and 8 p. m.

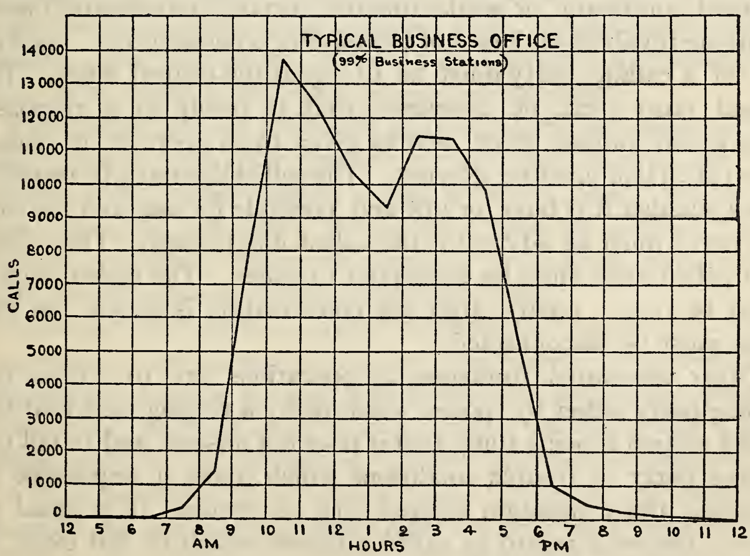

FIG. 50.—*Typical load curve for a business central office*

The total number of calls handled during any given hour is plotted for the middle of the hour except for the period from midnight to 5 a. m. Few calls were handled between 10 p. m. and 7 a. m. The maximum number of calls per hour—approximately 13 600—were handled between 10 and 11 a. m. This was the busy hour. The load decreased to a midday minimum of approximately 9 400 between 1 and 2 p. m. and increased to an afternoon maximum of approximately 11 400 between 2 and 3 p. m.

light on Sundays, excepting in a comparatively few localities, and in these it may be especially heavy.

Holiday and Seasonal Variations.—Holiday traffic is, in general, less than on other days, because of the cessation of commercial activities, but there are many exceptions, as, for example, at seashore resorts. On the day before and the day after a holiday the volume of traffic is often especially great, but the day after it may, in some cases, be especially light.

Traffic varies with respect to the seasons. Many central offices handle a large traffic in the summer and very little in the winter; others do just the reverse. Certain offices handle largely the traffic of a particular commercial interest which has a seasonal variation.

2. HANDLING TRAFFIC

Traffic may be handled manually by operators, by operators assisted by automatic and semiautomatic devices, or automatically by the plant itself without the assistance of operators. Full automatic operation has, however, been mainly applied to handling local traffic.

Fundamental Operation.—Whether the system of operation is manual, automatic, or semiautomatic, certain fundamental operations are involved in the act of establishing a connection. The first act of a calling party must be to signal the central office. The signal must next be answered; that is, result in a response. The called number must next be given to an operator, or dialed. The called line must be selected. The called line must be tested to learn whether it is busy, or idle and available for use, and the calling party must be advised if the called line is busy. The calling and called lines must be connected together. The called station must be rung. Lastly, after the conversation is ended, the two lines must be disconnected.

Other associated fundamental operations are to advise the calling party either by spoken words or by a ringing tone that the called station is being rung, that it does not answer, and to tell the calling party of trouble conditions which make it impossible to establish the connection desired. In all systems it is usual to advise also with regard to called numbers which do not exist, or which have been changed.

Closely associated with the fundamental operations involved in handling traffic are other switching operations which vary with the different methods of switching. The most important of these is that of trunking calls. In the manual system toll calls are handled over special toll trunks and part of the local calls may be trunked in small central offices, a large part may be trunked in multioffice local areas and all may be trunked in very large offices of a multioffice local area. In both the automatic and the semi-automatic systems all calls are trunked; furthermore the method of trunking is uniform and inherently a part of each system. In the manual system the method of trunking varies with the size of the central offices and with the traffic to be handled.

Operating details with respect to fundamental operations have been previously considered in part in the sections on Plant. They will be further considered in this section but on a classified basis.

Local and Toll Traffic in General.—A local call is made in single office areas by giving or dialing the number of the called station. In multioffice areas the name of the called central office must be given, or its equivalent must be dialed, as well as the number of the called station. Local traffic is usually handled on a mimimum delay basis. This basis requires such an amount of plant and operation facilities that very little delay will be caused by lack of these facilities. The size of the operating force is varied throughout the day to meet the demands, but the amount of plant can not be so varied. As the traffic decreases the amount of idle plant increases, and vice versa. Thus at slack periods the amount of local plant which is idle may be very considerable.

A suburban toll call is usually made by giving the name of the called central office, the number of the called station, and the number of the calling station. Such calls are usually referred to as two-number toll calls. Where such calls are handled via a separate toll central office the name of the calling central office must also be given to the recording operator.

Suburban toll traffic is usually handled on a slight delay basis, or subject to slight delay during the busy hours. This is because of the lesser demand for such service and because the greater cost of the plant facilities make it economically desirable that a proportionately greater utilization of these facilities be obtained.

A long-distance call is usually made by giving the recording operator the name of the called central office, the number of the called station, the number of the calling station, the name of the calling office, and the name of the calling party. In some instances, calls to certain long-distance points are handled on a two-number basis. Where automatic equipment is used the number of the station usually includes the central office designation.

Long-distance toll traffic is usually handled on a reasonable delay basis, which means subject to considerable delay during busy hours. This is because of the comparatively small demand for this service and because the great cost of the plant facilities make it economically imperative to keep them in use as much of the time as possible.

Local Traffic.—The handling of subscriber traffic differs from the handling of public telephone traffic, mainly because of the different methods of collection of the charges. The handling of subscriber traffic does not usually involve any actual collection. The handling of public telephone traffic usually does involve collections because most public telephones are now either provided with coin-collecting devices, by means of which the charges can be collected at the telephone, or are served by an attendant who collects the charges. Operators who serve unattended public telephones must always supervise the deposition of the coins and may also have to operate coin-collecting and coin-returning keys in addition to establishing the connection.

The method of handling business traffic does not differ from that of handling residence traffic. The traffic originating on business lines, however, often greatly exceeds that on residence lines, and the service requirements are usually somewhat more exacting with respect to speed, accuracy, and uniformity.

The methods of handling flat-rate and message-rate traffic differ because the latter involves the recording of all completed calls, whereas the former involves only the recording of toll calls. For charging purposes the calling station must be identified with respect to its call number, and in the case of local traffic also with respect to whether it is entitled to flat-rate or message-rate service.

In manual offices the line signal either bears the line number or is closely associated with the answering jack, which does bear the line number. Thus the operator identifies the calling line. The line signal is always so marked as to indicate whether it is an individual or party line, and also to indicate whether the charge should be on the flat or message rate basis. On a party-line call the operator asks the calling party what his telephone number or station designation is in order to identify the calling station.

Local calls are recorded in two ways. One is by means of message registers, and the other by means of form tickets. The registering device is only used in connection with individual lines and is caused to register on the operation of a push-button key associated with the connecting pair of cords. The register is operated at the completion of a call and just before disconnection.

Where automatic switching systems are used the handling of calls is also somewhat dependent upon the classes of service sold. Public telephones may be arranged to automatically collect a single coin and thus give local service without operator supervision. In those few localities where measured service is sold, message registers are associated with individual lines but party-line originating calls are handled through a manual switchboard. Until quite recently rural service also has been handled entirely through a manual switchboard, but recent developments have resulted in full automatic switching for a considerable part of the service.

Toll Traffic.—All toll service is charged for on a time and distance basis. Hence the handling of all toll traffic involves the timing of the connections. A form ticket is filled in to show the connection established, the time it is established, and the time of disconnection or the elapsed time, depending upon whether time is recorded by hand or by a timing device. If recorded by hand, the elapsed time is calculated. The methods of handling toll traffic differ materially with respect to distance and to whether or not a particular call can be completed promptly.

In small central offices the toll switching equipment is usually mounted on the same switchboard that carries the local switching equipment. The local operators may act as toll operators by directly establishing the toll connections or special toll operators may be provided. In the latter case incoming toll calls are received by the toll operators directly, and outgoing toll calls which originate at a local operator's position are passed to a toll operator; the local operator instructs a toll operator to connect with the calling line for the purpose of establishing the desired connection.

Toll traffic to near-by points is usually handled by the local operators. If small offices are involved the call may be handled over ring-down trunks, which may be used in both directions or one way only, depending upon the traffic to be handled. An idle trunk is selected by the originating operator, the other office is signaled by ringing on the trunk selected, and the order is passed to the distant operator over the same trunk. If large offices are involved the traffic frequently warrants handling by

A and *B* operators over one-way trunks equipped with signal lamps.

In connection with large central offices the toll traffic is usually handled by a separate toll switchboard which may or may not be in a separate toll central office, depending on the traffic to be handled. In very large cities the long-distance traffic may be handled by one toll central office and the suburban toll traffic by one or more toll central offices. While a toll central office handles toll traffic exclusively, it necessarily does so in conjunction with its associated local central offices.

Where separate toll switchboards are used calls for toll points are passed by the local central office operators to the toll switching center. The calling line is connected to a trunk to a recording operator, who writes the details of the desired call on a form ticket. In some cases the recording operator gets the call details from both the *A* operator and the calling party and in others from the calling party only. In all cases the *A* operators advise the recording operators of the class of service calling if it is involved in the handling of the call. If the desired connection is such that it can be promptly established the recording operator obtains connection with the calling line through a *B* operator in the local office, over a toll switching trunk, and then releases the connection with the recording trunk from the *A* operator, who receives a disconnect signal which in some cases is arranged to flash at regular intervals until disconnection is effected.

If the desired connection is such that it can not be promptly established, the recording operator writes the ticket, notifies the calling party that he will be called and disconnects from the recording trunk. On receipt of the disconnect signal the *A* operator releases the calling line.

In some cases of suburban toll operation the recording operator may be in fact a line operator at the toll switchboard, who handles the toll lines to the required point, but usually the recording operator is not a line operator, in which case she also enters the number of the toll switching trunk on the form ticket and then passes it by messenger, pneumatic tube, or other conveyor to a line operator at the switchboard who does handle the toll lines to the required point.

If the calling line is held on a toll switching trunk the line operator proceeds to establish connection with the called station over a toll line. The signaling is usually effected by ringing the distant operator. If the called point can not be reached directly over a single trunk the services of other toll operators are required to connect trunk lines together until the point is reached. Whether more than one trunk must be used is of course dependent upon the traffic to be handled. If the calling line is not held on a toll switching trunk the line operator secures the called station and then obtains the connection with the calling station over a toll switching trunk.

As toll service is paid for on a per-call basis the handling of toll traffic is in general independent of local service classifications. Exceptions may obtain in particular localities because of local operating methods. An important example is that of handling public telephone toll traffic where the telephones are provided with coin-collecting devices which involve operations for collecting and returning coins. In such cases the local end of the toll switching trunks must be equipped for coin operations and the local operator must be instructed by the toll line operator to collect or return, as occasion may require.

Because of the necessity for timing toll connections, manual toll switchboards are regularly a part of the automatic system. With automatic switching equipment the calling party is enabled to directly reach an operator by calling a particular number, which is usually O. The toll operator called in this manner may be either a recording operator or a line operator, depending upon the local method of handling toll traffic. In some cases the automatic switching operation is carried through to the distant central office, in which case but one operator is required to handle the connection.

Each line operator is provided with a dial and each pair of cords is provided with a dialing key by means of which the dial can be associated with any pair of cords. When a line operator receives a call ticket from the recording operator she dials the calling party over a toll switching trunk to the calling office and thus secures the calling line against seizure. The toll connector associated with this type of trunk does not ring the station when the line selection is completed as regular connectors do. The ringing is started by the toll operator when she is ready to call the station, that is, when she has secured the toll point required.

In the case of a delayed call the operator does not dial the calling station until she is ready to make the connection. Should the calling line have been seized in the meantime, it will be found busy by the toll connector, but the toll connector is so arranged that it will give the busy tone to the operator, remain in the connection position as long as the operator may desire, and seize the line the instant it is released.

The line operator's cord circuits are provided with lamp supervisory signals as usual. The one that is associated with the toll line is usually controlled by ringing on the part of the distant operator. The one that is associated with the toll switching trunk automatically notifies the operator when a busy line has been released and when the station called has answered. The release of the automatic equipment associated with a toll switching trunk is under the operator's control only and is effected when the plug is removed from the jack.

3. TRAFFIC MEASUREMENTS

The measurement of traffic and of the time elements of the connections involved is necessary in all systems in order to determine the amount of switching equipment and the number of trunk lines required and also to determine the efficiency of utilization of the switching equipment and trunk lines. In manual systems such measurements are also necessary in order to determine the number of operators necessary for each hour of the day, and the efficiency of the operating labor.

Both switching facilities and operators must be provided in advance of actual need. Measurements made under working conditions enable the determination of requirements under conditions which will in all probability be similar. Both switching facilities and operators must be provided on an ecomomic basis and because of the wide variation in traffic it must be measured at sufficiently frequent intervals to insure continuous handling on an economic basis. The method of making these measurements will be outlined under the heading of Measurements, but the application of the measurements will be outlined under succeeding headings.

Division of Traffic Measurements.—The measurement of traffic is effected by counting the number of calls handled. The methods of handling toll traffic usually involve the recording of all calls handled, by means of form tickets which may thus serve for counting of such calls. The methods of handling local traffic do not involve the recording of calls except in those cases where message-rate service is sold and in certain cases where the recording of public telephone service is required. In any case such records only serve for measuring a particular part of the total traffic. It is the usual practice to make periodic measurements of all local traffic a part of the routine work of handling the traffic.

The classification of local subscriber traffic previously considered was shown to be on several independent bases. Thus the actual local subscriber traffic originating in any particular case may be a combination of several classes, as for example, one particular subscriber may originate message-rate, two-party line, residence traffic, and another may originate flat-rate, individual line, business traffic. Each combination of subscriber classes thus has its own type of originating call. As public telephone traffic is classified only with respect to the methods of collections, no combination of classes results, and each method involves its own type of local call.

The number of calls per station per day is known as the station calling rate. While the calling rate varies greatly with respect to different stations, the average calling rate for each type of call originated in a given locality is fairly constant and serves as a basis for estimating the probable traffic which will be originated by similar stations in the same or in comparable localities.

It follows from the above that measurements of traffic are required with respect to each type of call that is handled in each particular central office. The variety of traffic measurements required is naturally greatest for large manual central offices. It is obvious that all irregular calls handled, such as for busy lines, out of order lines, changed and vacant numbers, stations that do not answer, trouble and complaint reports, etc., must be included.

Method of Counting Calls.—In manual central offices the usual method of counting the calls handled is to first register or record them individually and to then take the count from the register or record. Each operator is provided with a small mechanical or electro-mechanical counter for each type of call to be handled, or a tally slip, and each time she handles a call she registers or records it on the associated counter or on the tally slip. At the end of each hour a clerk records the total number of each type of call registered or recorded by the operator or operators at each operating position. Thus a complete record is obtained of the total traffic, of the traffic subdivided by types of call and of the traffic subdivided by operating positions. In automatic offices similar measurements may be made by counting the machines as they operate or by

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means of registers so associated with the machines that they operate to count a call each time a machine releases.

Frequency of Measurements.—The frequency of making traffic measurements is dependent upon the frequency with which conditions change. In automatic offices it is necessary to keep informed regarding the traffic variations and distribution with respect to the line groups during the busy hour only, and changes of importance are not frequent. In manual offices the cost of operating labor is a large part of the cost of rendering service and changes in the operating force are very frequent. It is therefore necessary to keep informed regarding both the variations of traffic and its distribution throughout the day.

Traffic measurements are usually made regularly in manual offices on two days of each month, excepting in the small offices where conditions change less frequently. Two days' measurements are made in small offices at intervals of several months or once each year as occasion may require. The two days chosen are those which are likely to be normally busy days.

Supplemental Measurements.—Regular traffic measurements may be supplemented at intervals by special measurements for the purpose of determining the traffic handled under various conditions, by various methods, by various routes, at various times, and for various groups of lines or operators. Regular traffic measurements may be supplemented also by comparative measurements. As will later be described, the telephone lines are always arranged in groups in the central office. In manual offices the number of plugs in the answering jacks of the several groups of lines may be counted at five-minute intervals. The totals obtained for a given type of call will be approximately the same in ratio as the traffic loads of the corresponding groups of lines. In automatic offices similar results may be obtained by counting the number of like machines in the operated condition.

Measurement of Time Elements.—Every connection, whether completed or uncompleted, has two important time elements. One is its duration and the other is its time of occurrence with respect to other connections. Each group of lines is served by a group of common switching equipment units or a group of trunk lines which are used in common. Both of these are used not only for handling the traffic but also for carrying the traffic, and a sufficient number of each must be provided to serve its associated group of lines.

The duration of a connection with respect to a particular unit of switching equipment or a trunk line is referred to as its holding time. Measurements are required with respect to each group of lines to determine the maximum number of calls which result in overlapping holding time. Such measurements are made by actual counts during the busy hour, and are used in the determination of the plant facilities required.

