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Telephone Communication System of the United States[1]

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This paper presents the results which have been obtained up to the present time in developing telephone communication in the United States of America, this development having been worked out in a form to meet the particular conditions which present themselves in that country. The paper first deals with a brief description of the general structure and organization of the telephone communication system giving the organization of the Bell System which handles the greater part of the telephone service of the country and the reasons for and advantages of this organization. In this connection some figures are presented with respect to the technical personnel who are continuously engaged in studies to develop the art and to provide new methods and facilities for improving the service.

Local service, that is the service within the limits of a single telephone exchange area, is next discussed. Figures are given with respect to the volumes of telephone calls handled in the Bell System, the speed with which the connections for these calls are completed and the operating force required. Reference is also made to the standards of transmission given and the various problems encountered in meeting these standards. Figures are given with respect to station growth, to the increased efficiency of station apparatus and to the improvement in types of instruments. Various types of private branch exchanges provided to meet the needs of customers using a large amount of telephone service are discussed. The cable plant is considered mainly from the construction standpoint and typical illustrations are given of some of the construction practices. The various types of central office switching systems in common use are described, including magneto, common battery and dial systems, the latter including both the step-by-step and panel systems which are being provided in increasing amounts in the Bell System. The subject of buildings to house these various equipments as well as the operating forces and headquarters staffs in many cases is briefly discussed, also standardized layouts and floor plans. The problem of giving telephone service in the rural communities, which is a very important one in the telephone development in the United States, is also briefly treated.

The toll service is considered, first with respect to the shorter haul toll business and the problems involved and then with respect to the long distance toll service. Figures are given showing the speed of service and the amount of traffic handled. For the short distance toll service, two important methods of handling the business are described, namely, manual straightforward tandem and dial tandem.

The long distance service, which has developed most rapidly in recent years, is described in some detail in the paper. Among the important features of this service is noted the recently developed method of completing toll calls with sufficient speed so that on most of the calls the calling subscriber remains at the telephone. The various types of toll circuits are described including open wire circuits operated both at voice frequencies and by carrier systems and long toll cable circuits. The operation of these long circuits requires a large number of repeaters in tandem and the design and maintenance problems which this arrangement requires are pointed out in the paper.

[1] Presented by Dr. F. B. Jewett before the World Engineering Congress, Tokio Japan, October, 1929.

Information is given with respect to international telephone connections in North America, between North America and Europe and other international connections. In covering this subject some of the important items relating to the operation of the transatlantic radio channels are given and reference made to the projected transatlantic telephone cable.

Various forms of special services closely allied with the message telephone service are described. These include telegraph service, telephone circuits provided for private use, foreign exchange service, telephone networks for program transmission to radio broadcasting stations, electrical transmission of pictures, telephony in connection with aircraft operation, ship to shore telephony, telephony to mobile stations such as railroad trains, telephone services of railroads and other public utilities, telephone public address systems and television. Reference is also made to some of the by-products of the telephone development work which include improvements in submarine cable telegraphy brought about by the discovery of the alloys known as "permalloy and perminvar," the development work in the reproduction of sound and in the talking motion pictures.

In concluding, the paper points out that careful studies of the future development of the telephone industry indicate a somewhat accelerated rate of development of the services required to meet the demands of the customers and a continuing very rapid technical development of telephone plant and systems to provide the necessary facilities.

In treating such a large subject in a paper of this kind it has been necessary to deal with technical problems in rather general terms and as an attachment to the paper references are made to numerous articles in the technical press for the more technical information.

General

THE purpose of this paper is to give a general description of the telephone communication system of the United States of America, outlining briefly some of the more important engineering problems involved and indicating the service results obtained. At the beginning of this paper it seems important to give a brief description of the general structure and organization of the telephone communication system.

The commercial telephone system of the United States is entirely owned and operated by corporations, partnerships, and individuals. A group of 24 closely associated Bell Telephone Operating Companies owns and operates 14.8 million telephones and the telephone lines used for toll service within their territories. In addition there are in the country about 4.7 million telephones owned by several thousand independent telephone companies which have operating agreements with the Bell Companies providing for the interconnection of lines, thus permitting the operation of 19.5 million telephones as a single system. There are in addition about 140,000 telephones in the country not connected with the Bell System.

The 24 Bell Operating Companies cover the entire area of the United States and are responsible for all Bell Telephone operations within their respective areas. A number of the larger companies are subdivided into autonomous operating units, there being at the present time a total of 34 such units in the country. In many cases the area within corporate limits or within the limits of an operating unit is identical with that of a major political subdivision of the United States (a State) and this simplifies the application of governmental regulation. A typical organization of a Bell Operating Company is indicated in Fig. 1.

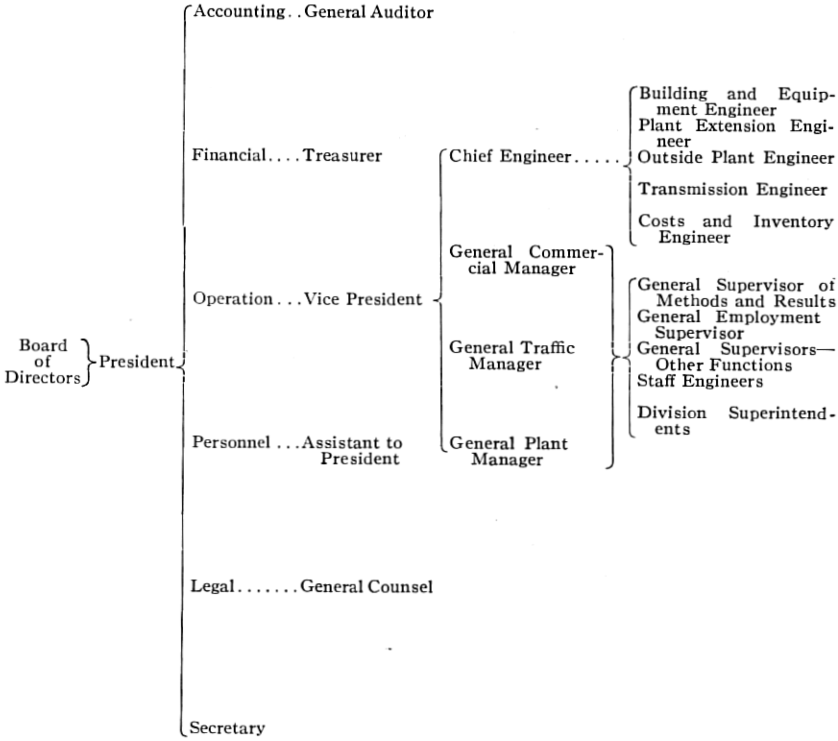

Fig. 1—Organization of typical Bell Telephone Operating Company.

In order to facilitate the best possible handling of the long distance service between points in different operating companies and to avoid the problems which would arise from divided responsibility, the long distance business involving territories of two or more Associated Companies is handled throughout the country by the Long Lines Department of the American Telephone and Telegraph Company. These operations are, of course, in the closest cooperation with the operations of the Associated Companies without duplication of construction or of operating effort.

An important feature of the Bell Telephone System is the general departments maintained by the American Telephone and Telegraph Company, including the Bell Telephone Laboratories. These departments, constituting about 7,500 engineers, scientists, business experts and assistants, are continuously engaged in studies to develop the art and to provide methods and facilities for improving the service. They also provide consulting advice to the operating companies on all phases of the telephone business and render to them a large variety of services. One of these services is making available to all the companies rights under all patents necessary for the fullest and most economical development of the business. It is the intention, in general, that work which can best be done once for all the entire telephone system rather than individually by the several operating companies shall be done by these general departments and that the specific solution of the telephone problems in each area shall be the responsibility of the operating company involved, who, however, are free at all times to get the advice and assistance of the general staff. In all of the work of the general staff close contact is maintained with the various operating telephone companies of the Bell System. The experiences of these companies are studied and analyzed to make available for all the companies the valuable results to be derived in this way, and the advantages to be obtained by comparing the experiences of different companies under similar conditions.

The organization of the American Telephone and Telegraph Company and the Bell Telephone Laboratories is indicated in Fig. 2.