4. DETERMINATION OF PLANT FACILITIES REQUIRED

If calls from a group of lines were received in succession and did not overlap in holding time, a unit amount of switching equipment or a single trunk line, as the case might be, could serve all calls; but calls are not so received. At one time they may be widely spaced with respect to time, and at another they may be received in rapid succession, and occasionally they are received simultaneously. Furthermore, the holding time varies because the duration of communications varies greatly, and because the operating labor varies with the different types of calls.

Dependence upon Delay Basis.—It is evident that under practical conditions the serving of each call without delay would require an impractical amount of facilities; that, on the average, some delay must be permitted; and that the required amount of facilities is decreased as the amount of tolerable delay is increased. Thus the amount of switching equipment or the number of trunks required to serve a given group of lines increases with the number of calls to be handled which have an overlapping holding time and decreases with the amount of average delay permissible.

Local switching equipment and local trunk lines are very generally provided in amounts which are sufficient to make delay in connection caused by lack of these facilities fairly infrequent, but toll trunk lines, which involve large costs, and their associated switching equipments, are not generally provided in amounts sufficient to make delay infrequent during the busy hour. The number of such trunks actually provided depends upon the permissible average delay. The permissible average delay increases with first cost and the annual charges against the trunks under consideration.

Dependence upon Community Needs.—Traffic is handled by a variety of methods; therefore switching equipment is designed to conform to the various methods of handling traffic. These have been developed to best meet the traffic requirements. In general the traffic and the demand for service of a better grade increase with the size of the community. Thus, as a community passes through successive stages of growth, the methods of handling traffic and the design of the switching equipment change.

Dependence upon Busy-Hour Load.—In all cases, whether the switching equipment is entirely automatic in operation, is partly automatic, or is operated manually, its amount is dependent upon the greatest traffic it has to handle and carry, and this occurs during the busy hours. The term "switching equipment" covers both the line equipment, which is designed for switching, and the switching equipment, which is used in common for establishing connections.

In the larger manual offices the telephone line equipment is usually divided into two parts, known as the answering equipment and the calling equipment. The answering equipment of the manual system comprises the line signals and the answering jacks, and both have their equivalents in the line switches of the automatic system. The calling equipment of the manual system comprises the multiple jacks, which are exactly equivalent to the multiple bank contacts of the automatic system. In small manual central offices no multiple jacks may be provided, the answering jacks serving for calling purposes also. The amount of answering equipment is dependent upon the number of lines only, but the amount of calling equipment is dependent upon the traffic to be handled, because each operator, manual or mechanical, must have direct or indirect access to a multiple terminal of each line for calling purposes.

Dependence upon Number of Operators.—In manual offices the common switching equipment is known as operator's switching equipment. Each operating position is provided with a definite amount of such equipment, which is known as the operator's position equipment.

Each *A* operator's position equipment comprises a certain number of pairs of cords and their associated apparatus and a telephone set. By means of a position equipment each *A* operator can handle a predeterminable amount of traffic, and it follows that as many *A* position equipments are required as there are *A* operators required during the busy hour. The number of pairs of cords required per operator is primarily dependent upon the *A* operator's loads.

In manual offices where *B* operators are required, the incoming trunks terminate in switching equipment which is individual to and a part of the respective trunk circuits. Such switching equipment may be regarded as common in the same sense that the trunks themselves are used in common.

Each *B* operator's position is equipped with a number of incoming trunk equipments by means of which she can handle a predeterminable amount of trunk traffic. It follows that as many *B* position equipments are required as there are *B* operators required during the busy hours. The actual number of trunks served by each *B* operator is dependent upon the load she can properly carry.

Dependence upon Grouping.—Trunk lines always serve in common to connect one group of lines with another group. Either group may consist of lines serving particular telephones (central office lines) or other trunk lines. The number of trunk lines required in any case is, like the amount of common switching equipment required, dependent upon the maximum number of connections which overlap in holding time and these will occur during the busy hour.

It is found in practice that on the average the number of overlapping connections resulting from a given number of calls does not increase in direct proportion to the number of calls. The greater the number of calls the less will be the proportion of such overlapping connections. Therefore the greater the number of calls handled by a group of common switching equipment or a group of trunk lines, the less will be the proportion of such facilities required; or, expressed in another way, the greater the number of calls handled by a common group the more calls a unit amount of common switching equipment or a single trunk line will be enabled to handle. Experience has established a definite relation between the number of calls with a given average holding time and the number of a given type of switching equipment units required to handle the calls on a given delay basis.

In automatic offices the common switching equipment comprises the selectors, connectors, and other associated devices. These are arranged in groups. The groups may vary in size, but each group can handle a predeterminable amount of traffic. The total number of selectors and connectors required is dependent both upon the traffic to be handled and upon the grouping of these devices, which follows the trunk grouping.

Spare Facilities.—Because of the fact that in the past the growth of the telephone industry has been very general, it has become the usual practice to provide spare switching equipments and trunk lines to care for the increasing traffic. The provision of spare facilities is always based on the load carrying capacities of existing facilities. Spare facilities are put in service as fast as required by increased traffic.

5. TRAINING OPERATORS

An operator's work is such as to require careful selection of individuals and their special training. The selection of individuals is based on a reasonable degree of intelligence, education, good health, and probable aptitude for the work. The amount of training required increases with the size of the central office, the degree of complexity of the operating methods, the amount of trunk routing to be learned, and the quality of the operation required.

On the average, operators remain in the service a comparatively short time. The time varies, however, in different communities. The turnover is particularly large in the large cities, where the average time may be as short as one year. Besides the replacements, additions to the force are required to meet the increasing demand for service. Thus the work of training operators is not only of importance but it may be of considerable magnitude.

The training of operators for work in large city offices is frequently effected in a special school which the telephone company maintains for this purpose. The school is provided with switching equipment which simulates that which the operator will use. The course ordinarily requires about three weeks, and when completed the operator has a working knowledge of how each type of call is handled and has acquired a fair degree of proficiency; she can therefore be expected to handle light loads in actual service with a fair degree of speed.

6. *A* OPERATOR'S LOADS AND POSITION EQUIPMENTS

Theoretically each operator should receive as many calls as she can handle and still maintain a required grade of operating service without undue physical or mental strain. To so load each individual operator requires that she shall receive calls just as fast as she can efficiently dispose of them.

As a general proposition it is impracticable to avoid some small average delay in handling calls for the reason that the rate at which calls are received always varies. They may be received infrequently, occasionally, in rapid succession, or they may even

FIG. 51.—*An operators' school*

In large cities switching equipment which simulates that of a switchboard in service is provided for practice purposes. The student operators are seated at the switchboard. Calls are originated and received at the desks by experienced operators. The student operators are thus familiarized with the switching equipment and are enabled to attain a fair degree of proficiency before assignment to a central office

FIG. 52.—*Switchboard for A operators*

An operator who answers originating local calls is known as an *A* operator. An *A* operator may or may not complete a call without the assistance of another operator, depending upon whether or not she has a jack of the called line within her reach. In all cases, however, she controls the handling of each local call received. When toll calls are handled by special toll operators, as is usually the case, the *A* operator switches originating toll calls to toll operators. The illustration shows a portion of a typical common-battery switchboard. From the top down may be seen the multiple station line jacks, the multiple trunk jacks with which designation strips are associated, and the answering jacks and line lamps in the lowest group on the face of the switchboard. Each cord circuit is provided with (reading from the operator) five ringing keys, a listening key, and two supervisory lamps. On the left of each keyboard may be seen a group of key buttons for call circuits be received simultaneously. The cost of providing enough operators and switching equipment sufficient to eliminate all delay in handling calls would be prohibitive; some delay must be tolerated. Among the practical expedients for reducing delay in handling calls is that of call distribution.

Call Distribution.—It has previously been stated that the larger a group of stations is the more nearly uniform is the distribution of the calls among the group with respect to the time of demand for service. Because of this fact and considered alone it would be an ideal arrangement to have all of the calls received in a given central office so distributed among all of the operators that each call would be received by the operator who first becomes idle. Each operator would then handle calls at a rate which would have the maximum constancy and under such conditions she would be enabled to handle a maximum number of calls with a minimum of delay.

With manual switching equipment as previously described the ideal distribution of calls can only be approximated, and the degree of approximation possible varies greatly with the number of lines to be served, the station calling rates, and the type of equipment used.

The lines are usually divided into groups, and each group has its line signals and answering jacks associated with a particular operator's position. The lines are usually distributed among the groups, so as to bring the total number of calls to be handled within the ability of the average operator to handle them. Thus the manual practice places each call within the reach of a particular operator and also within the reach of the adjacent operators. There are two means employed for distributing calls to more operators. One is by teamwork among operators, and the other is by duplicating or multipling the line signals and answering jacks.

The term "teamwork" is applied to the practice of having each operator, who has no signal directly before her awaiting an answer, assist the adjacent operators. By this means the total load is much more evenly distributed than if each operator served only her own small group of lines. The larger the number of lines and the higher the calling rates the larger will be the number of operators required. The efficiency of the teamwork in distributing calls evidently increases with the number of operators.

Teamwork can be used as a means of distributing calls in any office having more than one switchboard position, and it has a marked effect in reducing the answering time and increasing the number of calls that one operator can handle. Its effect with respect to each particular operator, however, is not proportional to the total number of operators. The maximum gain is obtained from the adjacent operators, and the gain per operator decreases as the distance away increases.

Thus far the multipling of line signals and answering jacks has been confined to common-battery switchboards which are usually of the multiple type and therefore adapted to such a practice. There are two methods of doing this. The most common method is to provide the usual line lamp and answering jack before a particular operator and one or two multiples in adjacent sections of the switchboard. One such multiple then brings each call within the reach of six operators and two such multiples brings each call within the reach of nine operators. The other method dispenses with the lamp and answering jacks before the particular operator and associates the multiple line lamps with the multiple jacks. As many as five or six such multiples per line have been provided in some cases.

Call distribution by means of multiple line lamps is not always practicable. Aside from the cost the space in the switchboard, which is limited by the average operator's reach, may be required for other purposes of greater value or necessity. Furthermore, the number of multiple lamps per line is limited because as the number increases the greater is the probability of more than one operator attempting to answer with consequent waste effort and the greater is the possibility of confusion because of double answers unless special equipment is provided for its prevention.

A number of automatic systems for distributing calls to operators have been developed, but few such systems have been placed in actual service. Semiautomatic switching systems as now designed are all arranged for automatic call distribution and all calls received by a particular office are distributed to all of the operators who may be on duty. The operators' positions are arranged in numerical order, and each call is received by the first operator in the row, who is ready to receive it. The design is such that no operator ever has more than two calls waiting to be answered, and rarely more than one. Thus the ideal distribution of calls is closely approximated.

Work Units.—The operation of any large manual switchboard may involve all classes of traffic previously referred to. The amount of operating labor per call for each type of call may differ, but with a given type of switching equipment it is a fairly definite amount for each. Furthermore the labor of handling each type of call with any type of equipment may be compared with the labor of handling a particular type of call on a particular type of switching equipment as a unit measure. The unit of measure commonly adopted is the labor involved in handling a flat rate, local, nontrunked call for an individual line on a certain standard type of common-battery switchboard having single line lamps and answering jacks. Such a call so handled is generally known as a unit call and the labor of handling is known as a work unit.

Basic Load.—In practice the average operator's load is largely determined by the particular average answering time regarded as satisfactorily meeting local service requirements.

It has previously been shown that the delay in answering calls is in part dependent upon the extent to which the calls are distributed by the type of switching equipment which may be used. The delay in answering a call with switching equipment of a given type is also dependent upon the number of calls to be handled in a given time and upon the type of call handled.

When the number of calls to be handled is very small, each call is disposed of before the next one is received, except infrequently. The frequency, however, is partly dependent upon the type of call handled and the type of equipment it is handled with, because different types of calls and different types of switching equipment involve different amounts of operating labor and therefore require different amounts of time for handling. If overlapping calls are infrequent, the average operator can maintain a low average delay in answering. As the number of calls of a given type to be handled increases, the average interval between calls is correspondingly reduced and the percentage of the calls delayed, because of the fact that the operator is handling a previous call, is increased. The average delay in answering is consequently increased. A limit to the number of calls which can be handled is reached when they arrive as fast as the operator can dispose of them. The actual load which an operator may reasonably be expected to carry, therefore, increases toward a limit as the average answering time increases, and conversely.

It has been determined from many measurements of actual traffic, handled by many operators, that an operator of average skill, working in a team of five or more, can handle 230 unit calls per hour and maintain a specified quality of switching service, which includes a specified answering time, with due regard to personal well being. With more than 12 operators at the switchboard, and if these operators are above the average in skill and are assisted by good supervisors, the number of unit calls per hour which can be handled with similar efficiency may increase to 245. For short periods of as much as an hour, during the busiest part of the day and under favorable conditions, even greater loads may be carried.

Number of Operators.—Extensive series of measurements of the labor involved in handling each type of call in connection with each type of switching equipment have enabled the expressing of that labor in terms of work units. Thus when the calling rates for each type of call are known, it is possible to determine the work units involved in handling traffic originating in any particular group of lines and from this total to determine the number of operators required for the time during which the calling rates apply by merely dividing by the basic load. The maximum number of operators required at one time is determined from the calling rates during the busy hour. The actual number of calls handled by an operator varies with the type of equipment used, which includes the extent of call distribution, the type of call handled, and the quality of the switching service to be rendered. This number may range from a comparatively few calls per hour on a toll board to six or seven hundred calls per hour on a modern local-service switchboard. It should, however, be borne in mind that the number of work units and not the number of calls handled is the measure of work.

Position Equipments.—The total number of operator's positions must at least equal the maximum number of operators required at one time.

The number of pairs of switching cords which an operator requires is primarily dependent upon the operator's load and, as has been stated, this number is directly dependent upon the probable number of calls which will have an overlapping holding time. The number actually required will vary with the locality because of the variation in holding time, with the type of call handled, and with the type of switching equipment used, but in order to maintain uniformity and flexibility it is usual to provide the same number for each operator's position in a given office and in like offices.

It is usual to add to the number of cords actually required to make connections a certain percentage of extra cord equipment to each operator's position because of trouble possibilities, the chief of which are caused by breaks in the fine metallic strands in the flexible cords. It may also be necessary to add one or more pairs of cords if the methods of handling certain calls involves the splitting of cord pairs; that is, the holding of two parties on different cord pairs. Seventeen pairs of cords per operator's position is a very common number.

7. *B* OPERATORS' LOADS AND POSITION EQUIPMENTS

A *B* operator usually handles but one type of trunk-switching equipment, although the trunk group as a whole may be divided into subgroups serving different central offices, in which case a separate call circuit is required from each such central office to the same *B* operator. In certain cases particular *B* operators may handle more than one type of trunk-switching equipment in order to make up a full load.

Basic Load.—The labor involved in handling trunk calls by a *B* operator is on the average much less than that in handling calls at *A* positions. Consequently on the average a *B* operator can handle more calls than an *A* operator and the trunk group she serves in turn serves for trunking calls from a large group of telephone stations. Thus the number of calls handled by a *B* operator is not only usually large, but the calls are received at a much more uniform rate than from a comparatively small group of telephone lines at an *A* operator's position.

Again, a *B* operator has the rate at which she will take calls under her own control to a large extent, and she takes them only as fast as she can handle them. Calls may, however, occasionally overlap on call circuits, as when more than one *A* operator attempts to pass calls at the same time, but ordinarily a *B* operator works more uniformly than an *A* operator, and consequently more efficiently.

On the other hand, however, as each *B* operator's telephone set is associated with one or more particular central offices, she alone can handle the calls which come over these call circuits. Thus there can be no direct team work among *B* operators. There is, nevertheless, a net gain in efficiency on the part of *B* operators, as compared with *A* operators, and the basic load is usually taken approximately as 245 work units per hour.

Number of Operators.—The type of trunk-switching equipment used in any instance is, of course, dependent upon the type of calls to be handled and the method of handling, but the operating labor for each type of trunk-switching equipment may be expressed in terms of work units just as is done in calculating *A* operator's loads.

The operating labor per call increases with the number of offices served by one *B* operator because more time is required for distinguishing the calling office and selecting an idle trunk from the correct office. Thus the work units per call handled with each type of switching equipment must be varied for different groupings of the calling offices for the purpose of calculating the number of *B* operators required. It may be stated that in most cases the equivalent labor is a fractional part of a unit of work.

Given the total number of calls to be handled by each group of trunks during a given period, and knowing the work unit equivalent per call, the number of *B* operators required during the period is readily found by dividing the product by the basic load of 245 work units. The maximum number of operators required at one time is determined from the number of calls to be handled during the busy hour.

Position Equipments.—The total number of *B* positions must at least equal the maximum number of *B* operators required at one time. Each *B* operator's position is usually wired for the maximum number of trunks of the type or types, which a *B* operator can be expected to handle, but it is not usual to provide the full equipment capacity unless it is to be used, because of the comparatively high cost of such equipment. Forty-eight trunks per position is a common number when the type is such as to involve a comparatively small amount of operating labor per trunk call.

8. DISTRIBUTION OF LOAD

It is the usual practice in manual offices to group all the telephone lines of a given central office according to the type of calls originated, and, so far as possible, to confine the load at each *A* operating position to a particular type of call, because the continuous handling of one type increases an operator's efficiency and because such an arrangement also localizes the particular switching equipments required. It is also usual to select the lines which will terminate in answering equipment before the operators so that the total load per operator will approximate 230 work units during the busy hour, though this load may be somewhat greater in some cases.