Another very important feature of the Bell System is the very close relation between operating and manufacturing branches of the work through the ownership by the American Telephone and Telegraph Company of the Western Electric Company, Inc., and arrangements between that company and the operating companies for the supply of telephone apparatus and materials. This permits the manufacture of apparatus and the purchase of materials from outside suppliers to be done on the basis of the large quantities required for the entire Bell System resulting in great economies.

The organization of the Bell Telephone System is such as to result in close cooperation between the companies dealing with different branches of telephone work. This brings about the conditions necessary for universal service, for the development of the art along orderly and non-conflicting lines, and for the standardization of all apparatus, communication systems and operating methods to the extent that such standardization is helpful.

New types of telephone plant, operating methods, methods of maintenance and business methods are standardized by the general departments of the American Telephone and Telegraph Company, and are adopted and placed in use by all of the Associated Operating Companies to the extent that they apply to their local conditions. Special arrangements are, of course, made available to meet special requirements. The specifications for all standardized apparatus and

- Board of Directors — President
  - Personnel.....Vice President
    - Assistant Vice President
      - Benefit and Medical Work
    - Assistant Vice President
      - Employee Relations
    - Assistant Vice President
      - Special Employment and Training
  - Operation and Engineering.....Vice President and Chief Engineer
    - Commercial Engineer
    - Assistant Vice President
      - Plant Operation Engineer
      - General Operating Results
      - Traffic Engineer
    - Plant Engineer
  - Legal.........Vice President and General Counsel
    - Attorney
    - Tax Attorney
    - Patent Attorney
    - General Solicitor
  - Development and Research
    - Vice President, Assistant Vice-President
      - Transmission Development Engineer
      - Outside Plant Development Engineer
      - Research Engineer
      - Equipment Development Engineer
      - Electrical Interference Engineer
      - Technical Representative in Europe
    - Bell Telephone Laboratories: Chairman of Board, President, Vice President
      - Director of Research
      - Director of Apparatus Development
      - Director of Systems Development
      - General Patent Attorney
      - Director of Publication
      - Personnel Director
  - Accounts, Finance and Business.....Vice President
    - Comptroller
    - Treasurer
    - Assistant Vice President
      - General Policies and Contracts
    - Assistant Vice President
      - General Service Bureau
  - Information...VicePresident
    - Advertising Manager
    - Assistant Vice President
      - Publicity
  - Secretary

Fig. 2—Organization of the general departments of the American Telephone and Telegraph Company, including Bell Telephone Laboratories.

materials are prepared by the Bell Telephone Laboratories, and the Western Electric Company is enabled to concentrate on the task of purchasing and manufacturing standardized supplies, materials and apparatus in accordance with these standard specifications. Standardization also has great operating advantages in minimizing stocks of materials and providing interchangeability both of materials and working forces and is very important in making possible the operation of the entire interconnected network as a single system with uniform grades of service.

As has been stated by Mr. Gifford, President of the American Telephone and Telegraph Company, "The ideal and aim today of the American Telephone and Telegraph Company and its Associated Companies is a telephone service for the nation, free, so far as humanly possible, from imperfections, errors, or delays, and enabling at all times any one anywhere to pick up a telephone and talk to any one else anywhere else, clearly, quickly and at a reasonable cost." With this aim in view, continuous effort is made further to improve and to extend the service within the nation and also the telephonic connections to other nations. It is recognized also that changes in business and social conditions bring about repeated changes in the services desired by the people of the nation and in the character and appearance of facilities furnished to them. These facts, in addition to the onward march of the application of science, form an important basis for the continued study by the general staff of the development of all phases of the telephone system.

A few figures relative to the size and growth of the Bell System are helpful in an understanding of the more specific telephone problems which are discussed below. Such figures are included in the statistical summary appended to this paper and include data regarding telephone messages, numbers of telephones, miles of wire and amount of telephone plant.

In accordance with the general organization of the Bell System, the engineering problems involved in the design, construction and maintenance of the plant of each operating telephone company are the responsibility of the engineering department of that company. General studies of methods of improvement of service and the development of new apparatus and systems of communication, together with consulting engineering advice, are provided by the general departments.

For the provision of new plant to meet additional demands for service, in the case of the more important items, often one year, and sometimes more, is required between the completion of detailed engineering plans and completion of construction. Furthermore, to obtain maximum economy it is necessary that much of the new construction provide for expected increases in demands for service for a number of years to come. This applies particularly to telephone buildings and to runs of underground conduit and to a lesser extent to cables, pole lines and many other very important parts of the telephone plant. The engineering of the additions to the Bell Telephone System, now aggregating over 500 million dollars a year is, therefore, necessarily based on careful forecasts of the amount and type of business to be expected for a number of years in the future and good engineering judgment must be applied in determining the types, quantities and design of plant. These must take into account not only the expected amount of service required but also expected future changes in the character and standards of service demanded and in the apparatus and materials expected to become available. In view of the capital expended in extensions and the large amount of plant already in service, the engineering work involved is considerable. There are now approximately 10,000 engineers engaged in the work of the Bell System of which approximately 6,300 are in the operating companies, 2,200 in the headquarters departments and 1,500 in the Western Electric Company. These figures apply to men doing work of engineering grade, and inclusion of assistants of all kinds, stenographical, clerical, laboratory, etc., would more than double these figures.

Local Service

General

Service within the limits of a single telephone exchange is spoken of as local service. This generally includes service within a large metropolitan area, a city with its surrounding suburbs or a town or village. During 1928 customers of the Bell System originated approximately 24,000 million local calls of which approximately 19,000 million originated from manual and 5,000 million from dial telephones. This represents an average daily usage of approximately 5.5 calls per telephone station per day.

The speed of service is illustrated by the following average figures. In the smaller cities with manual operation where the operator who takes the call completes it herself without trunking, the average time from the start of the call to the answer of the called station is 19 seconds. The corresponding figure for manual calls in large cities based on about three million observations made in the year 1928 in 38 large cities of the country is 28.8 seconds. The same observations indicate that when fully converted to the dial system the speed of service in the large cities will be about 22.5 seconds.

As to the accuracy of service, 98 per cent of all calls are handled without error. The most serious errors are those resulting in wrong numbers. The mistakes made by the subscribers and equipment under the dial system are about the same in number as those made by subscribers and operators under the manual system.

Calls resulting in busy reports amount to 10 per cent. This is something which is not directly under the control of the telephone company since the subscriber determines the telephone facilities which are provided. Records are kept, however, in both manual and dial offices of the lines responsible for the greatest number of busy reports and efforts are made to have the subscribers take additional facilities.

Standards of transmission are applied to the design of the plant to insure that transmission will be clear between the most remote parts of the exchange area. This depends on the design of station equipment, wire lines and switchboard equipment, and is expressed in terms of the combined electric and acoustic efficiencies of the circuits from the mouth of the talker to the ear of the listener. This overall efficiency is expressed in terms of the adjustment of a standard reference circuit. The standards in use in the United States refer to the maximum transmission loss permitted between any two subscribers and vary in magnitude between equivalents of 18 decibels and 22 decibels, depending on the circumstances of different cases.

In order to meet these transmission standards the Bell Companies have standard requirements regarding the efficiency of transmitters and receivers and other station equipment, and these are made the basis for engineering the wire plant. Transmission losses in switchboards are kept as low as practicable and within specified limits. The wire plant for subscribers lines and trunks is designed to be within the limits required for meeting the transmission standards. If under special conditions it appears desirable to exceed these limits, this is done only with the approval of responsible engineering authorities.

To handle calls at the local switchboards there was in the Bell System in 1928 an average operating force of about 122,000 young women. In addition an average force of approximately 36,000 were employed at the toll boards of the Bell System. This made a total operating force of 158,000. In order to make up for losses and for growth, 75,000 women were employed, and to select this number approximately 300,000 applicants were interviewed.

One of the important administrative problems is the scheduling of the operating forces so that an adequate number may be available in each central office throughout every period of the day. A method has been worked out whereby all types of operating work are equated to a common unit of measurements and the number of such units that an operator should handle to give the best service most efficiently has been determined. Frequent counts are maintained of the number of calls handled throughout each hour of the day and in this way the forces are adjusted to the work to be done.