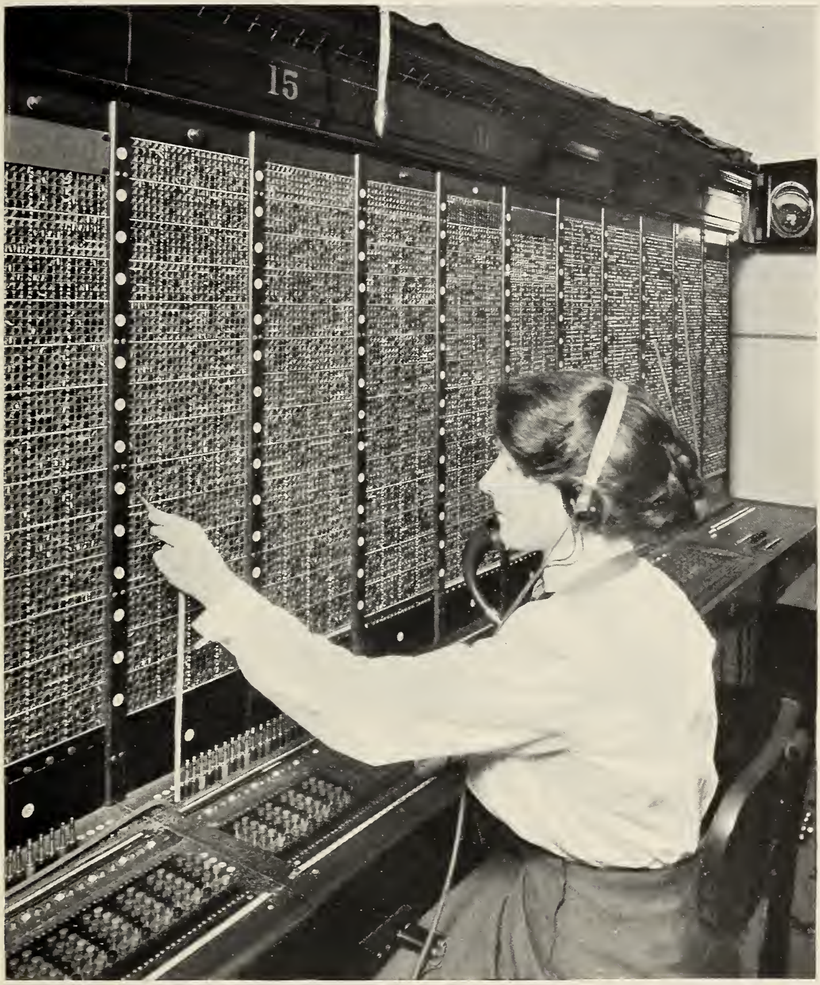

Fig. 53.—*Switchboard for B operators*

B operators assist *A* operators in handling calls to offices having multiple line jacks by testing the called lines, by connecting the trunks to the called lines, and by ringing the called stations. They receive their orders and disconnect signals from the *A* operators. As *B* operators have no occasion to talk over their trunk lines they are not provided with listening keys. The illustration shows a portion of a typical common-battery switchboard. Nearly the entire face of the switchboard is equipped with multiple station line jacks. A row of busy-signal jacks is placed within the reach of each operator. Each trunk line ends in a single cord and plug. A set of ringing keys and one supervisory lamp is shown in alignment with each trunk plug

Distribution of Lines to A Operators.—In the smaller offices which have no multiple jacks the lines are distributed directly from a main distributing frame, but in those offices which do have multiple jacks the lines are distributed by means of an intermediate distributing frame or its equivalent. All of the answering jacks and associated line signals are wired to terminals on one side of this frame. All of the multiple jacks are wired to terminals on the other side of this frame, and these terminals are in turn wired to the lines. Any line and its associated multiple jacks may be cross-connected to any answering jack and its associated line signal. By this means any line may have its calls handled at any particular *A* position.

During the busy hour an *A* operator is required at each switchboard position that carries working lines. At all other hours the number of operators on duty is made as nearly proportional to the demands as practicable. Because of the fact that each operator can reach over one position on each side of her, one operator may serve two or three positions during certain hours. During the late night or early morning hours when the load is very light the one or more operators required may or may not be obliged to leave their seats to handle calls, depending largely upon the extent of the call distributing facilities.

Distribution of Trunk Lines to B Operators.—Trunk lines to *B* operators are also distributed by means of a distributing frame. These lines, of course, must be routed to switching equipment which conforms to the required method of handling traffic. The number of trunks which each operator will serve and their grouping is determined so that the total load per operator will approximate 245 work units during the busy hour.

During the busy hour a *B* operator is required at each working *B* position. During other hours the number of *B* operators on duty is regulated by the traffic to be handled. This, however, requires the provision of special switching equipment for grouping the respective call circuits and trunk switching equipment with respect to the working operators.

Distribution of Load in Automatic Offices.—In automatic offices the traffic load is distributed over intraoffice trunk lines to machines. The machines are arranged in groups and the groups are associated with particular line or trunk groups. In general a sufficient number of machines of each type is provided to enable the establishment of 10 simultaneous connections to and from each group of 100 lines, though the percentage may be greater or less than 10, as required, either as a whole or for particular groups of lines. It is endeavored, however, to equalize the load to or from each group of lines so as to maintain uniformity. This can readily be done at the time of installation and to a certain extent with new lines, but subsequent differences must be cared for by changing the trunking percentages.

Efficiency of Utilization.—The efficiency of utilization of a unit or a group of common switching equipment or of a single trunk or group of trunks is represented by the ratio of the total holding time to the maximum possible holding time. Such efficiencies can be readily calculated from measurements of the time each is held in service.

Efficiency of Operating Labor.—The term efficiency, as applied to operating labor, is used in the sense of production efficiency. It is not possible to use the term efficiency as applied to production in the absolute sense, because there is no exact maximum. Efficiency of operating labor, therefore, always means its relative efficiency. Each operator or each operating force may do a certain amount of work in a given time which may be expressed in terms of work units. Thus the work of each particular operator may be compared with that of any other or with that of a theoretical operator of average ability. Thus also the work of a particular force of operators may be compared with that of another force. In making such comparisons unjustifiable conclusions may be reached if proper weight is not given to all the factors involved.

9. SUPERVISION AND OBSERVATION

The work of the switching operators, except in very small central offices, is always supervised by a chief operator. In large offices the switching operators are divided into small groups, each under the direction of a supervising operator. The supervisors are, in turn, under the direction of a chief operator.

The supervisory work is both executive and assistant in nature. A supervisor maintains discipline and thus promotes efficiency; she places the operators to the best advantage with respect to ability; she helps individual operators by giving instructions and by directing other operators to assist them, and she relieves all of her operators of all calls involving an unusual amount of labor, which would otherwise slow up the handling of traffic.

While divisional supervision of switching operators greatly facilitates the efficiency of traffic handling, it alone does not furnish any exact data upon which the quality of service can be judged. Such data can only be obtained by observing and timing many calls from the instant they originate until disconnection is effected.

It is a common practice in manual offices to secure the required data by means of special equipment, which may be connected with any line, and by means of special operators who are trained observers. The arrangement of the equipment is such that the observer can follow the establishment or attempted establishment of a connection from beginning to end and without the knowledge of other persons. Each operating step is observed, timed, and recorded. The records are summarized and analyzed and they enable the determination of the quality of service rendered.

Automatic switching equipment is not subject to variations in operating time. Its time elements of operation are fixed. Delay in handling traffic may be caused only by inadequacy of equipment, by the failure of the equipment to operate properly, and by the failure of the calling party to properly operate the calling dial. Automatic switching equipment is regularly provided with supervisory signals which aid the attendants in determining the actual cause of any delay.

VII. PRINCIPAL ELEMENTS OF TELEPHONE SERVICE

It is the purpose of this section to enumerate the principal elements of telephone service and to consider how the grade of service rendered is dependent upon each element. The elements are grouped under the headings, "Adequacy of service development," "Dependability of speech transmission," "Quality of operation," "Dependability of operation," "Degree of safety," "Quality of relations with public," and "Degree of public cooperation." It should be noted that the service elements of the last group differ from all of the others in that they depend upon the public for their value and not upon the telephone utility.

1. ADEQUACY OF SERVICE DEVELOPMENT

ADEQUACY OF CLASSES OF SERVICE

Telephone service, as sold in practically all localities, is classified. Service classification is based on the needs of the users. Each locality is entitled to a careful determination of its telephonic requirements so that such classes of service may be offered for sale as will cover all reasonable needs.

Local and Toll Service.—Reasonable needs cover both local and toll, and toll includes long-distance service. All of these are usually required for a complete service and there are comparatively few communities wherein the value of the local service is not enhanced by the availability of toll service.

Subscriber and Public Telephone Service.—Reasonable needs cover both subscriber and public telephone service. Cases occur where one or the other alone serves a given locality, but such cases are not general. Public telephones are a great convenience to the occasional patron and at the same time relieve subscriber telephones from public use. Public telephones are generally placed at locations where the returns will justify the costs, but public convenience occasionally requires that they be placed at locations where the financial returns are less than cost.

The provision of semipublic subscriber stations as well as private subscriber stations benefits subscribers having small needs and also the public as more public stations are thus provided. Thus both the public need and the needs of small users are involved in determining the need for semipublic telephone service.

Flat and Message Rate Service.—Although flat rates are generally divided into business and residence rates, they are strictly equitable only to the average user in each class. The degree of inequality is a maximum between the smallest and largest users of each class. A measure of the average inequality may be obtained by comparing the average cost of serving all subscribers in each class with the average differences of the individual costs from the average cost. If the average difference is not great as compared to the average cost, a uniform rate may be fully justified. The only way in which such inequalities can be eliminated is by making the charge proportional to the number of completed calls or messages. But the message-rate basis of charging requires that each message be recorded or registered, and thus increases the cost per completed call or message.

As communities increase in size both the calling rates and the variations in amount of use per subscriber tend to increase particularly with respect to business service. The increase in calling rates compels a corresponding increase in the flat-rate charges in order to make such charges approximately proportional to the average usage. The increase in the variation in amount of use increases the inequality of such flat rates. Each increase in rates reduces the number of small users, puts the service beyond the means of other potential users, and thus reduces its value to all users.

It is evident that as communities increase in size a point in the telephonic development will be reached where the increased cost of handling on a message-rate basis will be offset by the inequalities of the flat-rate charges to such an extent that a saving will result to a majority of the users by charging on the message-rate basis. Furthermore, the value of the service will be increased for all users by thus bringing it within the means of other small users. This point in development is usually reached for business service in advance of the residence service, and in the manual system of operation long before it is in the automatic system.

Party-Line Service —A wide variation with respect to party-line classes of service is found in practice. Party-line service is inherently a lower grade of service than individual-line service and with a given method of operation the grade decreases as the number of stations per line increases. As communities increase in size the demands for better grades of service increase. The grade of service is raised by reducing the number of stations per line, and by introducing semiselective ringing, and full selective ringing, not, however, without increasing the cost of rendering the service.

Communities may first be served by rural lines carrying 15 to 20 stations per line and each station may do its own calling of other stations on the same line. Rural lines may give way to multiparty lines carrying usually 8 or 10 stations. These may be rung by code, in which case each station may continue to ring other stations on the same line. Code-ringing multiparty lines may give way to semiselective-ringing or selective-ringing 8 or 10 party lines, in which case all ringing is done in the central office. The next step in improving the grade of service is to reduce the number of stations selectively rung to four or five. Such lines give a grade of service which is generally satisfactory in suburban communities, in small cities, and in some large cities. The highest grade of party-line service, that is, two-party-line service with selective ringing, is usually required in large cities.

Private Branch Exchange Service.—Private branch exchange service is regularly sold in all communities where subscribers may require a number of telephones both for central office service and for private intercommunication service. Such service is not only rendered by means of both manual and automatic equipment, but either may be used in connection with either type of central office equipment. Furthermore, if the private branch exchange is to be manually operated, either magneto or common battery equipment may be used, though in this respect the private branch exchange equipment is usually of the same type as the central office equipment.

ADEQUACY OF PLANT FACILITIES

The adequacy of plant facilities is closely related to the adequacy of classes of service, because it follows that plant facilities must be furnished for each class of service, although plant facilities may be so provided that they may also be inadequate for the proper rendering of service. Plant facilities may be inadequate from two points of view, first, with respect to rendering any service at all at certain points or to certain points, and second, with respect to rendering the required amount of service.

Geographical Extent.—It is the common practice to provide the bulk of the plant facilities in advance of actual need. If this were not so great delays would occur in rendering service. Such delays can be reduced on the average to a reasonable period by careful study and intelligent foresight.

It is, of course, not practical to provide plant facilities in advance to all points in every case. To reach a potential subscriber outside of a local-service area special line construction is often required, and mileage charges for such special construction are regularly imposed, as otherwise an unreasonable burden would be put upon the other subscribers. Such connections to the service are usually subject to considerable delay.

On the other hand, even within a local area, it is not always practicable to provide sufficient plant facilities to avoid all delay in making service connections, because the development can not be exactly predicted and because a lavish provision of plant would be a burden to the other subscribers.

Connections to all points may not be practicable, because they involve a minimum amount of business in order to be profitable with reasonable charges for the service. The delay in extending plant facilities to such points is dependent upon the economic need for the service.

Traffic-Handling Capacity.—The traffic offered determines the amount of switching equipment and trunk lines required. In the automatic system this determination is direct, but in the manual system it is indirect because it is determined by the number of operators required. The traffic to be handled must be provided for in advance in order to maintain a uniform grade of service. An increase in traffic without a corresponding increase in facilities results in overloading the existing facilities, and the grade of the service rendered is lowered.

ADEQUACY OF OPERATORS

The term adequacy as applied to operators involves both a sufficient number and their competency to handle the traffic offered. Like switching equipment, operators must be provided in advance of need; therefore their training must be begun considerably in advance of need in order to make them competent to handle the traffic offered. Because of the great variation in traffic most careful studies are required to economically proportion operating forces so as to maintain a uniform grade of service during all hours. Furthermore, a sufficient reserve force is required to meet those occasions when other operators are incapacitated. An increase in traffic without a corresponding increase in the operating force results in overloading, and the grade of service rendered is lowered simply because calls are received faster than they can be handled.

2. QUALITY OF SPEECH TRANSMISSION

Speech is transmitted by means of electric currents which are varied in strength by the transmitter in correspondence with the original speech sounds and which cause the reproduction of these speech sounds at the receiving end of the telephone line. The quality of the speech transmission is in all cases dependent upon the degree of loudness of the reproduced speech, upon the accuracy of its reproduction, and upon the degree of uniformity with respect to both.

Phonetic studies have shown that human speech may be resolved into elementary vocal sounds. These are classified as vowel sounds (including combinations of vowels known as diphthongs) and consonant sounds, and when uttered in proper combination and sequence they form the spoken word.

Each elementary vocal sound as uttered is found to consist of variations in air pressure following a pattern characteristic of the particular speech element. These pressure variations produce sound waves. The waves differ from those corresponding to simple tones in their vastly greater complexity. The pressure variations corresponding to a simple tone follow a simple law, resulting from the fact that the air particles are given a to and fro motion in the direction in which the sound is propagated, the particles vibrating in a manner similar to that of an engine piston. This motion is called simple harmonic motion.

Simple tones differ only with respect to two characteristics, the loudness, determined by the displacement of the air particles from their mean positions, this being called the amplitude, and the pitch, determined by the number of double vibrations per second, this being called the frequency.

Musical sounds differ from a simple tone in that they are composed of a complex of simple tones. In general the frequencies represented are those corresponding to all the possible natural modes of vibration of the sounding source. In the case of string instruments, the possible frequencies consist of a fundamental tone of lowest pitch and a series of harmonics or overtones which are simple multiples of the fundamental frequency. The particular modes of vibration and therefore the number and amplitudes of each component are dependent on the manner in which the string is set in motion, which may be done by bowing, plucking, or striking, as well as by the manner of supporting the string and the size, shape, and material of the resonator by which the sound is intensified. Thus the same notes sounded on a piano and violin are readily distinguished from one another through the particular harmonics present and through their relative amplitudes with respect to the fundamental.

Similarly the same notes sounded on a flute, oboe, and clarinet are differentiated from one another and from those sounded on other musical instruments. All are said to differ from one another in timbre or musical quality. Musical sounds can be analyzed by suitable methods for the purpose of determining the frequencies and amplitudes of the component sounds, and, vice versa, a musical sound can be exactly reproduced by the simultaneous production of each of its constituents thus determined, each sounded with proper loudness.