In order that the demand for telephone service may be met promptly as it develops and further that plant additions may be along sound and economic lines, calls for careful planning. To this end the fundamental plans prepared for the different exchange areas forecast the telephone development from 15 to 25 years in the future. Such fundamental plans show the proposed central office locations, the boundaries of the districts to be served by each office, and the plan of the underground conduit system. They are based on analysis of the existing market for telephone service; the forecasted market at a future date, considering both growth and distribution of population; expected changes in wage levels; estimates of the amount of service that will be sold under probable future rate conditions; and other factors.

Station Apparatus

One of the most important parts of the telephone plant is the apparatus installed on the subscribers' premises known as the station apparatus. Of this equipment the telephone transmitter and telephone receiver are fundamentally important elements and continued research work has been carried out to improve the efficiency, clarity of reproduction and reliability of these instruments. As a result of improvements in transmitters, receivers and induction coils the overall efficiency, for example, of the station apparatus has since 1912 increased by a factor of 6.5. At the present time commercial transmitters when fully energized by direct current, are capable of delivering electrical energy in the form of voice currents 200 times as great as the acoustic energy of the voice of the speaker by which the transmitter is actuated. For the most important part of the frequency range used in speech this ratio of output power to speech power is considerably greater. That is to say, the transmitter acts as a high ratio amplifier.

In the Bell System the type of station equipment most generally in use is the desk stand. As the result of extensive development work it has been possible to produce a hand set which has transmission characteristics equal to those of the desk stand equipped with the best instruments heretofore in use. The hand set development involved the solution of difficult problems, the principal of which were to prevent singing or distortion of quality on account of the rigid connection between receiver and transmitter and to make the transmitter efficient through the wide range of positions in which it is placed by the user.

The latest form of this instrument is shown in Fig. 3. In addition to the usual black finish, this telephone as well as the bell box and other station apparatus have recently been made available in five colors, statuary bronze, old brass, oxidized silver, ivory and French gray.

Practically all the service for business purposes is provided by individual lines or by private branch exchanges as discussed later.

Fig. 3—The latest form of hand set.

For residences, however, there is in the United States a large development of two-party and four-party lines. The two-party stations are provided with selective ringing so that each station is signaled only for its own telephone messages, and the four-party stations are provided in some places with selective ringing and in others with semi-selective ringing.

Party lines have furnished a satisfactory means of providing service to small users and have been an important factor in the development of new fields of service in residences.

To care for situations where something more than a single line with one or two telephones is needed, but where an inter-communicating system or private branch exchange is not justified, so-called wiring plans are used which provide various arrangements for associating the station equipment with the telephone lines. For the most part the customers' needs are satisfactorily met by one of the ten standard arrangements in general use. A specific example is that of

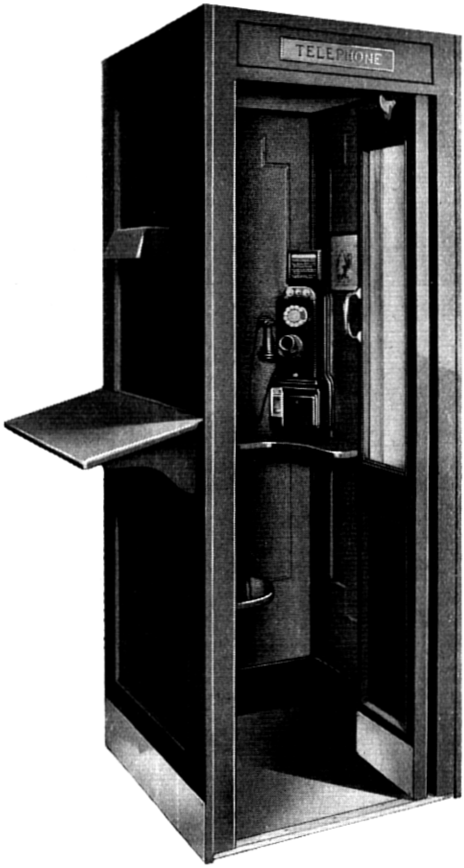

Fig. 4—Telephone booth provided for public telephone stations.

two central office lines with two main and two extension stations. Calls to or from either telephone line may be made from any one of the four telephones. Answering at a main station provides privacy by cutting off all the other telephones.

There are in the United States a considerable number of extension stations. At the present time there are in the Bell System over 1.3

million of such stations. This number is rapidly increasing particularly for residence use as people appreciate further the advantages of having telephones in a number of convenient locations. The best residences are more and more being equipped to have telephones available in all parts of the house.

In order to make telephone service possible for those people whose sense of hearing is more or less deficient, special sets are installed. By means of a vacuum tube amplifier which the user can adjust, the receiving may be amplified so as to bring the range up to the point giving best results, this point depending on the degree of impairment of his hearing.

Public telephone stations constitute an important part of telephone development in the United States, there being at present more than 275,000 of such stations in service. Whereas residence and business service is largely given by contract, the customers contracting to pay a definite amount per month or a certain amount per call, a great many of the public pay stations are supplied with coin boxes by means of which the money is collected at the time the call is made.

These installations are also for the most part in booths to insure quiet and privacy. Fig. 4 shows a form of booth furnished by the telephone companies, provided with a seat and with lighting and ventilation as well as a convenient location for the necessary telephone directories.

Private Branch Exchange

For customers who use a large amount of telephone service, one of several types of private branch exchange is provided which not only permits distribution of the incoming calls to the particular station desired but also makes it possible for one extension to call another without going through the central office. In the Bell System

Private Branch Exchange Stations	2,740,000
Per Cent of Total Bell Stations	19.0
Private Branch Exchange Boards	
Cordless	53,300
Cord	60,900
Total	114,200
Private Branch Exchange Cord Positions	
Manual	68,600
Dial	1,700
Total	70,300
Private Branch Exchange Attendants	
Cord Board Attendants	75,000
Cordless Board Attendants	53,000
Total	128,000

Fig. 5—Private Branch Exchange Statistics for the Bell System as of Feb. 1, 1929.

there are 36 million telephone connections handled each day by about 128,000 private branch attendants. About 17 per cent of all local calls originate at these boards. Equipment of both the manual and dial type is installed, the latter being particularly adapted to extension-to-extension calling. Further data regarding private branch exchanges are given in Fig. 5.

The smallest manual installation is the cordless board illustrated in Fig. 6 where connections are established by means of keys, and the capacity is limited to three trunks and seven stations. A larger type,

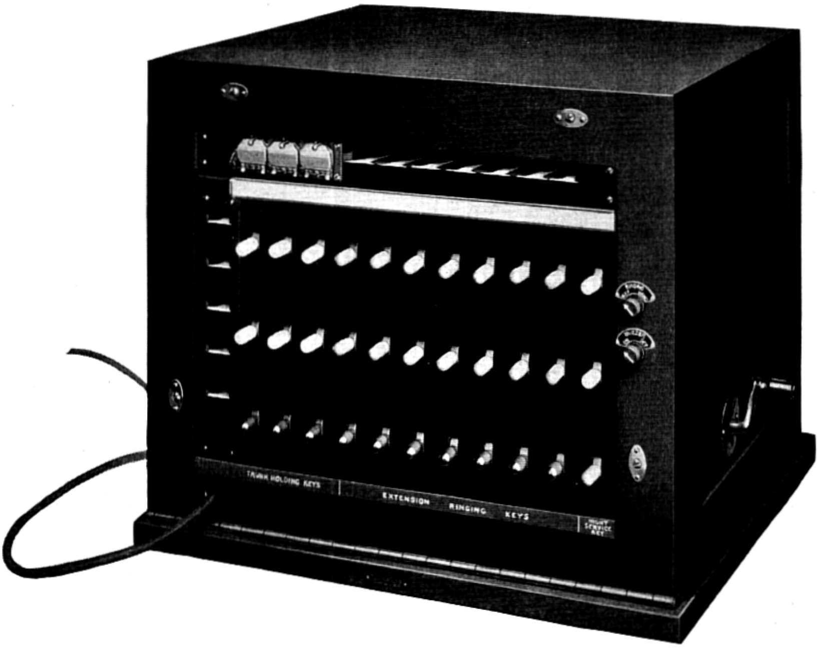

Fig. 6—Cordless private branch exchange installation for 7 stations and 3 central office trunks.

using cords for the completion of connections, is illustrated in Fig. 7 with a capacity for fifteen trunks and 200 stations.