Each elementary speech sound when enunciated by a particular individual has its own individual peculiarities which makes it possible to distinguish it from the same speech elements enunciated by a different individual. This is largely dependent upon the manner of enunciation and differences in the vocal organs involved. A spoken or sung vowel sound gives rise to a pressure

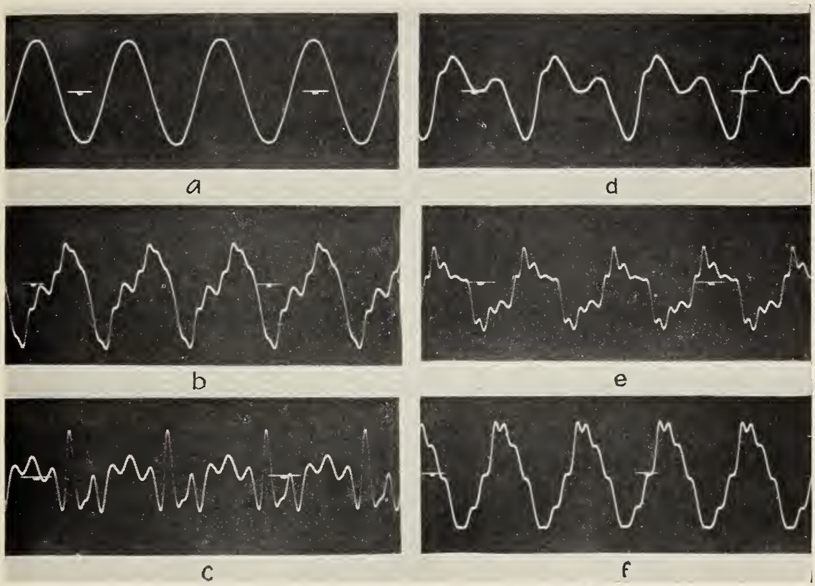

FIG. 54.—*Wave forms of musical sounds—middle C pitch*

(*a*) Tuning fork—nearly pure simple tone
(*b*) Violin
(*c*) Oboe
(*d*) Bass flute
(*e*) Clarinet
(*f*) Clarinet—played with less force than above—overtones not so loud

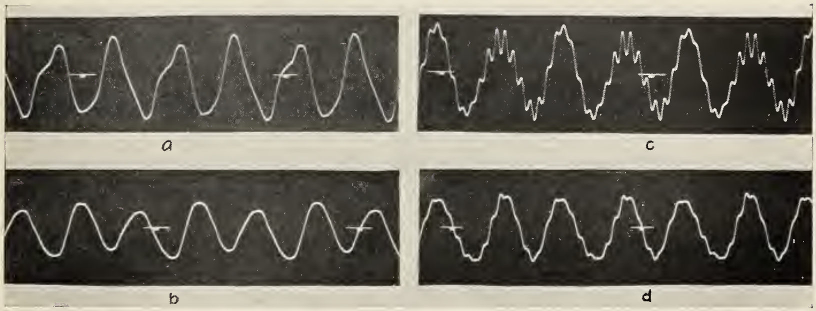

FIG. 55.—*Wave forms of vowel sounds $\overline{oo}$ and $\overline{ee}$ intoned by two baritone voices*

(*a*) $\overline{oo}$ as in gloom—voice "A"
(*b*) $\overline{oo}$ as in gloom—voice "B"
(*c*) $\overline{ee}$ as in bee—voice "A"
(*d*) $\overline{ee}$ as in bee—voice "B"

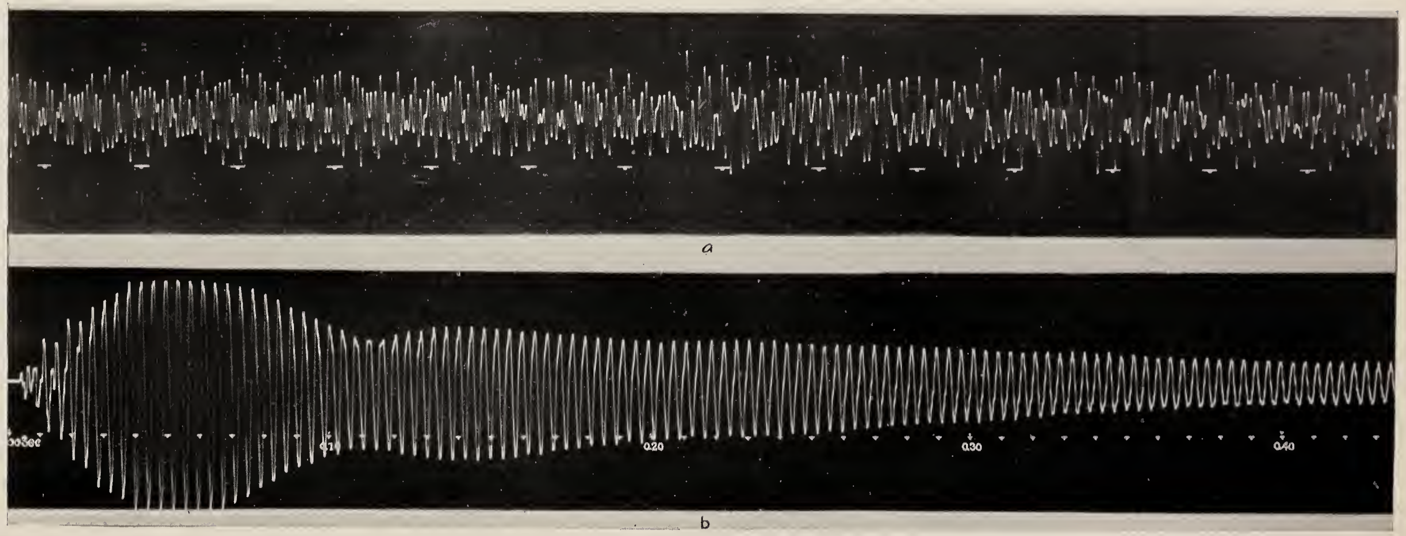

Fig. 56.—*Wave forms of musical sounds*

(*a*) Seven-inch dinner bell of extra good quality. This is a complicated nonperiodic curve
(*b*) Piano string—middle C pitch

variation pattern composed of a fundamental, corresponding to the voice "pitch" of the speaker or the pitch at which the vowel is sung, and a complex of harmonics, depending on the manner of enunciation and individual characteristics of the speaker or singer.

Sung vowels have been found best adapted to experimental study, since they can be sustained for a considerable time with considerable amplitude. Photographic records of the pressure variations have been obtained from which the components have been determined.

The different vowels are distinguished from one another by the relative intensities of the fundamental and harmonics, which differ also with the individuality of the singer or speaker. Much less is definitely known about consonant sounds, though in general it may be stated that they are more complex than vowel sounds. Speech itself, being made up of combinations of vowel and consonant sounds uttered with varying degrees of intensity, intoned in varying pitch, and modified by varying inflection as well as individual voice peculiarities, gives rise to a highly complex wave pattern, as in the wave trace of the words "Bureau of Standards."

Experiments show that intelligibility of speech in general is determined in a large part by the harmonics lying in the higher frequency ranges. It is also interesting to note that the normal sensitivity of the human ear has a maximum in this region.

DEGREE OF LOUDNESS

The degree of loudness of speech telephonically transmitted is directly dependent upon the amplitudes of each of the separate components of the speech currents in the receiver and on the efficiency of the receiver and the sensitivity of the ear throughout the whole range of speech frequency, these determining the magnitude of the complex sensation produced on the hearer. This sensation is the resultant of the separate sensations produced by each of the simple sounds constituting speech. The receiver current is in turn dependent on the efficiency of the transmitter and on the attenuation resulting from line and apparatus characteristics, each throughout the whole range of speech frequency. The degree of loudness can therefore only be judged relatively, as for example, by comparison with the loudness of transmission for the same speech sounds transmitted by the aid of two telephone sets of a selected type connected together in a prescribed manner. The test circuit includes standard telephone cable which can be adjusted until equal loudness is attained. The number of miles of standard cable in the standard test circuit required for equalization may therefore be taken as specifying the relative loudness in question.

ACCURACY OF REPRODUCTION

Absolute accuracy of telephonic reproduction of speech is not commercially attainable, though it may be approached in the laboratory. It would require that the pressure variation pattern of the received sound would differ when analyzed into its component fundamentals and harmonics merely in having a proportionate reduction of amplitude throughout the whole frequency range involved.

In commercial telephony almost every circuit element introduces distortion, though these effects are not always additive. The resonance characteristics of receiver and transmitter diaphragms necessarily introduce distortion, though advantage is taken of this to intensify the more important speech characteristics involving the higher frequencies. Line distortion, especially that of cable lines, may be reduced to a great extent by the use of loading coils, but it can not be entirely corrected.

NATURALNESS AND INTELLIGIBILITY

These are the criterions of accuracy of reproduction. Naturalness may, to a slight extent, be dependent upon the degree of loudness, but it is primarily dependent upon the accuracy of reproduction. Naturalness enables the listener to readily identify a familiar voice. Intelligibility is greatly dependent upon both the degree of loudness and the accuracy of reproduction. The original speech may be accurately reproduced and yet be so faint as to be unintelligible. Again the original speech may be reproduced with the requisite degree of loudness and yet be so inaccurately reproduced as to be unintelligible.

The degree of naturalness obviously can not be expressed in specific terms. The degree of intelligibility, though dependent upon the personal factors introduced through the individuality of the speaker and listener, may be expressed by finding the percentage of monosyllables typifying vocal sounds selected in proportion to their occurrence in actual speech, which are correctly interpreted by a listener when spoken into the transmitter and transmitted over a circuit under test. In making such tests it is

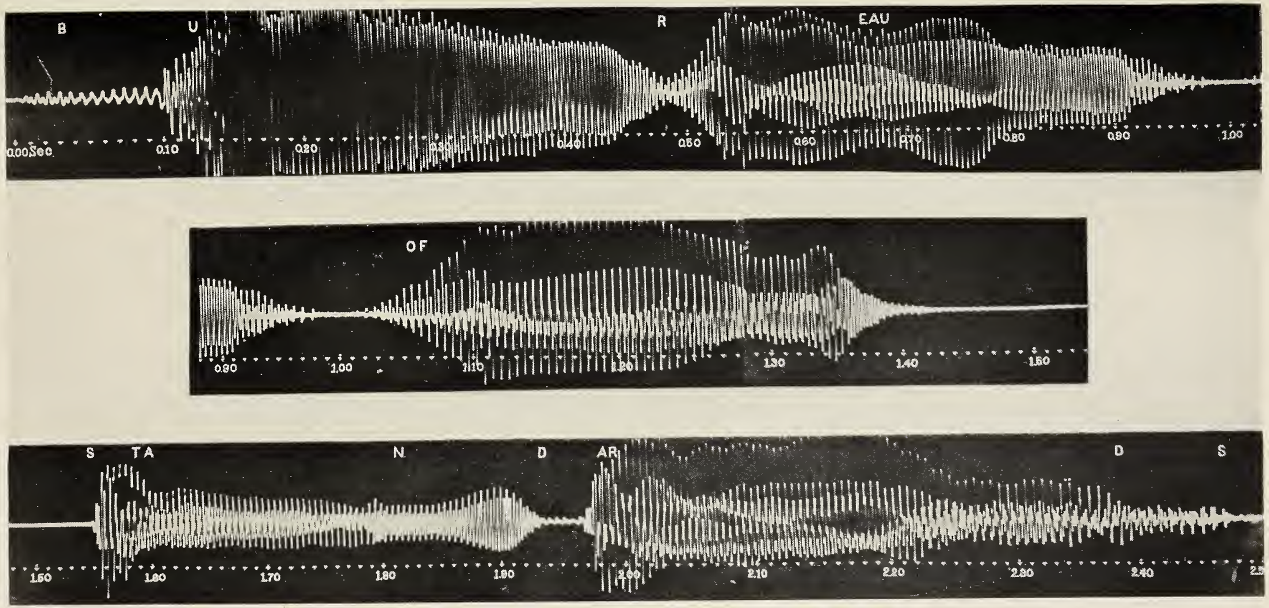

FIG. 57.—*Wave trace of the words "Bureau of Standards"*

This wave trace and those shown in Figs. 54, 55, and 56 are photographic records made with a "Phonodeik" by Prof. Dayton C. Miller. The principal elements of the apparatus employed are the following:

1. A circular diaphragm against which the sound is directed, thus causing it to vibrate in correspondence with the variations in air pressure produced by the sounding body or the vocal organs
2. A simple though delicately constructed mechanism for translating the to and fro motions of the diaphragm into corresponding oscillations of a tiny mirror
3. A suitable optical system for directing the light from a fixed source on the mirror and focusing the reflected beam on a moving film
4. A photographic camera designed to furnish a continuous trace of the to and fro motion of the beam of light on a uniformly moving film

The wave trace above has been secured to furnish the reader with some idea of the complex nature of speech which it is necessary to reproduce with considerable fidelity to meet even every-day telephonic requirements

important to make corresponding tests, using a standard test circuit. The determination of both percentages by different individuals makes it possible to take into account individual peculiarities of the speaker and listener. It is therefore usual to take the average of the results obtained by a number of speakers and listeners.

In the past it has been customary to combine the measurement of loudness and intelligibility by direct comparison of speech transmitted over a circuit under test with that transmitted over the standard test circuit, the standard cable mileage in the latter being adjusted until, in the judgment of the listener, equality in both respects is attained. The results thus obtained are more or less unsatisfactory, as greater weight is unconsciously assigned to loudness than to intelligibility, particularly where interpretation is aided by context, as in the case of familiar phrases or subject matter. Loudness is largely determined by the fundamental and lower harmonics, which may be suppressed without great sacrifice to intelligibility, as indicated above.

Dependence on Plant Conditions.—The physical properties of telephone circuits or parts thereof which attenuate the transmission currents may be seriously affected by certain plant conditions, of which the resistance of joints and contacts and the insulation resistance of the line are the most important. All wire joints are made on the basis that the resistance of each joint shall be negligible. All contacts which are a part of the switching apparatus are designed to afford ample conductivity. Wire joints are subject to only slight deterioration if well made, but poorly made joints may seriously affect transmission. Outside line insulation resistance, which is subjected to weather conditions, may vary between wide limits. Leakage of current resulting from low insulation resistance seriously affects the transmission of speech.

The degree of loudness, which is an important factor of intelligibility, is greatly dependent upon the conditions of the electric power supply. Common-battery equipment is furnished with power from a large storage battery and the condition of this battery is of such importance to the system as a whole that it is most carefully attended. Its ability to supply electric power for speech transmission decreases as a result of discharge, but the total discharge permitted is usually insufficient to seriously affect transmission. Magneto equipment is furnished with transmission power from dry-cell batteries located at each individual telephone station. The ability of these batteries to supply electric power for speech transmission decreases continuously as a result of both use and age. Such batteries are usually replaced with new ones when the falling off in strength of current delivered reaches the limiting value for good transmission and before exhaustion.

Effect of Disturbances.—Every telephone line is subject to disturbance if it is in proximity to any other line which carries a current of varying strength, because such currents tend to induce the flow of currents in all other lines in the vicinity. The flow of such induced currents, however, may be prevented in some cases, and in others it may usually be reduced to a strength insufficient to operate a telephone receiver. When such disturbing currents do operate a receiver they cause it to emit noises of various kinds. These receiver noises may seriously interfere with speech transmission. Every telephone line which is exposed to lightning discharges is also subject to noise of a peculiar crackling character when such disturbances are sufficiently near.

UNIFORMITY

Uniformity of speech transmission involves all of the factors which determine the quality of speech transmission. The term uniformity may be used with respect to different times of reference in a given locality and also with respect to different localities. Uniform quality of speech transmission with respect to different times of reference may be reasonably approximated in any locality, but uniform quality with respect to different localities would not be a reasonable requirement, unless the needs of the different localities were comparable.

The degree of uniformity of naturalness and of intelligibility is dependent upon the uniformity of the magnitude of those elements upon which naturalness and intelligibility are dependent, and those elements involve the design, manufacture, construction, installation, and the condition of the telephone plant. For each of these, excepting the last, a high degree of uniformity may be obtained by standardization. Plant condition is not entirely under the control of the telephone company. It is varied by the elements and in many cases by unavoidable damage. A reasonable degree of uniformity of plant condition may, however, be obtained by efficient maintenance of the plant.

3. DEPENDABILITY OF SPEECH TRANSMISSION

The dependability of speech transmission is directly dependent upon the plant design, the plant construction and installation, and the plant condition. The details of this dependence are very great in number, but the more important may be summarized as follows:

PLANT DESIGN

Mechanical Strength and Durability of Structures, Suspended Wires, and Apparatus.—This includes buildings, pole lines, subways and manholes, insulators, and wire spans in general, and all special cases of each where each may be subjected to unusual conditions caused by the elements. It also includes the permanence of all wire joints.

Protection from Mechanical Hazards.—This includes such protection as may be necessary in specific instances from machinery, vehicles or attachments thereto, animals, and maliciously inclined persons.

Protection from Fire Hazards.—This includes the fire resistivity of buildings, careful design of heating and lighting systems, protection from internal-combustion engines, the hazards incident to the storage of combustible material, fire-resisting insulation, and bulkheads for limiting the spread of incipient fires.

Protection from Electrical Hazards.—This includes lightning, light and power circuits, telephone talking and signaling circuits, and from electrolytic corrosion.

PLANT CONSTRUCTION AND INSTALLATION

A plant may be designed with great care and thoroughness, but its actual dependability is to a large extent dependent also upon how it is constructed or installed. Among the important considerations are workmanship in manufacture of apparatus and equipment, inspection of construction materials, precautions in handling materials, care and thoroughness in carrying out all specifications relating to design, construction, and installation.

PLANT CONDITION

A plant may be well designed and well constructed, but it is always subject to continuous deterioration which may or may not result in actual breakdown, and it is often subject to damage.

Deterioration is chiefly caused by the elements and by wear and tear of operation. Poles rot, improperly made joints corrode, cross-arms split, outside wire-insulating materials gradually lose their insulating qualities, and iron wires and iron fastenings corrode. The operation of apparatus wears the moving parts and eventually compels replacements. Damage may be caused by low temperature, wind, sleet, or combinations of these may result in broken wires, poles, or attachments. Damage may also be caused by mechanical injury, electrical injury, or by fire.

While deterioration and damage may be reduced in amount to a degree which is dependent upon economic considerations, it is evident that they can not be entirely eliminated, and the dependability of speech transmission can not therefore be made absolute. Nevertheless, a reasonable degree of dependability can be obtained by efficient maintenance of the plant. Efficient maintenance involves the provision of reasonable safeguards, the periodic and careful inspection and testing of those parts of the plant which are most liable to defect, the prompt and efficient repair of defective plant, and the replacement of parts when their useful life is ended.

Reasonable safeguards include the elimination of external hazards to buildings and encroachments such as tree limbs and underbrush, the provision of an emergency stock of plant units and parts, the provision of adequate alarm signals, and both adequate and accessible fire-fighting appliances. The inspection and testing of the plant requires adequate facilities for such work. The replacement or repair of plant parts requires reasonable noninterference with the service and thorough workmanship.

4. QUALITY OF OPERATION

SPEED

In general the handling of calls by the manual system involves a certain average amount of time for answering on the part of the operators, a certain average amount of time necessary to connect the calling and the called lines together, a certain average amount of time to ring the called station, and a certain average amount of time to effect disconnection after the disconnect signals have been received. In addition a certain average amount of time is involved in answering recalls. The disconnecting time, as far as the calling party is concerned, has been eliminated in some manual systems.

It has been stated with respect to the automatic system of switching that while the bulk of the service is handled auto-

FIG. 58.—*Damage caused by wind and sleet*

The accumulated ice on the wires has overloaded both wires and poles. During sleet storms a wire may become so coated with ice as to cause it to stretch or even to break. When an unusually heavy ice coating is accompanied by very high winds the strains may occasionally be greater than even a well constructed pole line can withstand. Pole lines which may be subjected to severe climatic conditions should be designed to withstand such strains as may be reasonably anticipated

matically, some classes of service are still handled manually, either wholly or in part. An automatic system as a whole must therefore be regarded as involving both automatic and manual switching. The references to automatic switching which follow pertain only to that portion which is fully automatic.

With automatic switching there is no equivalent to the disconnection time with respect to operators of the manual system. Disconnection is effected with great speed as soon as both parties hang up their receivers. All of the other time elements of operation referred to with regard to the manual system apply to automatic switching, though not necessarily in the same degree.

Average Answering Time.—When a call is orginated at a station by the act of signaling the central office, either by removing the receiver from the hook for common-battery equipment or by operating a hand generator for magneto equipment, there will be on the average an appreciable delay before the operator answers. Most of this delay is caused by the operator or operators who have the line within reach being busy with the handling of other calls. The intimate relation between average answering time and *A* operator's loads and with particular reference to call distribution has been outlined in the section on Traffic. The average answering time decreases with increases in the extent of call distribution up to a practical limit, with decreases in operator's loads, also to a practical limit, and with decreases in the labor of handling calls.

As the number of *A* operators and the amount of switching equipment provided are both dependent in a large degree upon the average answering time, it follows that any change in this time directly affects the cost of rendering service. Within wide limits increasing the average answering time lowers the cost of rendering service and decreasing it increases the cost. Thus answering time is a very important element of speed with manual switching.

With automatic switching there is an exact equivalent to the average answering time of manual operation. When the central office is signaled the calling line is connected through to a first selector with great speed, providing there is an idle first selector available. In case there is no idle first selector available the call is held up. Very recent installations provide a so-called dial tone, which the calling party can hear if a first selector is available.

Because of the comparatively low annual charges it is the usual practice to limit delays caused by lack of first selectors to a small percentage of the calls. Thus the average actual delay is made so small that it is immaterial to the telephone user, nevertheless, as a whole it is an important factor in the cost of rendering service.

Average Connecting Time.—The term connecting time is applied to the time required for connecting the calling line to the called line. It includes the busy test and ends when the ringing is started. With manual switching this time is dependent upon the methods of handling traffic, upon the rates of working on the part of the operators, and upon any delays caused by lack of plant facilities. As the methods of handling largely determine the nature of the switching equipment associated therewith, the dependence upon the method of handling will be understood to include the nature of the equipment.

In general the more labor-saving devices used the faster the traffic is handled. Magneto equipment in a very small central office requires manual operation to the maximum degree. As the size of the office increases signaling devices are provided which reduce the amount of labor. The greatest degree of labor saving is effected in large common-battery offices where the power for the operation of labor-saving devices is readily made available. Practically all of the signaling is associated with other indispensable operations and in certain installations of the latest type the operation of both listening keys and traffic registers have been eliminated.

The connecting time for flat and message rate traffic differs if the handling of the latter involves the extra labor of writing tickets, as it is desirable that such tickets be written at the time the calls are received. The connecting time for subscriber and public telephone calls differs because the latter involves the collection of charges. The speed of handling public telephone calls with coin collectors is greatly dependent upon whether the method of operation of the collector involves the prepayment or postpayment of the charges. The great majority of public telephone calls are for local service, for which the charge is usually 5 cents. The prepayment method of operation requires the deposition of a coin before the operator is signaled. If the call to be made is a local call the patron naturally deposits the proper coin. The operator knows a coin has been deposited when she receives the call and delays caused by lack of the correct coin or by its not being held in readiness for deposit are practically eliminated as far as local service is concerned.

The speed of manually handling all calls which must be trunked is greatly dependent upon the method of trunking and this involves the amount of series trunking required and the way in which the call and the disconnect signal are passed from operator to operator. The amount of series trunking is dependent upon the traffic between the two points in question. If warranted the two points will be connected by direct trunks; otherwise trunk connections between the two points will be handled via at least one other central office. It is evident that the speed of handling decreases as the number of operators required to establish each connection increases.

In manual systems trunk calls are usually passed in one of two ways. When traffic to be handled is light or when distances are great, the operators usually signal each other by ringing on the trunk line to be used for the connection. When the traffic is large the required trunks are usually split into two groups, each group is used for establishing connections in one direction only, the *B* operators who handle the incoming ends of such trunks do no other work and calls are passed over a call circuit from the *A* to the *B* operator. By this means calls may be passed much more rapidly than by ringing. Trial installations are now being made with the object of eliminating the labor required to pass trunk assignments back over an order wire from the *B* to the *A* operator and by this method to further increase speed.

As the method of handling trunked calls varies with the traffic to be handled, the increased efficiency of the faster methods is often made available by routing trunks to a common switching point. By this means the total traffic to be handled at that point may be so increased as to warrant the faster method of handling which also results in greater utilization efficiency of the trunks and a consequent reduction in the number required.

Standardized phraseology for operators' use has a direct effect on the speed of handling calls. Operators must, of necessity, talk with other operators, and with the telephone users. Phraseology may be standardized so as to convey the desired information with a minimum number of carefully selected words. Such phraseology not only increases speed directly, but indirectly also, because when a few words having a definite meaning are used errors are avoided.

Speed is directly dependent upon the rate at which operators actually work and the rate of work varies with their individual characteristics. Operators' working rates are also dependent upon both their training and their practical experience.

The speed of handling calls has been materially increased by relieving all switching operators of irregular calls which involve abnormal periods of handling time. Information calls are switched to special operators. Calls regarding outside plant defects are switched to a repair clerk. Calls regarding operating errors and complaints in general may be handled by supervising operators or other special operators.

With automatic switching equipment the connecting time begins with the dialing and ends when the dial comes to rest after dialing the last digit of the number. Because of the fact that the rate of operation of the machines is fixed between comparatively narrow limits the connecting time equals the time required by the calling party to dial the correct number correctly. The amount of time required depends upon both the number of digits to be dialed and the efficiency of the calling party in performing the dialing operation. The number of digits to be dialed increases with the size of the system. The return movements of the dial and the movements of the mechanisms it controls are at the approximate rate of 10 steps per second for each digit. The remainder of the connecting time is dependent upon the calling party.

With both manual and automatic switching equipment the average connecting time necessarily includes any delays which are caused by lack of plant facilities. The amount of this delay on the average which is tolerable is purely an economic problem limited to the probable demands during the busy hour. From a comparative point of view if the cost per unit amount of that portion of the plant under consideration is large, as, for example, that of a trunk line, the permissible delay will also be large; if the cost is small the permissible delay will also be small and if very small no delay at all is permissible. In general, switching equipment is provided on a basis of very infrequent delay, but interoffice trunk lines are provided on varying delay bases that will meet the needs of the users.

Average Ringing Time.—With manual switching equipment the ringing time may be divided into two parts, that required by the operator to start the ringing, which is very small, and that required for the called party to answer. The time required to answer can not be considered as under the control of the telephone company, but there is a noticeable decrease in this time when machine ringing equipment is used. This is no doubt because of the regularity of the ringing periods. With automatic switching equipment the time required to establish the ringing connection is practically nil.

Manual ringing equipment requires the services of the operator at intervals until the called party answers and unless the ringing tone for the calling party is provided, extra labor is required to report the progress of the call to the calling party when the answer is slow and to report that the called party does not answer, if such is the case. The combination of machine ringing and the ringing tone both relieve the operators of a very material amount of labor which is made available for other operations. Operators may thus be enabled not only to handle more calls, but also to handle them faster.

In certain cases, also, where machine ringing and the ringing tone have been provided on *A* operator's positions, the control of the ringing cut-off has been associated with the calling telephone hook switch and the calling supervisory lamp has been made to act as a ringing guard signal in which case lighted calling supervisory lamps are eliminated during the ringing period. With such equipment all ringing supervision is eliminated and all lighted supervisory lamps are caused to indicate a demand for immediate action on the part of the operator. This demand has been further emphasized by the association of large pilot-lamp signals with the less conspicuous supervisory signals.

Average Disconnecting Time.—Operators are not generally required to make disconnections immediately, since delay results only in case the connected parties desire to call and when lines so held are called for, and because disconnections can be economically made during the intervals between calls. To require immediate disconnection operation would slow up the handling of calls and this would in turn bring about a reduction of operators' handling efficiency. With manual switching equipment of the usual type there is an average disconnection time of very considerable magnitude.

The actual disconnection time is also dependent to a considerable degree upon the type of switching equipment used. With magneto equipment the disconnect signal is received on the clearing-out drop if the parties to the connection do not forget to ring off. With common-battery equipment the disconnect signal is received on a supervisory lamp the moment the receiver is replaced on the hook. When the passing of calls over trunks requires ringing on the trunks the disconnect signal is usually operated by ringing also, but with call circuit trunks the disconnect signal is usually lighted by the mere act of disconnection on the part of the *A* operator.

In certain recent common-battery installations special equipment has been provided by means of which the busy condition of the calling party's line is removed as soon as the receiver is replaced on the hook, thus freeing that party's line immediately. With automatic switching equipment disconnection is also effected promptly. The calling party's line is freed as soon as the receiver is hung up; the called party's line is freed as soon as both parties have hung up.

Average Recall Time.—The term recall applies only to the calling party, though either party to a connection may desire to make a call while yet connected. The speed of handling such calls is greatly dependent upon the method used for signaling the operator.

With magneto manual equipment either party signals the operator by means of the hand generator. This causes the operation of the clearing-out drop and causes its latch hook to vibrate so as to give an audible signal as well. The operator's attention is readily attracted. With the usual type of common-battery manual equipment the operator's attention is attracted by the flashing of a supervisory lamp when the telephone hook is moved down and up a number of times. Flashing supervisory signals are generally given preference over line signals. Supervisory signals, however, are less conspicuous than line signals, and the telephone hooks are often moved spasmodically or even faster than the lamp can follow.

In practice the calling party frequently makes a recall, but the called party seldom makes a call while connected. Hence, the incentive to provide more positive means for attracting the operator's attention in the case of recalls. In some instances audible signals have been provided to supplement the supervisory lamps on a recall, but the more generally approved method is to associate with the answering supervisory signal, equipment which causes that signal to flash at regular intervals from the time the hook makes its first upward movement until the operator answers. In still other instances equipment is provided which causes the recalling line to become reassociated with its line signal and that signal is flashed by the movement of the hook instead of a supervisory lamp. This method puts a recall on the same basis as any other call. All of these methods of attracting the operator's attention increase the speed of handling recalls.

With automatic switching equipment a recall, or, rather, a new call, may be made just as soon as the previous disconnection is effected and this usually requires much less than one second.

Dependence on Plant Design.—The speed of handling calls by operators is indirectly affected by certain elements of plant design of which ease of handling and uniformity of arrangement are characteristic. Ease of handling implies simplicity as well as a small amount of labor. Uniformity of arrangement is of great importance because operators are enabled thereby to locate each line by its position as well as by the slower method of identifying its number or other designation.

Dependence on Plant Conditions.—Speed is also affected indirectly by plant defects which may or may not cause actual trouble to the telephone users. Apparatus or trunk lines which are defective may not be known as defective until their use is required. Delay always ensues, whether in the manual or the automatic system. In the former the operator has to make a substitution and in the latter the calling party dials again.

Effect of Inaccuracies.—Speed is also affected indirectly by inaccuracies in directories, on the part of calling parties, of operation and of certain plant features. Inaccuracies always cause delay, as will be evident from the consideration of the subject matter under the next heading

ACCURACY

Accuracy of operation is directly dependent upon the accuracy of the directory, of the calling party, of the operators, and upon certain features of the plant. Operating errors always result in delay and annoyance.

Directory.—The calling party is primarily dependent upon the directory for the number of the party to be called and secondarily upon information service, which necessarily supplements the directory. Errors are found in both directory and in records used by information operators, though not in general to any considerable extent.

Calling Party.—The calling party is usually depended upon to give or to dial the correct number, and, in the manual system, to give the name of the connecting central office and the party letter or other ringing designation listed in the directory. The efficiency of the public in this respect varies widely and many errors are made. Giving or dialing wrong numbers results in waste effort, delay, and may result in annoyance to a wrongly called party if there is such a number as the one called. Inaccuracies are also frequently the result of indistinct speech on the part of the calling party.

Operators.—Operators must first of all clearly understand the calling party's order. Operators must not only know how to establish connections and to interpret supervisory signals correctly; they must also establish only those that are called for. Called lines may be carelessly tested and double connections result, the calling plug may be inserted in the wrong jack, the wrong station may be rung, trunk assignments may be misunderstood and double connections result, and neither last nor least, correct connections may be prematurely disconnected.

Accuracy of operation is also affected by the operator's loads. These may be correctly forecasted in amount but nevertheless be beyond the ability of a particular operator, or they may be incorrectly forecasted in amount and the actual load may be beyond the average operator's ability. Furthermore, abnormally heavy loads may be occasionally received. Efforts on the part of operators to maintain excessive speeds can not fail to result in inaccuracies.

Plant.—Accuracy of operation is directly dependent upon the accuracy of the plant records, designations, placing of signal plugs, and upon all other markings upon which operation is dependent. Accuracy is affected to some extent by plant defects. Errors may be made in making permanent connections and insulation breakdowns occasionally result in crossing lines or the lines may be unbalanced to an extent which will permit of intelligible cross-talk. Furthermore, apparatus may fail to function properly.

SECRECY

The information which may be passed over telephone lines is unquestionably the private property of the users of the telephone and is so regarded. Telephone line construction is of such a nature that access to the lines is generally difficult and involves a very considerable risk to the trespasser, who must also be provided with the necessary apparatus and know how to use it. Telephone service is, however, of such a nature that many of the companies' employees must have access to the lines, and it follows that the possibility of overhearing conversation increases with the number of employees who must have such access, and conversely. On rare occasions talking parties may be overheard because of double connections and cross-talk. Listening by subscribers on party lines is not under the control of the telephone company.

Probably the main preventive of secrecy violation lies in the laws which have made it illegal to divulge any information which an employee may gain from telephone conversations. On the other hand, the gaining of such information is in a very large measure prevented by the operating and maintenance routines, which forbid listening to a greater extent than is absolutely necessary and which are enforced with rigor not only because of the impropriety of such listening, but also because it may seriously impair the quality of the speech transmission

UNIFORMITY

Uniformity of quality of operation involves all of the factors which determine the quality of operation. The term uniformity may be used with respect to different times of reference in a given locality and also with respect to different localities. Uniform quality of operation with respect to different times of reference may be reasonably approximated in any locality, but uniform quality of operation with respect to different localities would not be a reasonable requirement unless the needs of the different localities are comparable.

All of the time elements of speed have been referred to as averages. In general the degree of variation from the average is the criterion of uniformity. It is obvious that economic considerations alone would prevent absolute uniformity with any method of switching, though it may be approximated more closely with some methods than with others. How close the approximation should be in any case is a local economic problem. From a service viewpoint speed can be too low and it is equally true that from an economic viewpoint speed can be too high.

Accuracy has been considered with respect to the directory, calling party, the operators, and the plant. Uniform accuracy of the directory and of the associated information records can be reasonably attained. Uniform accuracy on the part of calling parties is beyond the control of the telephone company except through the instruction of the public. Uniform accuracy on the part of operators may be reasonably approximated by training, by discipline, and by properly adjusting their loads. Uniformly accurate plant operation may also be reasonably approximated by routine checking, testing, and the elimination of defects in advance.