For the largest private branch exchanges the equipment is of much the same type as that used at central offices. A large switchboard for one of the public utilities having 1,600 stations is shown in Fig. 8. Connecting this private branch exchange with the central office there are 148 lines and in addition 151 tie trunk lines extend to other private branch exchanges having a business association. There are a total of 42 switchboard positions.

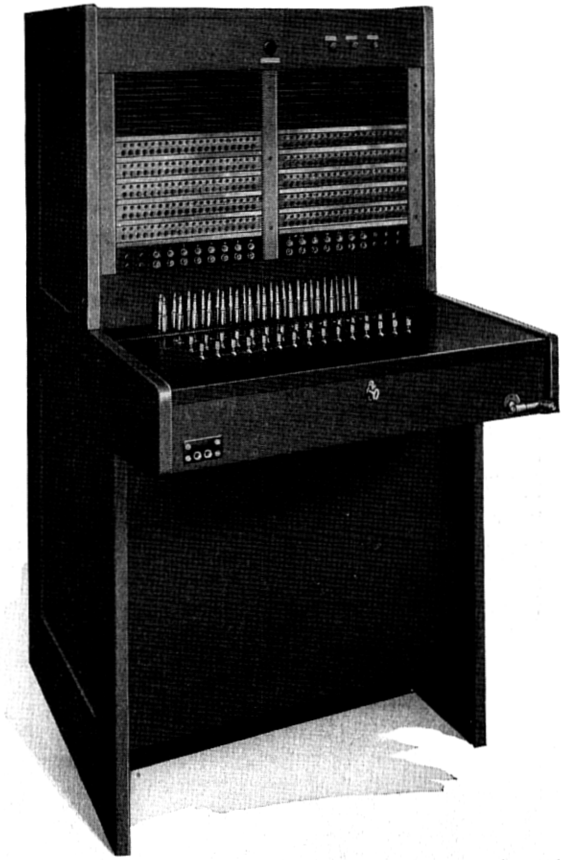

Fig. 7—Private branch exchange switchboard arranged for 15 trunks and 200 stations.

Fig. 8.—Private branch exchange—1600 stations, 148 lines to Central Office, 151 tie trunks to other private branch exchanges, 42 switchboard positions, 60 operators and 24 hour service.

At the end of 1928 in the Bell System there were about 650 dial P.B.X. installations with about 100,000 lines. The smaller sizes of this equipment are designed to meet the needs of the larger residences and the larger sizes are adequate for any business office and large industrial plant. Typical equipment arrangements are shown in Fig. 9.

In general the private branch attendants are in the employ of the subscribers having this type of equipment. It is essential that the attendants be recruited and trained with the same care as central office operators, and to this end, the telephone companies maintain employment bureaus and training courses for the benefit of private branch exchange attendants. Subscribers are encouraged to send their attendants to these training courses for retraining wherever this appears advisable.

Instructors highly trained in local and toll central office operation and in the best methods for handling private branch exchange work constantly visit private branch exchanges in order to be of assistance both to the subscribers and to the attendants in giving the best possible service.

Cable Plant

While open wires are occasionally used in limited quantity at outlying points, 96 per cent of the exchange area wire plant is in cable. Of this 74 per cent is underground.

An outstanding development is the steady increase in the number of pairs of conductors which it is possible to place in a single lead sheath of 6.7 cm. outside diameter. From the early use of 30 to 60 pair 19 gauge conductors there has been a continual increase in the number of pairs and a decrease in the size of the wires until at the present time 1,800 pairs of 26 gauge conductors are placed under a single sheath for use in the denser areas. The significance of this development is indicated in Fig. 10 which shows the year in which each important step was taken and the relative cost per pair of conductors resulting from each step in the development.

In urban development main cables, called feeder cables, usually of the maximum size, radiate from each central office through underground conduit to the various parts of the area served. These feeder cables in general are run full size for considerable distances rather than being diminished at branch cable points, and the flexibility thus obtained is found advantageous for conditions in this country. Each main feeder cable has smaller branch cables bridged to it at intervals. The main feeder cable may continue all the way through the area

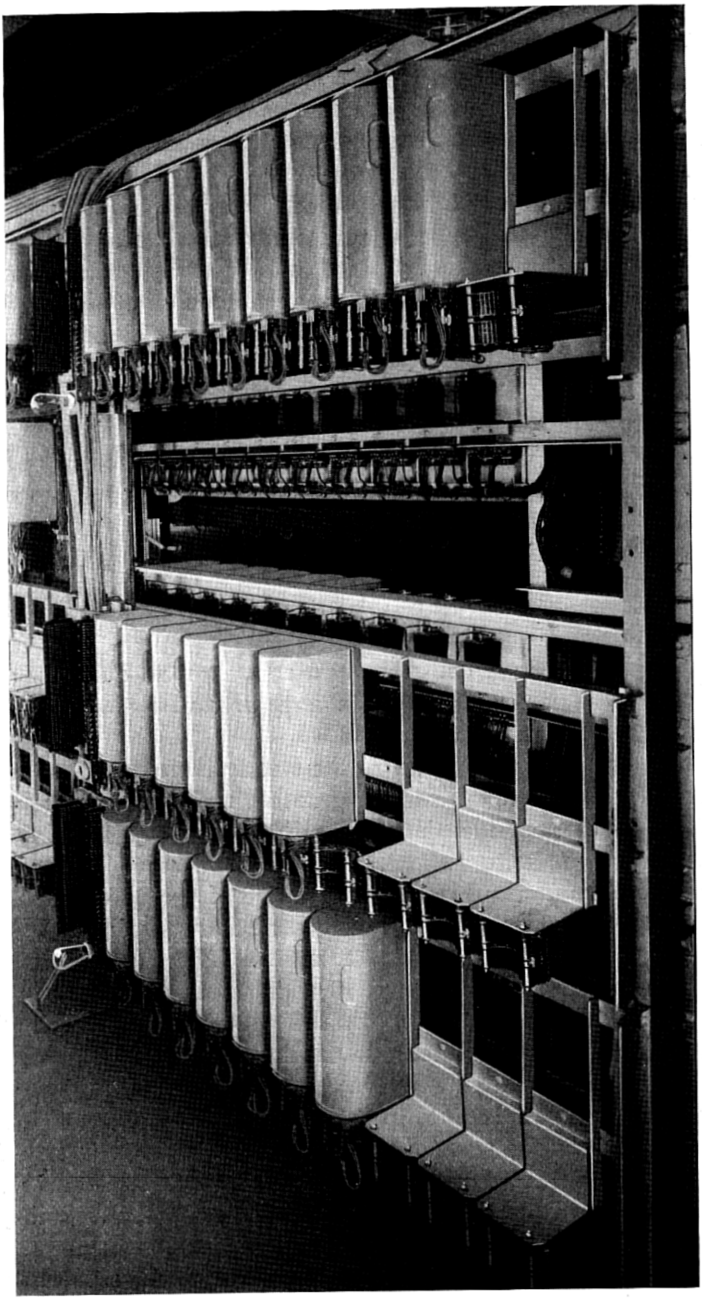

Fig. 9—Typical small dial private branch exchange installation.

or it may divide into two or more smaller cables branching out either underground or aerially in the area.

A type of distributing plant located along the rear properties of a residential block is illustrated in Fig. 11. This represents the usual

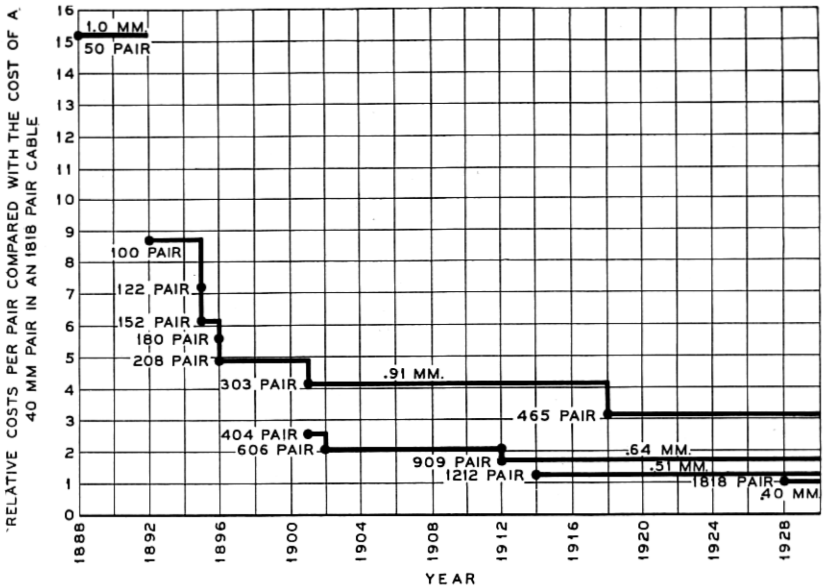

Fig. 10.

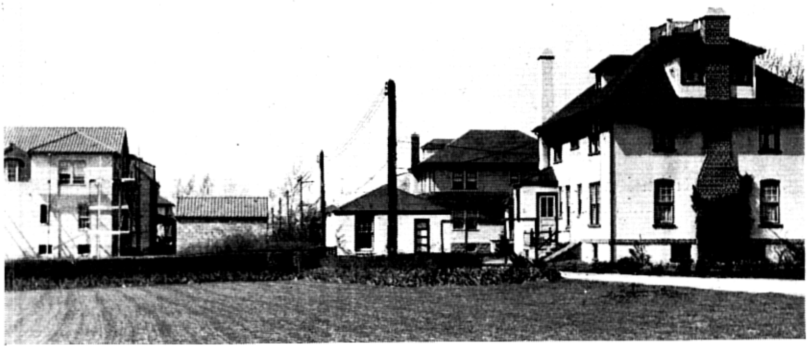

Fig. 11—Aerial cable distribution along rear property line. Poles used jointly for electric lighting power and telephone distribution.

type of construction followed in such areas. With continuous building construction the distributing cables are often attached to the rear walls as in Fig. 12 or extended through the basements of the buildings.

Underground cables are carried in conduit consisting of various combinations of multiple tile duct. A typical duct run, shown in

Fig. 12—Distribution telephone cable attached to rear wall of building showing terminal boxes and entrance by twisted pair into cellar.

Fig. 13, illustrates the materials and methods of construction generally employed.

At the central office the conduit system is designed to meet the ultimate requirements of the building and terminates in a cable vault as shown in Fig. 14. With this entrance arrangement the main cables are spliced in the cable vault to smaller units of silk and cotton insulated conductors which extend up through the building in slots or ducts to the main distributing frame.

Switching Systems

The outstanding development in switching systems for a telephone communication has, of course, been the rapid trend toward an increase

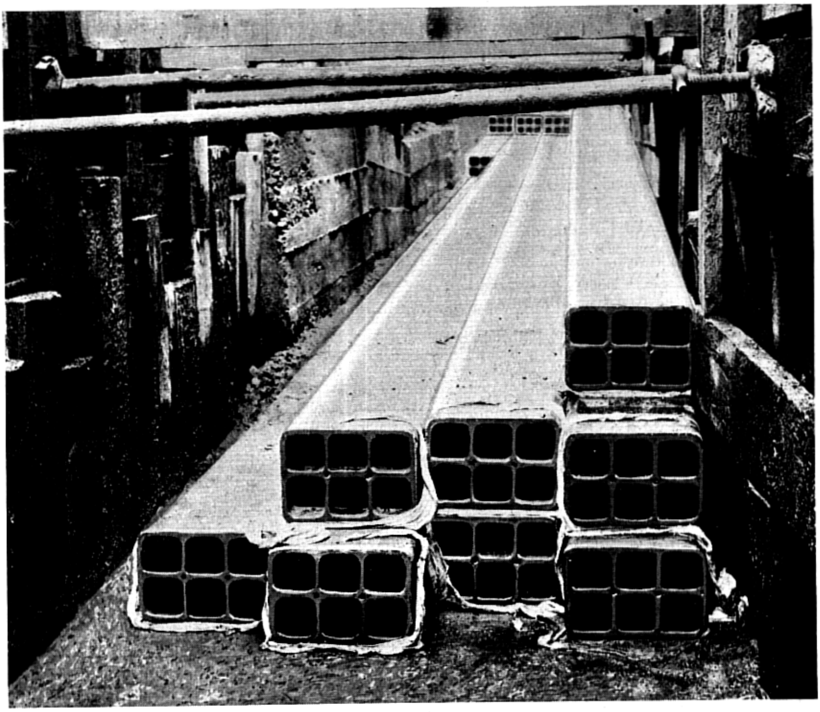

Fig. 13—72 duct underground cable run under construction.

in the extent to which the operations are performed by automatic machinery. The general characteristics of the different types of switching systems in use in the United States and their extent of use are briefly discussed below.

Magneto

Magneto switching arrangements are used in small places and scattered rural areas. They vary in size from an arrangement to interconnect two or three lines up to a switchboard handling 300 to 400 lines. The average size of the magneto switchboards in the Bell

System is 170 lines. At the end of 1928 there were about 3,500 magneto offices with approximately 5,500 operators' positions, serving 1.1 million telephones.

Common Battery

At the end of 1928 there were 2,036 common battery offices, the maximum size office serving 10,500 lines and the average being 3,700

Fig. 14—Cable vault in Central Office, St. Louis, Missouri, showing entrance of cables through ducts and connecting to silk and cotton insulated cables extending up through the building.

lines. There was a total of 46,000 switchboard positions where the subscribers' lines are answered. In addition, there were 13,000 so-called trunk positions which are required where it is necessary to trunk calls from one office to another in areas having more than one central office.

The trend in development in manual switchboard has been toward performing more of the necessary switching and signaling operations automatically by means of somewhat more complicated circuit and equipment arrangements and less and less by the operator. These changes have resulted in less manual operating labor and in an improvement in the service. Some of the more important of these changes are as follows:

1. Automatic ringing which continues automatically at regular intervals until the subscriber answers.
2. Ringing tone, very much reduced in volume, to the calling subscriber automatically advising him when ringing is in progress.
3. The audible busy signal, a tone placed on the calling line when the called line is busy.

An important recent change in manual central office equipment relates to the trunking methods employed in completing a connection from one central office to another. In most of the larger cities the so-called "straightforward" method is used. With this operating plan the number that is desired in the distant office is passed by the originating or "A" operator to the completing or "B" operator over the trunk that is used for completing the trunk connection. This is in contrast to the "call circuit method" where all orders between operators are passed over a separate wire known as a call circuit. The principal equipment changes at the "B" positions have to do with the different circuit plans for connecting the trunk operator's telephone set to the trunk. This is done either by means of a key, by means of plugging the trunk into a listening jack or automatically by means of suitable relays. At the "A" end the principal change is the arrangement for testing whether or not an outgoing trunk is busy. This is done either by means of a lamp indicating a free trunk or by a lamp or tone indicating that a part of a trunk group is free.

Dial Equipment

Dial equipment of two types known as the step-by-step system and the panel system respectively are used in about equal amounts in the Bell System. The change from manual to dial operation presented a very large problem from an engineering, a manufacturing, an installing and an economic standpoint. At first the dial installations were to care largely for growth but they have been followed by installations for the replacement of existing manual equipment where, all factors considered, this was clearly justified. In this way an orderly program has been developed. Figure 15 indicates the total number of stations on a dial and on a manual basis for each year since 1921 and the expected program up to 1933. Under the present contemplated dial program it is estimated that the areas employing step-by-step equipment will be on a complete dial basis by 1937 and that all areas employing panel equipment will be substantially completed by 1942.