While the element of secrecy has an unquestioned value, its violation in practice is not frequent. If additional secrecy can be obtained, as it has been, by the installation of equipment which materially increases the quality of operation with respect to speed and accuracy also, it adds to the value of such an installation.

5. DEPENDABILITY OF OPERATION

RELIABILITY OF SWITCHING EQUIPMENT

The reliability of the switching equipment is dependent first upon its design, manufacture, and installation, and second upon its maintenance. Switching equipment may be designed with great skill, and manufactured and installed with great care, but, being subject in a large degree to wear and tear, it has its failures and its parts must at times be repaired, readjusted, or replaced. It is evident that the dependability of the switching equipment can not be absolute and that the degree of dependability is directly dependent upon the reliability with which it normally functions, upon the care with which it is inspected and tested and upon the promptness and thoroughness with which it is restored to normal operating efficiency. It is the usual practice to guard against delay by the provision of automatic alarm signals to indicate the lack of power supply to operating circuits and in the automatic system, which requires a proportionately large amount of switching equipment, it is also usual to provide automatic alarm signals to indicate operating failures.

RELIABILITY OF OPERATING FORCE

The reliability of the operating force is dependent on the individual characteristics of each member and upon the esprit de corps of the force as a whole. The esprit de corps is dependent upon the establishment of a proper mutual regard of the rights of the employee and employer. The employee is entitled to wages, working hours, and conditions of employment consistent with prevailing standards, and the employer is entitled in return to the faithful, efficient performance of the duties assigned.

Because of the fact that correct operation requires special knowledge, training is imperative. Reliability increases with experience because experience increases this special knowledge and the skill of the operators. Discipline makes continued employment dependent upon reliability.

6. DEGREE OF SAFETY

The element safety differs from the elements previously considered in that its application is not confined to the safety of the telephone users. It of necessity includes the safety of employees and the public in general. It is evident that generally acceptable dependability of transmission involves a grade of plant design and construction which includes the element of safety to a large degree, but from a safety standpoint alone special design, construction, construction methods, or additional facilities may be required to meet special conditions. The subject of safety is a large one and is considered in detail in other publications of the Bureau of Standards. Only a few of the most important aspects of the subject will therefore be mentioned.

Special construction is required for joint use where telephone and electric power or light wires are carried on the same pole line. The important considerations in connection with such construction involve the relative positions of the different circuits, the insulation of the respective wires and associated apparatus, and the spacing of the wires for ease and safety of access to employees.

Special construction is required at those points where high-tension power lines cross telephone lines and where telephone lines cross railroads. Power lines are usually carried over telephone lines because of their greater mechanical strength and the crossing spans are so designed that in case of a break the wire ends thus freed will not reach to the telephone lines, or so that they will be caught in a guard net. Telephone lines crossing railroads are always built with extra strong construction and with a wide clearance. Crossing spans of power lines and of telephone lines over other lines and over railroads are always reenforced so that when breaks occur the poles will be enabled to withstand the strains which result.

It is recognized that the telephone plant, in process of construction and in process of repair or replacement, as well as when completed, must be safe with respect both to the public and employees. Special safety precautions during construction and reconstruction are continually required in order to guard against possible accidents from unstable or temporary construction, street openings, tools and materials used in aerial work and gas in manholes and ducts. Such precautions also include the avoidance of obstructions such as interfere with highway traffic in general and to fire alarms and water hydrants in particular. When work is done in and around buildings such precautions also include the protection of inflammable materials and the prevention of rubbish accumulation.

Safety with respect to the completed plant also involves the proper insulation of all metal conductors constituting a part of any telephone circuit or which may become a part of any electric circuit if such conductors are within reach of the public; also the provision of protective devices which will limit the current in each circuit to a safe strength, the protection of highway traffic from low wires and pole guys, the keeping of transmitters and receivers at public telephones clean and free from infection, the safeguarding of buildings from fire, and also the equipment from both fire and water, the provision of adequate fire-fighting appliances, and the provision of ample and safe exits from all rooms and buildings in case of fire.

7. QUALITY OF RELATIONS WITH THE PUBLIC

The subject of public relations considered as an element of service covers such a broad field that it is thought best to limit the discussion to a few specific examples which will amply illustrate the importance of this subject.

COURTESY

The telephone utility is unique in regard to the intimacy of contact between its representatives and the users, required for rendering service. With manual switching equipment, which is most common, and with semiautomatic switching equipment not a connection can be established without a brief conversation between the user and at least one operator. Such conversations are usually of extreme brevity in the case of local service, not so brief in the case of long-distance service, and may be of considerable length in case some difficulty is experienced. With all types of switching equipment the user is also brought into direct contact with installation and maintenance employees.

No employee of a telephone company is exempt from the obligation of courteous dealing with the public. This obligation covers both language and tone of voice, and it includes suitable apologies for annoyances caused.

PROPERTY RIGHTS

The telephone utility, like certain other utilities, occupies public property, but unlike other utilities it occupies private property to a very great extent, and such occupation is not limited to the property of service users. The utility must, therefore, have corresponding business relations with the general public which are closely associated with the rendering of service. The character of these relations has a direct bearing on the adequacy and cost of the plant.

The telephone company is under obligations to recognize the property rights of both the subscriber and the general public. Such property can, in most cases, be so occupied as to cause a negligible amount of damage to buildings and contents and to lawns, trees, and shrubbery.

SIGHTLINESS OF PLANT

The term "sightliness" applies to both telephone installations and line construction, but principally to the latter. The degree of sightliness required is dependent upon the nature of the community served.

The most important element of sightliness is uniformity of construction. Plumb pole setting, straight alignment of poles and attachments, equal wire or cable sags, symmetrical tree trimming, and right-angle wire runs all add to sightliness. Increased sightliness may be obtained by using poles that are straight, that have been shaved or both shaved and painted, by using pole steps, and thus avoiding the marring of poles with climbing irons, and in some cases by replacing bare wires by a cable, or several small cables by one large cable.

ASSISTANCE

The obligation of the telephone company to furnish complete information as to the several classes of service sold and all rates which apply is generally conceded. Prospective subscribers may require assistance in determining what class of service will best meet their needs.

Telephone users frequently require operating instructions. These are often printed in the directories. Directory instructions are often supplemented by specific directions for the use of certain devices, as, for example, the coin collectors associated with public telephones. Also, when systems are changed, it is the common practice to instruct the users through the daily press or by special circulars. It often happens, notwithstanding all printed instructions, that users require the personal assistance of operators or other attendants in order to successfully communicate with the desired party.

COMPLAINTS AND CRITICISMS

Both subscribers and public-telephone patrons require the interested attention of the telephone company, as represented by its employees, to all complaints and criticisms. Some complaints and criticisms will, of course, be made by incompetent persons; nevertheless they require some action, and in many cases an investigation and a report. If a demand is proper, it requires compliance, and if improper, it requires an explanation.

DISCRIMINATION

A telephone company is under obligations to the community which it serves to render service without discrimination. This applies to connections to the service, to the grade of service, and to rates.

In all fairness, connections to the service should be made, in so far as practical, in the order in which the applications are received. The grade of service rendered to all subscribers having the same form of contract should not differ.

An important feature of nondiscrimination is covered by the denial-of-service routine for nonpayment of overdue bills. Such a routine is unquestionably in the interest of the subscribers as a whole.

OPERATING ANNOYANCES

The telephone utility is also unique in regard to the degree of consideration which must be given to the design of equipment with which the user comes in direct or indirect contact and to the devising of operating routines from the standpoint of the comfort and the convenience of the user.

Considered alone, the more simple the station equipment and the less the user is called upon to do the greater is his satisfaction. The operation of the station equipment is, however, so closely associated with the operation of the central office equipment that the joint operation must be considered in the determination of whether or not a particular operation on the part of the user is objectionable.

In times past there have been many features associated with telephone operation which were sources of annoyance to the users. Many of these have been entirely eliminated from modern service by suitable design of equipment and by the adoption of suitable operating methods, but others remain in certain localities. Examples of such annoyances are: Clicks in the receiver caused by switching operations, the possibility of getting weak electric shocks from the telephones, the continuation of ringing after the receiver has been removed from the hook, the tapping of bells when other stations on the same line are called or lines tested, failure to report on delays, reports of "busy" when lines are actually out of order or when a shortage of switching equipment or trunk lines occurs, and reports of "don't answer" on dead-number calls.

8. DEGREE OF PUBLIC COOPERATION

Telephone service is of such a nature that it requires the cooperation of the public with the utility and mutual regard for each others interests by the users. Both the using and nonusing public are concerned with rights of way, and the using public is concerned with the operation of the telephone.

RIGHTS OF WAY

The benefits which telephone service brings to a community are so generally recognized that cooperation with regard to rights of way is steadily increasing. No doubt improved types and methods of construction are largely responsible for this satisfactory condition.

COURTESY

All users of the telephone expect courtesy from telephone-company employees and from all other users. Courtesy on the part of each user will aid materially. A courteous apology is due all persons who may have been annoyed as a result of errors.

CARE OF TELEPHONE

The subscriber is under obligation to properly care for the company's property which is on his premises, and to allow access to it by authorized representatives of the company, who show proper credentials during reasonable hours. The property in question comprises the telephone, any auxiliary equipment, and the wiring thereto. Such property should be safeguarded against mechanical injury, should be kept clean, and inflammable material should be kept clear of all protective devices.

USE OF TELEPHONE

Each user is under obligation to all other users to call the correct number. This involves a careful use of the directory and in the automatic system it also involves the correct use of the dial which controls the operation of the switching equipment. Calling a wrong number not only causes delay, it also wastes labor, holds switching equipment and lines busy, and may annoy a wrongly-called party.

Each user is also under obligation to use the telephone to the best advantage. The transmitter design is such as to require the speaker's mouth to be close to and directly in front of the mouthpiece. In any other position the transmission efficiency is reduced, and errors and misunderstandings are certain to occur. The speech should be distinct. The earpiece of the receiver is designed for close contact with the listener's ear. In any other position the transmission efficiency is reduced.

The hook-switch is a part of the signaling circuit with common-battery equipment and is a part of the local-battery transmitter circuit with magneto equipment. The weight of the receiver operates the hook-switch so as to open these circuits. Leaving the receiver off the hook with common-battery equipment causes the signal lamp in the central office to burn continuously; with magneto equipment it causes waste of the battery, and in both cases it renders the telephone bell practically inoperative. A line having a receiver off the hook in the manual system is usually reported as out of order; in the automatic system it may test busy even though provision is made to signal an attendant. It always causes annoyance and increases the cost of and delay in rendering service.

When a person makes a call he always feels that he is entitled to a prompt answer on the part of the party called. Similarly the person called feels that he is entitled to find the calling party on the line when he answers. Delays occur in both cases. In the manual system such delays often require extra labor, and in all systems increase the holding time and compel the provision of extra switching equipment. Thus both the cost of and delay in rendering service is increased.

While a subscriber to individual-line service is not usually limited with respect to the duration of local connections, he should be cognizant of the fact that each connection not only holds two lines busy against incoming calls but it also holds the associated switching facilities busy likewise. The amount of switching facilities provided is largely dependent upon the average duration of the calls handled. The lower the average duration the less is this element of cost.

Each subscriber on a party line is under a particular obligation to consider the welfare of the other subscribers on the line. Long conversations may work injustice, and listening to the conversations of others may be a source of great annoyance.

Special recall equipment has not as yet been provided in a great many central offices; therefore a prompt response on recalls is, in most cases, greatly dependent upon the cooperation of the calling party, who can flash the operator to best advantage by moving the hook continuously and at a comparatively slow speed.

Users of public telephones can speed up the service and reduce its cost by having the required coins in readiness for the coin collector. This applies to all calls in connection with postpayment collectors and to toll calls in connection with prepayment collectors.

All users of the telephone can assist in reducing the cost of the service by making as many of their calls as may be practical during the nonbusy hours, and by using good judgment as to how soon to repeat a call for a busy line or for a station that did not answer.

ADEQUACY OF INCOMING FACILITIES

A telephone line in use is busy to all calls for that line. Each call for a busy line involves a certain cost of handling, a possible loss of the call to the called party, and a certain degree of annoyance to the calling party. In practice the busy calls handled during the busy hour often average 20 per cent and over of the total calls handled.

It is obvious that busy calls can not be eliminated, but their number can be kept below a reasonable percentage if each subscriber provides himself with adequate telephone facilities for receiving calls. It is also obvious that such provision on the part of each subscriber is not only in his own interest, but also in the interest of all telephone users.

REASONABLENESS

The telephone user is entitled to a particular grade as well as a particular quantity of service, but the value of certain service elements, as previously explained, is dependent upon some conditions which are not under the entire control of the telephone company. Therefore reasonableness is an important element of cooperation.

The user should bear in mind that the company must meet variations in traffic in an economical manner. Temporary traffic overloads that either can not be anticipated or for which provision could not be economically justified may occur from time to time and temporarily degrade the service. Such conditions may obtain as a result of extraordinary use of the telephone caused by fire, flood, or other similar emergencies.

The service may also be degraded temporarily because of a shortage of operators or of plant facilities. Labor shortage may result from epidemics and from war and unusual local conditions. A shortage of plant facilities may result from market conditions and from unpreventable damage to the plant.

VIII. PUBLIC RELATIONS

Public relations as here treated include all the various subjects in connection with which the public may be brought into relation with the utility. Before the advent of public regulation, the public and the utility of necessity dealt with one another directly, except when recourse was had to the courts. Since the coming of regulation, however, many of the relations involving the subscribers as a whole have been largely taken care of by the commissions, while the direct relations concerning contracts, collections, complaints, etc., have become considerably simplified through the introduction of more nearly uniform company practices. Various national and State telephone associations have contributed to this end. Differences relating to such matters which can not be satisfactorily adjusted by mutual agreement between the company and its patrons and which may also affect subscribers in general are often submitted to regulatory commissions for settlement. Because public-utility laws and commission rulings at the present time so largely define and control public relations, the subject may perhaps best be treated here by an outline of the nature and scope of regulation.

1. THE NEED FOR REGULATION

Before the day of regulation the frequent disregard of the public interest by utility corporations and instances of vindictive reprisals on the part of the public led to the recognition of the necessity of something being done to protect the public and at the same time insure fair treatment to the utility.

The chief reasons leading to the adoption of the principle of public-utility regulation may be briefly summarized as follows:

(*a*) The individual himself is unable or can not economically and advantageously furnish for his own use various classes of service found essential in the life of a modern community.

(*b*) The furnishing of such services to meet the common needs of the community, if not undertaken as a community enterprise, must be intrusted to private business organizations.

(*c*) The recognition that competition in this field generally results in economic waste, the cost of which is eventually and almost invariably borne by the public, eliminates an important form of control found effective in other lines of business. In the absence of competition public-utility enterprises may, therefore, be regarded as monopolies, and, indeed, some courts have declared them to be "natural monopolies."

(*d*) Such undertakings require for the conduct of their business certain quasi-governmental powers which must be conferred on them by State or municipal authority, such as the right of eminent domain, enabling them to acquire by condemnation proceedings, property, including right of way, necessary for the conduct of their business.

(*e*) They must also be given the right to use highways, streets, alleys, etc., which have been dedicated to public use.

(*f*) The utility must supply its services to the public in general without discrimination.

2. THE LEGALITY OF PUBLIC REGULATION

For these and other reasons the public-utility business has been held to be peculiarly affected with the public interest, and therefore subject to the police power of the several States of the United States. The right to regulate public utilities for the common good has long been justified in the eyes of the law. The United States Supreme Court has held that police powers are "nothing more or less than the powers of government inherent in every sovereignty to govern men and things;" that they include "everything essential to the public safety" and extend "to all of the great public needs;" and has repeatedly asserted that private property, devoted to public use, is "clothed with public interest," and is, therefore, subject to public regulation. The validity of the commission form of control, which was attacked on the ground that utility commissions are simultaneously granted legislative, executive, and judicial power has also been upheld by the United States Supreme Court, which has stated that "there can be no doubt of the general power of the State to regulate, and this regulation can be carried on by means of a commission." Also that "such a commission is merely an administrative board created by the State for carrying into effect the will of the State as expressed by its legislation."

These questions can therefore now be regarded as having been definitely removed from the realm of legal controversy. Utilities in general no longer contest the principle of regulation nor the commission form of control. In fact, almost without exception, they express themselves as being committed in principle to both.

Public-utility regulation exists in three forms, Federal, State, and local or municipal. Municipal regulation has largely been superseded by State regulation and will, therefore, not be discussed in this publication.

3. FEDERAL REGULATION

The United States Government has confined its public-utility regulation to interstate carriers, broadly interpreted to include not only railroads, but also express, telephone, telegraph, and pipe-line companies engaged in interstate business. Because practically all telephone companies at times handle, over their lines, long-distance business across State borders, it has been held by the Interstate Commerce Commission that such companies are interstate carriers and are therefore subject to its jurisdiction. The commission, however, has thus far merely required telephone and telegraph companies to adopt a prescribed system of accounting, to file annual reports, and to furnish certain cost data.

4. STATE REGULATION IN GENERAL

Practically all of the States now have laws relating to the regulation of public utilities and have created commissions charged with their administration. Congress, which legislates for the District of Columbia, enacted a public-utility law for the District in 1913.