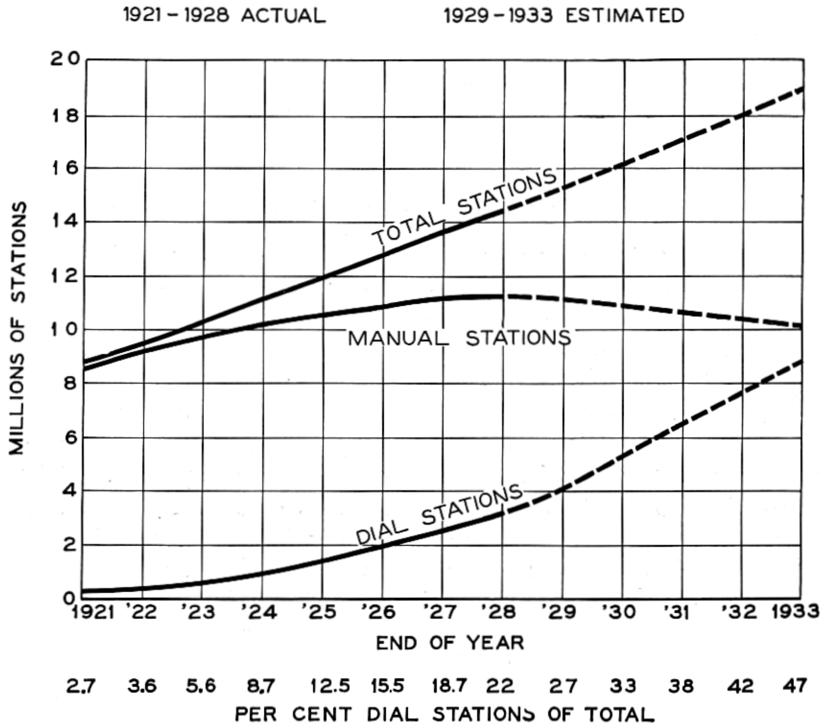

Fig. 15.

Fig. 15—Relation between manual, dial and total stations—Bell owned stations.

Step-by-Step Dial System

The step-by-step system is used in the Bell System in single office areas and in the smaller and medium sized multi-office areas where the number of central offices is limited and consequently the trunking problems are not complicated. Step-by-step equipment is in service in 194 offices to which are connected 1.6 million stations.

The fundamental unit of the step-by-step dial system is the selector illustrated in Fig. 16. This switch has a capacity for 100 terminals placed ten on a level and ten levels high, thus making possible the selection of any one of a hundred lines. By placing several selectors in series a network of central offices may be built up, each office serving 10,000 telephones.

The selectors are mounted on iron frameworks and the terminals are cabled to cross-connecting frames so that any grouping can be made as may be demanded by the number of calls which the particular selector handles. A typical arrangement of selectors is shown in Fig. 17.

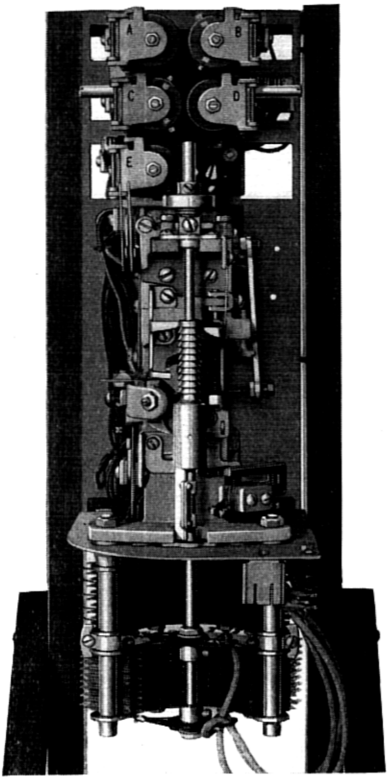

Fig. 16—Typical step-by-step selector showing relays which control the circuit operation mounted at the top, and the selector banks of 100 terminals at the bottom.

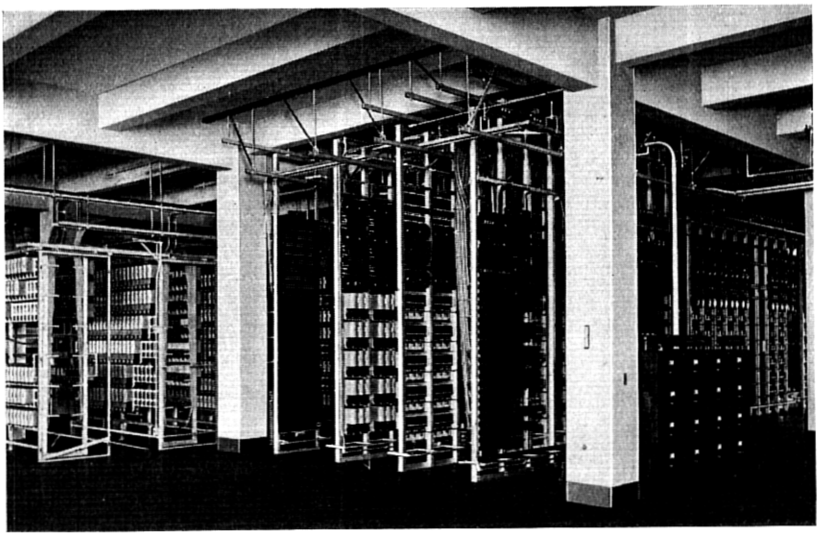

Fig. 17—Installation of step-by-step dial equipment showing selectors mounted on iron framework.

Panel Dial System

In the largest cities and the smaller municipalities around them making up the large metropolitan centers, a much greater degree of complexity is encountered in switching the calls due to the large number of offices of varying types to which calls are destined and due

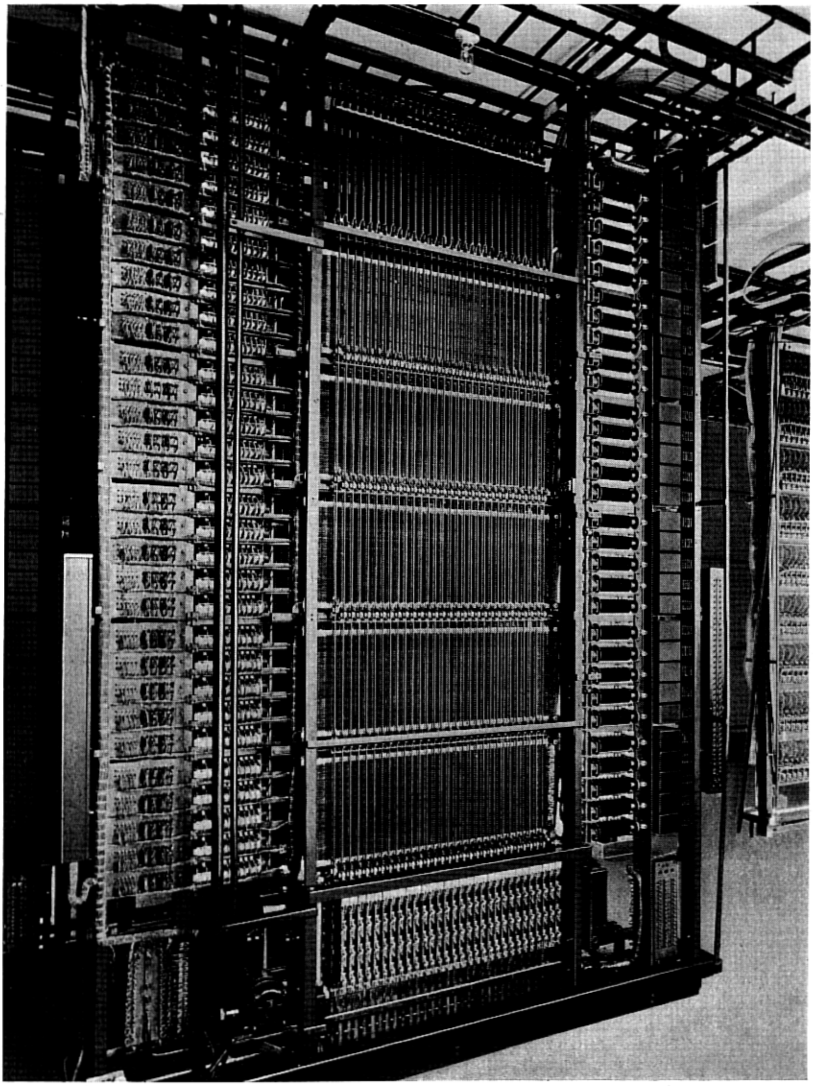

Fig. 18—Typical panel selector frame. Capacity 30 selectors in front and 30 selectors in rear. Motor driving mechanism is at the bottom of frame and controlling apparatus at either side.

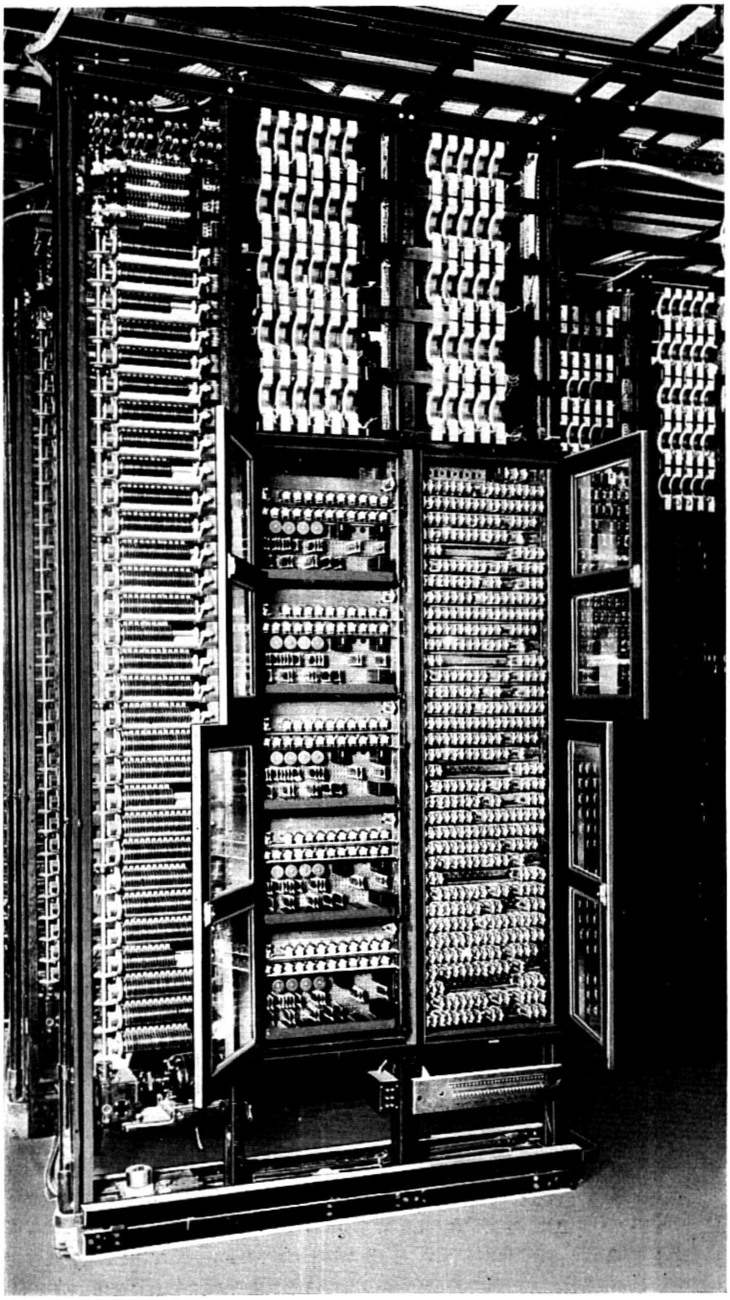

Fig. 19—Panel dial office sender frame showing the apparatus for five senders.

to the routings involved in order to trunk economically either large or small volumes of traffic. The panel system was developed to meet these requirements and is now installed in a number of such metropolitan centers, notably, New York, Chicago, Philadelphia, Boston, Detroit, Cleveland, St. Louis, Pittsburgh, Baltimore, San Francisco, Buffalo, Kansas City, Seattle, Providence and Omaha. Panel equipment is in service in 128 offices to which are connected 1.6 million stations.

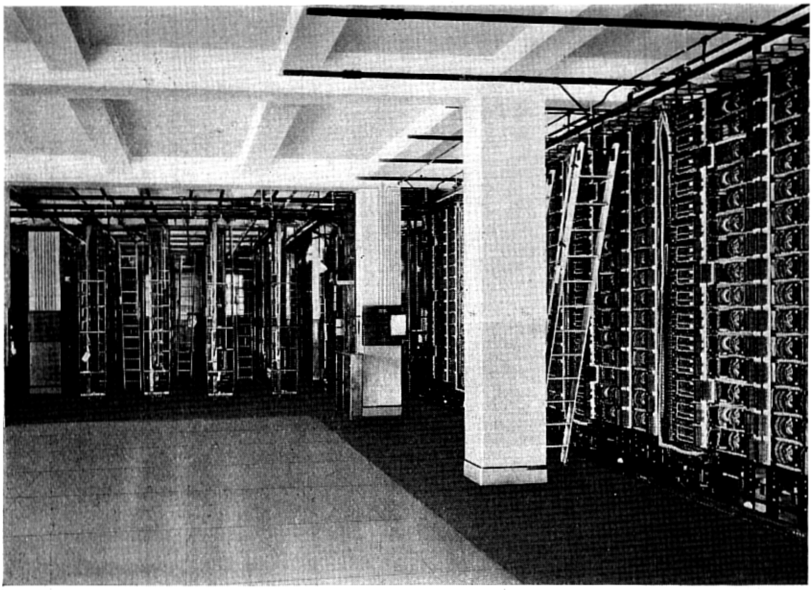

Fig. 20—Installation of panel dial equipment. The unused floor space is provided for future growth.

In the panel system the fundamental switching unit is a large switch consisting of five banks of 100 terminals each. The selectors, by which contact is made with any one of the 500 terminals, move vertically on both sides of the terminal banks. A typical panel frame having capacity for 60 selectors is illustrated in Fig. 18.

In the panel system the selectors do not follow in synchronism with the impulses of the dial as in the step-by-step system. Rather, a group of apparatus known as the "sender" records the impulses and in turn directs the operation of the several selectors in the train until the called terminal is reached. By this means the trunking arrangements and the numbering scheme can be designed independently of each other. This, combined with the large capacity of the panel selectors, makes possible economies in interoffice trunks and a reduction in the number of selectors involved in completing a connection in a large exchange. The selection may be either to a dial office or to a manual office reached direct or through a tandem switchboard. Figure 19 illustrates the apparatus for five senders. A switchroom in a typical panel office is shown in Fig. 20.

Buildings

The buildings in the Bell System at present number about 6,000, excluding those occupied by the Western Electric Company. All of

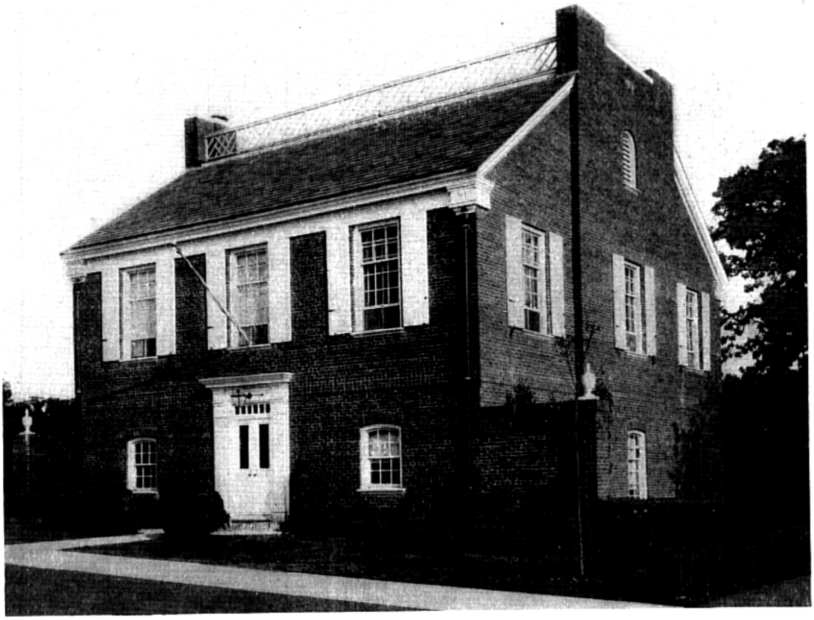

Fig. 21—Telephone office in the residential district of Silver Spring, Maryland. Designed for small manual switchboard with a present capacity of 2,200 lines.

the larger and many of the smaller are owned by the telephone companies. The range in size of the buildings is illustrated by Fig. 21 showing a small building for a single manual switchboard with a present capacity of 2,200 lines, and Fig. 22 showing a headquarters office and equipment building in a large city. This building has 66,000 square meters of floor space, in the lower 9 floors has space for dial equipment to serve 100,000 telephones, and in the upper floors includes offices for 5,000 people. Figures 23 and 24 further illustrate

Fig. 22—Combined equipment and office building, New York City, containing headquarters of the New York Telephone Company, 31 stories, 66,000 square meters of floor space. Lower 9 floors arranged for toll tandem equipment and for dial equipment with an ultimate capacity of 100,000 telephones. Upper 22 floors arranged for offices with a capacity of about 5,000 people.

some of the recent combined equipment and office buildings for large cities.