The earliest utility laws in the United States related primarily to railroads, though carriers by water were often included, and the commissions, generally designated as railroad commissions, which were created to carry out the laws, had at first only advisory and publicity powers. Through subsequent amendment and additional legislation the scope of the laws and the jurisdiction of commissions have been greatly extended in consequence of the wider recognition of the vital public interests involved. Other enterprises organized to furnish the public many other kinds of service, such as gas, water, electric light and power, central heating, telephone and telegraph, express, and even dock and warehouse service, have been declared to be public utilities and placed under commission control, though the scope and the extent of this control varies greatly from State to State.

Although in some of the States the regulatory commission still bears the title, railroad commission, or board of railroad commissioners, in most of them the commission is known either as the public utilities commission, public service commission, or corporation commission. Those States having no railroad commission at the time of adoption of general public utility laws naturally created commissions having general jurisdiction over most, if not all, generally recognized public utilities.

The laws of the several States and of the District of Columbia are not uniform either as to scope or intent, and the powers vested in the several commissions differ greatly. In a few instances, however, several States have adopted laws closely modeled after those of another State.

In general the various State laws, besides prescribing the organization of the commission, the qualifications of the commissioners, the manner of their appointment, their term of office and compensation, and other matters pertinent to the commission itself, define in detail its jurisdiction and powers. The laws also generally define a number of commonly used terms, upon the correct interpretation of which the intent of the laws depends. Among the terms thus defined are "commission," "public utility," "corporation," "common carrier," "telephone utility," "telephone plant," "service," etc.

5. STATE REGULATION OF TELEPHONE UTILITIES

As applied to telephone utilities the general purpose of these laws is to assure the public, without discrimination, reasonably satisfactory, safe and adequate service at reasonable rates, and to assure the utility a "fair return" on the "fair value" of its property, in use and useful, for the rendition of the service. The laws differ principally in the extent to which specific provisions are incorporated for accomplishing the purposes sought.

CERTIFICATES OF PUBLIC CONVENIENCE AND NECESSITY

To prevent further destructive competition resulting in injury to the public interest, many States have incorporated in their utilities laws provisions requiring telephone companies to secure from the State commission certificates of public convenience and necessity before beginning the construction of new plants or systems or exercising any franchise right that may have been granted them. In several States a certificate of public convenience and necessity is a prerequisite to the granting of a franchise. In either case, a company seeking a certificate must prove to the satisfaction of the commission that there is a real need for the proposed new service and that the public convenience and necessity will be served thereby. Certificates of public convenience and necessity are, in general, not required of companies for mere extensions of their systems within the city or community served, nor into contiguous territory not served by another company.

SERVICE REGULATION

Most of the State utility laws contain provisions authorizing or directing the commission to determine, fix, and prescribe just, reasonable, and adequate service. Thus far, however, only two States, Wisconsin and Illinois, have undertaken to establish even tentative rules governing telephone service in general. These provide for:

(*a*) *Standards of Construction.*—The standards of construction which have been adopted usually follow the Bureau of Standards National Electrical Safety Code. These were drawn up primarily to reduce to a reasonable minimum hazards to life, limb, and property, special stress being laid on the necessity of guarding communication wires from contact with or influence by power lines at crossings or when carried on the same poles, and also to protect employees who make repairs. This requires a character of construction which, at the same time, may be said to satisfy the requirements of good engineering practice.

Besides Wisconsin and Illinois, a number of other States, including California, Pennsylvania, Kansas, Nebraska, Iowa, Arizona, Washington, Nevada, Montana, Utah, North Dakota, Connecticut, and Idaho, have adopted rules for overhead line construction. The California commission has made a detailed investigation of the disturbing effects produced on telephone lines by electric-power lines, and as a result of its findings has prescribed rules to reduce these effects to a minimum. Among other States having rules on inductive interference are Iowa, Illinois, Nebraska, and Nevada.

(*b*) *Maintenance of Plant.*—The State laws generally require that provision be made for the proper upkeep and repair of the plant, including such inspections and tests as may be required for detecting trouble and incipient trouble.

The objects of this provision are: (1) To assure the public of a reasonably uniform grade of service comparable with that afforded by the plant when maintained in a condition of normal operating efficiency. Under such conditions service interruptions resulting from plant failure, as well as cross-talk and noise, are reduced to a minimum.

(2) To assure the employees, subscribers, and the general public reasonable freedom from hazards incident to the development of faulty conditions of the telephone plant.

(*c*) *Adequacy of Service.*—(1) Through provision of sufficient switchboard capacity and sufficient operating force to handle the traffic at all times with reasonable facility.

(2) Through limitation of the number of subscribers served by a multiparty line.

(3) Through limitation of the use of toll lines to toll purposes only, except where the traffic is so light that a small number of subscriber stations may also be served.

(*d*) *Dependability of Service.*—Through the adoption of reasonable provisions against failure of lighting or power circuits, damage by fire or storm, and against other emergencies, such as sudden increase in traffic or illness of operators, which might seriously impair the service if not properly met.

(*e*) *Speed Requirements.*—Through prescribing reasonable requirements as to the speed with which calls are to be answered, the size of the exchange and other pertinent factors being taken into consideration.

(*f*) *Standard Operating Practices.*—Through adoption of requirements covering phraseology and methods to be employed by operators to facilitate the handling of traffic.

(*g*) *Handling of Complaints and Irregularities.*—Through requirements relating to the recording of complaints and irregularities in service, their nature, duration, and final disposition.

(*h*) *Publication of Directories.*—Through provisions regarding the publication and revision of directories for large and small

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companies, including the character and scope of special information which should be included for the benefit of the public.

PLANT EXTENSIONS

Most State commissions have been given jurisdiction over extensions of existing telephone systems and are either authorized or directed, after hearings, to order telephone companies to make such additions and extensions to plant as shall be reasonably necessary for public convenience and adequacy of service, and at the same time shall not be unjustly burdensome to the public utility. The commissions may fix the manner in which such extensions are to be made and may also specify the time of their completion. In some instances, municipalities may control extensions within their boundaries, subject to review by the State commission. Franchise stipulations are, however, the controlling factors.

ABANDONMENT OF SERVICE

Few of the utility laws have provisions relating specifically to the abandonment of established telephone service. Some of the commissions have exercised their authority to forbid such abandonment by virtue of the fact that they may require adequate service and full compliance with franchise terms. In other States in which this authority has been questioned the enactment of necessary supplementary legislation has been recommended.

PHYSICAL CONNECTION

Most State utility laws recognize the necessity of control over the physical connection of the lines of one telephone company with those of another company. Subscribers and patrons of the one company may desire connection with subscribers of another company, or the company itself may desire the connection of its lines with those of another company to increase the value of the service. In general, commissions may require such physical connections if it is shown in hearings held on application or on their own motion, that such connections are necessary to serve the public convenience. Most commissions limit physical connections to lines of companies serving different communities and not in local competition. Such laws either specifically or by implication also give the commission the power to fix just and reasonable terms and conditions of physical connections and just and reasonable charges to the public for the use of the same.

ACCOUNTING

Many of the individual States, following the Interstate Commerce Commission, have recognized that efficient supervision and publicity of accounts are essential to the proper regulation of telephone utilities. The Interstate Commerce Commission has prescribed uniform systems of accounts for telephone utilities doing interstate business, and in so doing has recognized the wide difference in the accounting requirements arising from differences in volume of business by dividing them into four classes according to the average amount of their gross annual operating revenues. The companies are classified as follows:

Class A.—Companies having average annual operating revenues exceeding $250 000.

Class B.—Companies having average annual operating revenues exceeding $50 000, but not more than $250 000.

Class C.—Companies having average annual operating revenues exceeding $10 000, but not more than $50 000; and

Class D.—Companies having average annual operating revenues of $10 000 and less.

The commission has prescribed standard forms of accounts to be kept by companies of classes A, B, and C. The use of other forms of accounts is prohibited. No forms have as yet been prescribed for class D companies, although the commission has suggested a form of bookkeeping for their use.

The forms prescribed for classes A, B, and C differ principally in that the larger the operating income the more detailed the form of accounting prescribed. The smaller companies may, if they so desire, keep the more extended accounts prescribed for the larger companies.

Among the accounts prescribed by the Interstate Commerce Commission may be mentioned the following:

(*a*) Fixed capital account, or account showing the original fixed capital, together with the costs of additions, betterments, and replacements. The Interstate Commerce Commission defines the term "fixed capital" as "the property, both tangible and intangible, which is devoted to the accomplishment of the principal purpose of its business, and which has an expectation of life in service of more than one year from the date of installation in service (exception being made in the case of hand tools and other small portable tools that may be lost or stolen)."

(*b*) Operating revenue account, or account showing all moneys received or entitled to be received for services rendered or as a return on property used by the company in its own operations. Separate accounts are provided for exchange-service revenues, toll-service revenues, and miscellaneous revenues.

(*c*) Operating expense account, subdivided into maintenance, traffic, commercial, and miscellaneous expenses incidental to the rendering of the service and the proper maintenance of the plant and equipment.

Practically all State utilities commissions are empowered to classify the telephone companies under their jurisdiction, to prescribe a uniform system of accounts for each class, and to adopt forms according to which such accounts are to be kept. Generally speaking, the State commissions have followed the Interstate Commerce Commission, both as to the classification of telephone companies and as to the accounting forms prescribed. Many of the State commissions have prescribed accounting forms of their own for class D companies, no Interstate Commerce Commission forms having been adopted.

VALUATION

Most State commissions have been authorized or directed to make valuations of all public utilities under their jurisdiction, either specifically or by having been given control over rates.

Considerable valuation work has been undertaken in accordance with specific provisions of the respective State laws. To date, however, most of the work has arisen in connection with individual rate cases submitted to commissions or taken up on their own initiative. Valuations by State commissions are also made for control of the issuance of securities, when such jurisdiction exists, as a basis for purchase and sale and for other purposes. Municipal authorities may make valuations of privately owned utilities, in order to fix the basis on which taxes are to be levied.

The valuation placed on a utility and the method of making the valuation depend, in part at least, on the purpose for which it is made. State utility laws in general provide that the valuation made shall be "fair" to both the public and the utility. This permits the commission to take into account all factors judged to have a proper bearing on the case, some of which may be peculiar to the particular utility.

In general the first determination of a "fair" value as a basis for rate regulation presents great difficulties, frequently because of inadequate records and accounts pertaining to earlier transactions of the utility.

No uniformity of procedure in valuation work has been established, but it may be said that in general a commission is required to take into consideration all the numerous factors bearing on the value of the property under appraisal. Factors to be considered in valuations are the historical cost of the utility, the reproduction cost new and the reproduction cost less depreciation. These are ascertained as far as possible as of the date for which the valuation is sought.

The historical cost is the total amount of money which has actually been expended in building up the utility as a going concern, including the costs of the original physical plant and the net additions thereto, engineering costs, interest, taxes, and insurance during construction, as also franchise, organization, and promotion costs. Determination of historical cost presupposes an intimate knowledge of the financial history of the utility and an accurate inventory of its property, tangible and intangible.

In many cases, on account of the manner in which the books and records have been kept, or on account of the fact that such books and records are no longer in existence, it is impossible to ascertain the true historical cost. Since it has to be left out of consideration in so many cases, less weight is attached to it than would otherwise have been the case.

The cost of reproduction new has in most instances been estimated as of a particular date, often the date on which a prescribed uniform system of accounts was put into effect, a period of time usually based on all available data bearing on the time required to reproduce the property under valuation in one complete job, being assumed for the reconstruction. The determination of the reproduction cost involves a complete inventory of the physical property of the utility used and useful in the conduct of its business, including, in the case of telephone utilities, right of way, land, buildings, central office equipment, station apparatus, private branch exchanges, pole lines, conduits, overhead and underground wires and cables, office furniture and fixtures, general stores, tools, implements, teams, motor vehicles, etc.

To determine the cost of reproduction new, unit costs are applied to each inventory item. The unit costs are based on the best available data and are intended to represent a fair average cost covering the total range of market prices for the period of reconstruction assumed. Among other factors which must be given consideration are general labor conditions, wages and salaries, transportation costs, and subsistence charges.

To make the reproduction cost estimate complete there must be added to the reproduction cost of the physical property certain other items. Some of these are organization and promotion, preliminary engineering, interest during construction, taxes and insurance during construction, omissions and contingencies, and working capital. Going value is also given consideration.

The depreciated reproduction cost is the reproduction cost new less the accrued depreciation, preferably determined by inspection of the physical condition of the property but sometimes estimated from the age and average life of the plant elements.

The reports of the commission's engineers and of the engineers of the utility are presented and considered in public hearings. After verifying all the evidence submitted the commission arrives at a "fair" value of the property, tangible and intangible. This value is binding unless set aside by court decision.

Many of the commissions are required to make revaluations when deemed necessary. The work connected with revaluations of telephone utilities is naturally much less difficult than that involved in a first valuation because uniform systems of accounts are now in general use.

RATES

Public utility laws in general authorize or direct the commission to determine and fix such rates and charges for utility service as shall be "just," "reasonable," and "sufficient." They also provide that rates be nondiscriminatory as between customers, subscribers, or patrons of the same class and as between those belonging to different classes.

The question as to what is a "just," "reasonable," and "sufficient" rate of return can not be exactly defined for general application, and indeed is difficult to answer even in a specific case. The wording of public-utility laws, probably for this reason, intentionally admits of a wide range of interpretation. The matter of "just" rates, like "fair" value, is left to the discretion of the commission and each case is governed by conditions peculiar to itself.

Generally speaking, however, the rates as a whole are so fixed that the net operating revenue, left after deducting from the gross operating revenue all expenses recognized as proper, will be "sufficient" to yield a "just" and "reasonable" return on the "fair" value defined above.

Rate regulation is therefore based on the following:

(*a*) The basic valuation of the property, tangible and intangible, used and useful in supplying service;

(*b*) On that rate of return determined by the commission to be "just," "reasonable," and "sufficient";

(*c*) On the estimated cost of supplying the service based on actual costs in the past, allowance being made for changes in cost. It is obvious that the total cost of supplying the service, together with the return on investment, must be met by service charges.

Among the recognized legitimate expense items is an annual depreciation allowance designed to provide for the replacement of plant elements, excepting small short-lived elements, by new plant, when, on account of wear and tear, inadequacy or obsolescence from any cause, such elements have served their useful life. The depreciation allowance is based on proper and adequate rates of depreciation as determined by experience for each class of property and are such as will provide the amount required over and above the expense of current maintenance to keep the property as a whole in a state of normal operating efficiency.

The fixing of nondiscriminatory rates for different classes of service presents very great difficulties. Unlike the water company, the gas company, and most other public utilities, the telephone company is called upon to supply many classes of local service as well as toll and long-distance service.

RATE SCHEDULES

Rate schedules cover all classes of service sold and the charge fixed by the utility for each class is largely governed by the average cost of rendering that particular service. The general principles underlying the rates for the various classes of service are set forth in the following paragraphs:

(*a*) *Toll and Local Rates.*—Rates may be divided into two general classes, one covering toll service and the other covering local service. Toll rates generally are on a cost per call basis, involve the actual distance and the duration of the connection, and a charge is made for each completed call. In certain cases uncompleted calls also involve charges. Local rates are based on the average distance and duration. Charges are not always made per call and no charge is made for uncompleted calls.

(*b*) *Public and Subscriber Local Rates.*—Local rates for public or semipublic telephone service do not vary with the number of completed calls; the charge is uniform to all users. The rate per call may, however, be greater at a privately attended telephone having no coin collector than at other public telephones.

Local subscriber rates vary in a general way with the amount, extent, and grade of the service rendered. The total cost of rendering service to a particular subscriber naturally increases with the amount of service rendered, but the cost per call generally decreases as the number of calls increases. The cost of rendering service increases with the size of the local area and with the telephonic density in that area. As a community grows, the size of the local-service area and its telephonic density both increase. Furthermore, the service demands become exacting. Local rates therefore vary with the size of the community.

(*c*) *Business and Residence Flat Rates*.—Where service is sold on flat rates the price or prices are naturally based on average usage. This varies widely between business subscribers and residence subscribers. Where flat rates exclusively obtain it is therefore usual to charge a higher rate for business service than for residence service. As a further basis for a rate differential, it is held that telephone service has a greater value for business purposes, and is therefore worth more, and that residence service adds to its value, being a business feeder as well as a convenience to the business man.

(*d*) *Message Rates*.—Message-rate service is always sold with a fixed minimum charge, for which a specific number of messages is allowed, plus specific excess charges for calls in excess of those allowed for the minimum charge. In many cases the excess rate for specific messages is uniform, regardless of the number of messages used. In other cases, the excess rate varies, decreasing at certain points in the scale of message use. In some cases, all messages above the minimum number and below a fixed number (the highest given) are divided into blocks which may or may not be uniform as to number. Each successive block of messages has a lower rate per message. All messages above the highest scheduled number have a fixed rate. In general the minimum rate for party-line service is less than for individual-line service, and that on four-party lines is less than that on two-party lines; the minimum number of messages may also vary in the same manner.

(*e*) *Individual and Party-line Rates*.—As rates always involve costs and as costs vary as the amount of the plant and operating facilities provided vary, it follows that rates may decrease as the number of stations per line increases, but as the number of stations per line increases, the amount of service allowable per station and the grade of service both decrease. Hence there is a practical limit to the number of stations placed on party lines which varies with the needs of different communities.

Large cities do have two and four-party-line service, but in very large cities party-line service is not sold at all in the congested areas. Eight or 10 party-line, or multiparty-line service, as it is frequently called, is more or less limited to suburban sections. Lines having more than 10 stations are generally classed as rural lines, and the number of stations per line often exceeds 15.

(*f*) *Private Branch Exchange Rates.*—Private branch exchange service requires switching equipment on subscriber's premises for the purpose of establishing connections between any two of the subscriber's telephones and between the telephones and the central office. Such switching equipment is furnished and maintained by the telephone company at rates which are based upon the amount of such equipment. Private branch exchange telephone stations usually require little wiring and no protectors and are furnished at rates which are based upon the investment charges. The trunk lines to the central office are furnished at rates which may include the whole or part of the local central-office charges. In general all completed outgoing messages are metered and paid for according to a sliding scale as described under message rates.

In most States new rate schedules must be submitted for approval by the commission and do not go into effect until after approval has been given. In a few States the utility companies may at any time establish new rates which are binding upon the subscribers or customers of the utility unless set aside by commission order after public hearings.

A change of rates applying to one class of subscribers may affect not only the number of subscribers as a whole but also their distribution among classes. The rate policy of the company under which its business was developed must, therefore, be given full consideration whenever rate schedules are revised. Such matters do not, however, fall within the scope of this publication.

CONTRACTS AND COLLECTIONS

Subscribers are generally required to enter into contractual relations with the telephone company in order that the obligations of each may be clearly defined. While a contract is executed with respect to a particular subscriber, who may be an individual or a legal association of individuals, the use of the telephone is not restricted to the subscriber. It may be used also by the subscriber's employees, agents, family, or guests, but the subscriber is responsible for the charges for all service rendered.

Contracts may be on either the flat or message rate basis, but in either case they specify the local-service area, cover local service in that area for one month, and usually call for monthly payments in advance. Contracts also cover the subscriber's liability for the charges for all toll calls which may originate at his telephone or telephones.

Contracts also cover the facilities for rendering service which the telephone company is under obligation to furnish, though only that portion of these facilities which is required for use on the subscriber's premises is actually specified. These include main-station telephones, extension-station telephones, extension bells, all switching apparatus, and the connecting telephone lines.

Monthly bills are usually rendered to subscribers giving the amount due in advance for local service as per the terms of the contract and the amount due for toll service during the preceding month, which may or may not be a calendar month. An itemized list of the toll calls, giving the number of calls to each toll point usually is furnished also. Connection details for toll calls billed are furnished on request but are not included on the toll-call statement.

It is also usual to include in the telephone-service bill the charges for telegraph service handled by telephone in those localities where arrangements have been made between the interested companies.

Bills are payable within a certain number of days after date. Discounts may or may not be given for prompt payment and penalties for delay in payment are not generally exacted. Delinquents usually have the matter called to their attention by telephone within a fixed period of delinquency. At the expiration of a second delinquent period notice is given that the service will be discontinued at a specified time unless the obligation is met before that time. At the expiration of the time limit the subscriber's line connection is either opened altogether, in which case service is reported as temporarily discontinued, or the line terminal is so designated that operators will switch all originating calls to that department which is in charge of collections until the amount due is paid. The denial of service routine is, however, subject to liberal interpretation by authorized representatives in case of need. At times it is impossible to reach the subscriber and in spite of the notification subscribers occasionally overlook the matter without intent. In such cases service is restored on the receipt of reasonable assurance regarding payment. Furthermore, in these cases where originating calls from delinquent subscribers are routed to the collection department, real emergency calls are permitted.

DISCRIMINATION

Nearly all public-utility laws forbid discrimination in terms broadly expressed or capable of broad interpretation. In principle, all subscribers are entitled to an equal standing in their relations with the utility, and hence the interested public is entitled to equally favorable consideration relative to applications for service, service contracts requirements, the quality of service rendered subscribers of the same class, the rates for the same class of service, the proper adjustment of rates for different classes of service, terms of payment, discounts and deposits when required, and the imposition of penalties for nonpayment of charges.

6. STANDARDS OF TELEPHONE SERVICE

As previously indicated, only two States, Wisconsin and Illinois, have thus far undertaken to establish even tentative standards for telephone service, though most of the State laws, either directly or by implication, provide for the setting of such standards.

Telephone service involves a considerable number of factors, the more important of which have been discussed in the preceding section. The grade of any given service may be determined by the values of the separate factors, each measured by actual accomplishment, expressed in terms of a specified requirement defined as standard. The specifications covering the requirements with respect to all factors would constitute a set of telephone service standards.

The fixation of suitable service standards involves a comprehensive study of individual community needs. These vary widely with the size of the community and with the nature of its business and social interests. Moreover, service standards can not be considered independently of the costs because the cost, which largely determines the charge, increases with the grade of the service and because a different estimate of value is placed on grade in different communities.

Many commission cases involve directly or indirectly both grade of service and rates. All parties interested are at a disadvantage on account of the absence of service standards by means of which the grade can be measured. Decisions must, therefore, be based on judgment instead of established fact. It is therefore in the interest of both the public and of the telephone utility that standards for telephone service be determined. The Bureau of Standards confidently hopes to enlist the cooperation of regulatory commissions and of the telephone interests in thls work.

APPENDIX—DEVELOPMENT OF THE TELEPHONE INDUSTRY

1. GENERAL DEVELOPMENT

The growth and present status of the telephone industry may be indicated in numerous ways. For example, the number of telephones at stated periods serves as an index of the number of stations at which telephone messages may be originated and received. Taken alone, however, it fails to indicate geographical distribution. Other objections may apply if any other single factor be taken as a statistical index. It is, therefore, necessary to submit data of various kinds which must be considered as a whole in order to gain a correct conception of the development of the industry and the importance it has attained in our business and social life.

The extensive telephone development in the United States as compared with other countries on any basis of comparison may be traced to a number of causes, among which the most important are:

1. The greater readiness of the American public to adopt new ideas and practices.
2. The higher average per capita income in the United States.
3. The demand of American business for time-saving devices of all kinds, which has firmly established the telephone as a business necessity, even in the small business establishment.
4. The reflection of business habits and customs on social habits.
5. The more intimate business and social relations between widely separated communities.
6. The initiative and aggressiveness of the American telephone industry, which directed the attention of the general public to the uses and value of the telephone; the readiness of the industry to devise and supply less expensive grades of service, and the readiness of investors to supply the necessary capital.
7. Competition in the industry.

In the presentation of the following data two main classes of telephone systems are recognized, namely, the Bell system, which includes all lines owned and operated by the American Telephone and Telegraph Co. and its associated companies, and non-Bell or independent systems. The latter class is further divided into those systems reporting annual incomes of $5000 or more, and those reporting annual incomes of less than $5000.

A census of the telephone industry was taken for the years 1880, 1890, and every fifth year beginning with 1902. Data collected before 1902 were incidental to the regular 10-year census and are therefore less complete than the more recent data. None of the statistics presented here include data regarding private telephone systems used in conjunction with steam or electric railways or in industrial plants, hotels, etc., or for strictly intercommunicating purposes.

2. NUMBER OF TELEPHONES

Table 1 gives, in so far as data are available, comparative figures for the number of telephones in the entire country and for the several classes of systems for the census years from 1880 to 1917. It may be noted that in 1880, only four years after the first public demonstration of the telephone by Bell at the Centennial Exposition in Philadelphia, there were over 54 000 telephones in use; also that the increase since 1880 has been over two hundred fold.

The large percentage increase from 1890 to 1902 is worthy of note. It was brought about by several factors, of which the more important were the rapid development of competition and the intensive development of party-line service, both tending to lower rates. The introduction of message-rate service also played its part during the latter part of this period.

New York, Pennsylvania, Illinois, and Ohio are the most populous States and have the largest number of telephones. In 1917 these four States reported 4 106 452 telephones, or 35 per cent of the total for the entire country.

The number of telephone per thousand population is perhaps the best index of telephone development in the several States. The number of telephones installed has increased much more rapidly than the population, the average number per thousand population for the whole country being 30 in 1902, 72 in 1907, 91 in 1912, and 113 in 1917.

Twenty-one States reported more telephones per thousand population in 1917 than the average for the United States, Iowa leading with 220, followed by Nebraska, District of Columbia, California, and Minnesota, with 193, 192, 190, and 176, respectively. South Carolina had the smallest number, 27, being slightly below Mississippi with 29.

3. NUMBER OF MESSAGES OR TALKS[1]

The increase in the use of the telephone is indicated by the estimated total number of annual messages shown in Table 2. No data are available for the year 1880, nor do the figures for the years 1890, 1902, and 1907 include messages over farmer or rural lines not included in the Bell System. The vast traffic and its rapid growth are, however, very evident and clearly show the extensive use of the telephone in this country.

Although the total annual number of messages or total traffic for all systems reporting incomes of $5000 or more has shown a marked increase on each census, 1902 to 1917, the average number of messages per telephone per day decreased during the greater part of the period, as shown in Table 3, the figures reported for 1902, 1907, and 1912 being 6.7, 6.5, and 5.8, respectively. This decrease in usage may in part be attributed to the increase in the number of telephones per thousand population, made up in part of private branch exchange stations, and to the extensive adoption of message-rate service.

For 1917 the number of messages per telephone per day was reported as 6.1, an increase over 1912, notwithstanding the influence of the above factors tending to lower the usage. This was undoubtedly brought about by the unusual conditions resulting from increased business activities incident to the war. Figures for 1918, if available, would probably show a further increase over the usage reported for 1917.

4. NUMBER OF SYSTEMS AND LINES

Table 4 gives data regarding the total number of systems and lines from 1880 to 1917. As an index of the growth of the industry these data are relatively of little value because the number of systems and lines as given in the census reports is largely determined by ownership. As these may be regrouped under one management or consolidated under one ownership, the actual number reported may have decreased whereas all the other items may have increased. An example of this is shown in the reports of all systems and lines for 1880 and 1890, where there is a decrease from 148 to 53, and also in the reports for the Bell System for 1912 and 1917 a decrease is indicated from 176 to 145. Of the total number of systems and lines in 1917, 51 034, or 95.8 per cent, reported annual incomes of less than $5000.

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[1] Used in the Census schedules as synonymous with originating calls, completed and uncompleted.

5. NUMBER OF MILES OF WIRE

The rapid growth and present status of the telephone industry are probably best illustrated by Table 5, which shows the wire mileage for the census years from 1880 to 1917, both inclusive. This table gives the miles of single wire in use and spare for each of the several census years.

The rapid growth in the number of telephone systems and lines, coupled with the extension of both local and long-distance lines, resulted in a corresponding increase in wire mileage. This increase was greatly augmented, however, by the general adoption of metallic or two-wire circuits for long-distance and urban use and by the spare-wire mileage which became an economic necessity when aerial and underground cables were introduced. It is interesting to note that the total telephone-wire mileage in the United States at the end of 1917 was more than sufficient to encircle the earth a thousand times.

6. NUMBER OF CENTRAL OFFICES AND PRIVATE BRANCH EXCHANGES

Telephone companies and systems reporting an annual income of $5000 or more for 1912 and 1917 were required to report the number of central offices operated by them, and also the number of private branch exchanges connected with their central offices. The figures for 1907 were obtained by the Census Bureau from data collected in that year, which was reclassified in accordance with the above basis. The private branch exchange, as distinguished from the central office, consists of a switchboard located within a business building, apartment house, hotel, or other establishment and serving as a means of interconnecting telephones on the premises as well as connecting them with the central office.

Table 6 shows the growth in central offices and in private branch exchanges. It may be noted that there has been a substantial increase in the number of central offices and a very much more rapid increase in the number of private branch exchanges. The private branch exchange has become indispensable to the modern business establishment, apartment, or hotel.

7. 1917 SUMMARY

A composite idea may be gained of the magnitude of the telephone industry in the United States as of 1917 by an examination of the data presented in Table 7. This table brings together most of the data already given for 1917, and also data relative to the number of employees, salaries and wages, total revenue, total expenses, and the value of plant and equipment.

Vast as is the telephone industry in the United States to-day, every indication points to its continued rapid development and a greater and more useful future.

TABLE 1.—Number of Telephones

Systems	1880	1890	1902	1907	1912	1917	Percentage of total in 1917
All systems and lines....	[a] 54 319	[a] 233 678	2 371 044	6 118 578	8 729 592	11 716 520	100
Bell Telephone System .	([b])	([b])	1 317 178	3 132 063	5 087 027	7 326 858	62.5
Independent systems reporting annual income of $5000 or more ..	([b])	([b])	[c] 998 119	1 774 630	2 239 721	2 626 852	22.4
Independent systems reporting incomes of less than $5000	([b])	([b])	[d] 55 747	1 211 885	1 402 844	1 762 810	15.1

[a] Independent farmer or rural lines not reported.
[b] Not reported.
[c] All independent systems exclusive of farmer and rural lines
[d] Independent farmer and rural lines only.

TABLE 2.—Number of Messages or Talks (Estimated)

Systems	1880	1890	1902	1907	1912	1917	Per cent of total in 1917
All systems and lines	([a])	[b]453 200 000	[b]5 070 554 553	[c]10 400 433 958	[c]13 735 658 245	21 845 722 335	100
Bell Telephone System	([a])	([a])	3 074 530 060	6 401 044 799	9 133 226 836	14 597 567 869	66.8
Independent systems reporting annual incomes of $5000 or more	([a])	([a])	[b]1 996 024 493	3 999 389 159	4 602 431 409	5 211 493 216	23.9
Independent systems reporting incomes of less than $5000	([a])	([a])	([a])	([a])	([a])	2 036 661 250	9.3

[a] Not reported.
[b] Number reported by all systems which had exchanges.
[c] Exclusive of systems reporting annual incomes less than $5000.

TABLE 3.—Number of Messages or Talks per Telephone

Systems	Messages per year				Messages per day [b]			
	1902	1907	1912	1917	1902	1907	1912	1917
All systems and lines [a]	2190	2120	1875	1990	6.7	6.5	5.8	6.1
Bell telephone system	2334	2044	1795	1992	7.2	6.3	5.5	6.1
Independent systems reporting annual incomes of $5000 or more	([c])	2254	2055	1984	([c])	6.9	6.3	6.1

[a] Telephone systems reporting annual income under $5000 excluded.
[b] Computed on basis of 325 days.
[c] Not reported.

TABLE 4.—Number of Systems and Lines

Systems	1880	1890	1902	1907	1912	1917	Percentage of total in 1917
All systems and lines	[a]148	[a]53	9136	22 971	32 233	53 234	100
Bell Telephone System	([b])	([b])	44	175	176	145	0.3
Independent systems reporting annual incomes of $5000 or more	([b])	([b])	([b])	1 461	1 740	2 055	3.9
Independent systems reporting income of less than $5000	([b])	([b])	[c]9092	21 335	30 317	51 034	95.8

[a] Independent farmer or rural lines not included.
[b] Not reported.
[c] All independent systems.

TABLE 5.—Number of Miles of Wire

Systems	1880	1890	1902	1907	1912	1917	Per cent of total in 1917
All systems and lines	[a]34 305	[a]240 412	4 900 451	12 999 364	20 248 326	28 827 188	100
Bell Telephone System	([b])	([b])	3 387 924	8 947 266	15 133 186	23 133 718	80.3
Independent systems reporting annual incomes of $5000 or more	([b])	([b])	....	2 974 694	3 886 205	4 164 308	14.4
Independent systems reporting incomes less than $5000	([b])	([b])	[c]1 512 527	1 077 404	1 228 935	1 529 162	5.3

[a] Independent farmer or rural lines not reported.
[b] Not reported.
[c] All independent systems.

TABLE 6.—Number of Central Offices and Private Branch Exchanges

[Systems reporting annual incomes of $5000 or more]

Systems	1907		1912		1917	
	Central offices	Private branches	Central offices	Private branches	Central offices	Private branches
All systems	10 613	28 276	11 515	52 651	12 294	80 914
Bell System	5 418	24 702	5 853	45 387	6 288	72 253
Independent systems	5 195	3 547	5 662	7 264	6 006	8 661

TABLE 7.—1917 Summary

Items.	All systems and lines	Bell Telephone System	All other systems	
			Reporting annual incomes of $5000 or more	Reporting annual incomes of less than $5000
Number of systems or lines	53 234	145	2 055	51 034
Number of miles of wire	28 827 188	23 133 718	4 164 308	1 529 162
Number of telephones	11 716 520	7 326 858	2 626 852	1 762 810
Estimated number of messages or talks	21 845 722 335	14 597 567 869	5 211 493 216	2 036 661 250
Number of central offices	21 175	6 288	6 006	8 881
Number of employees	262 629	198 700	45 790	18 139
Male	91 510	69 457	15 782	6 271
Female	171 119	129 243	30 008	11 868
Salaries and wages paid ... dollars	175 670 449	144 914 867	24 740 199	6 015 383
Revenue, total (operating and nonoperating) ... dollars	[a] 372 501 800	311 918 260	60 583 540	....
Expenses, including taxes and fixed charges, total ... dollars	[a] 313 103 060	260 783 288	52 319 772	....
Value of plant and equipment ... do	1 492 329 015	1 140 639 666	295 272 476	56 416 873

[a] Systems reporting annual incomes of less than $5000 are not included.

WASHINGTON, February 16, 1921.

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