The objective in connection with buildings of all types, including equipment and office buildings, garages and warehouses, is to provide

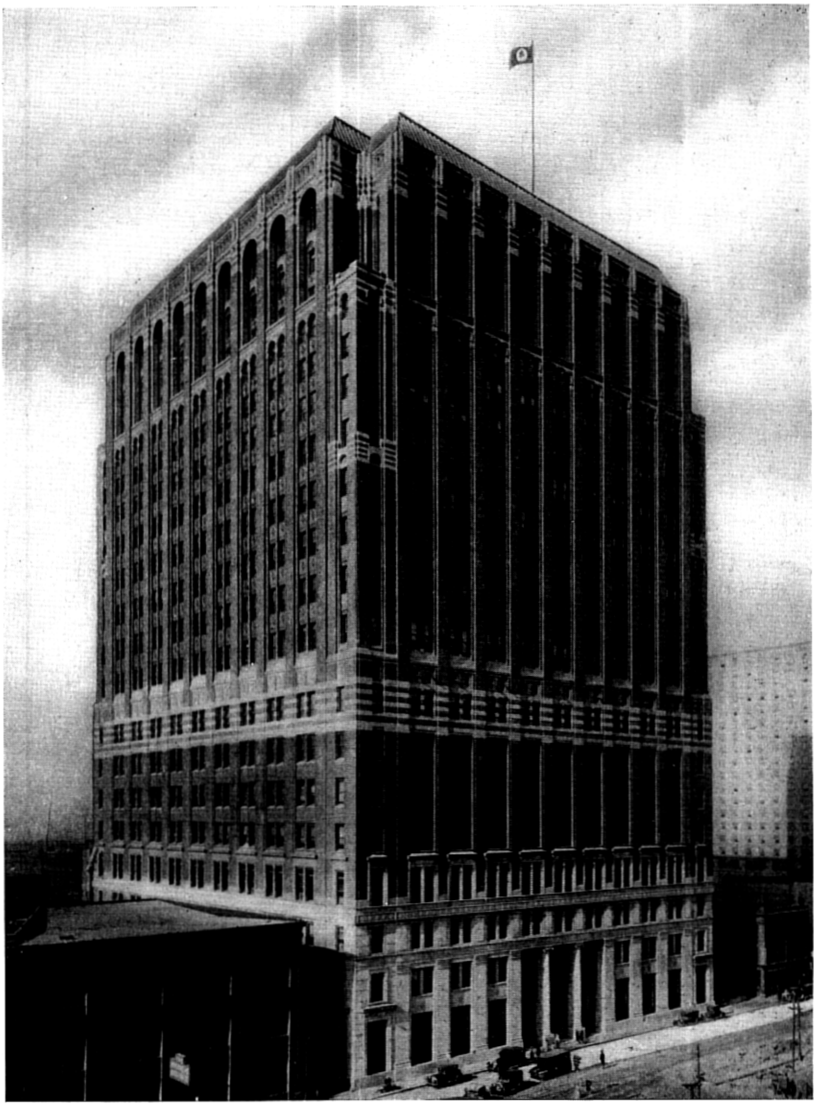

Fig. 23—Combined equipment and office building at Detroit, Michigan containing headquarters of the Michigan Bell Telephone Company. 19 stories, 28,000 square meters of floor space. 13 floors arranged for equipment including toll board and dial equipment to serve 60,000 telephones. 6 floors are arranged for offices.

Fig. 24—Combined equipment and office building at Cleveland, Ohio containing headquarters of the Ohio Bell Telephone Company. 22 stories, 25,000 square meters of floor space. 13 floors designed for equipment including the toll board and ultimate dial equipment for 100,000 telephones. 9 floors arranged for office space.

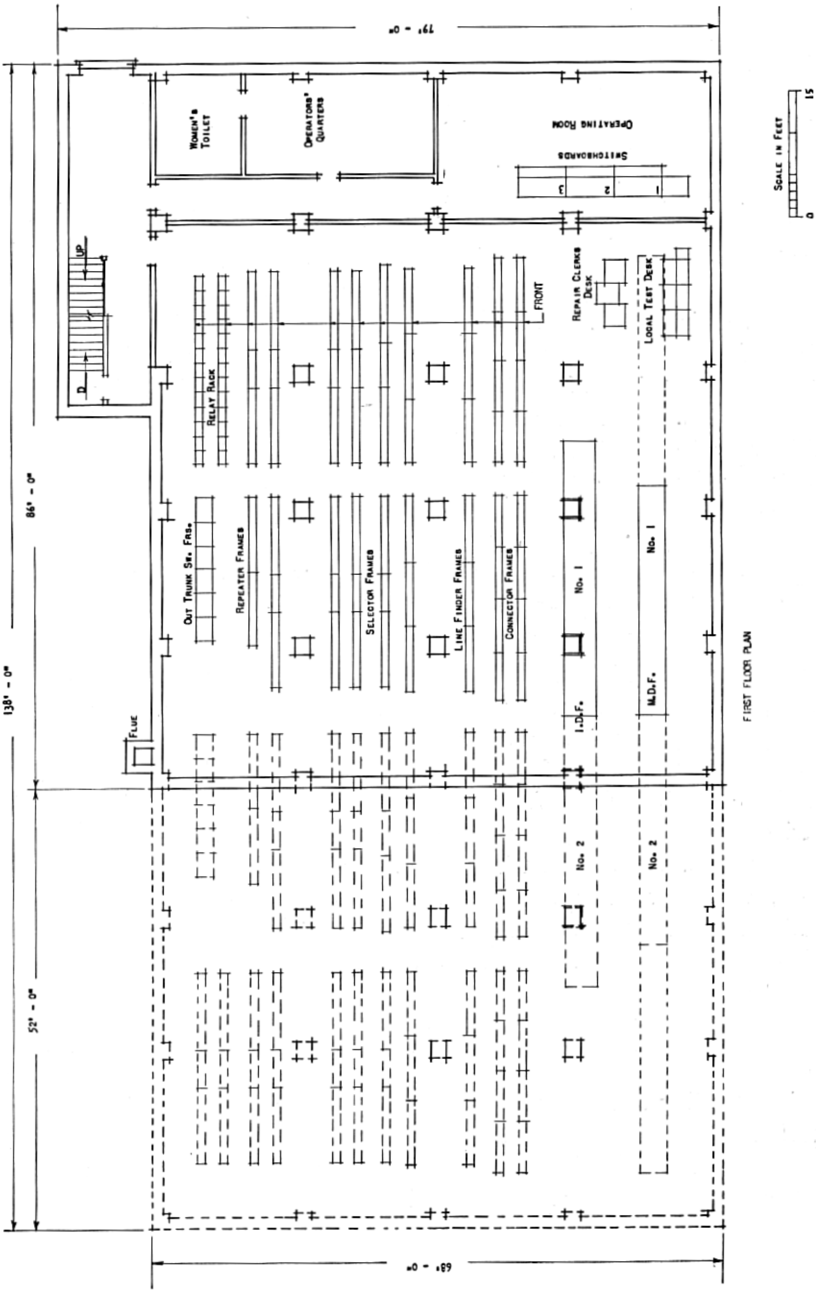

Fig. 25—Standard floor plan for step-by-step dial office designed for best arrangement including flexibility for future growth.

buildings which adequately, economically and comfortably house the equipment and personnel—both initially and throughout the useful life of the building—and which at the same time are outstanding and attractive, appropriate to their surroundings and a continuing source of satisfaction to the communities in which they are erected.

The initial size of a building is determined by the costs and rate of increase in space requirements, with due regard to the service reactions caused by extensions of the building which is being used for operating purposes. As a result of these considerations central office buildings are usually designed with a capacity of about twice the initial requirements. In many cases space provided for later extensions of equipment is used temporarily for office space. Possibilities of future extensions of the buildings are provided for either by buying more land than is required for the initial building, thus making possible lateral extensions, or by providing strength in the steel framework for future vertical extensions. The possibility and type of future extensions must, of course, also be taken account of in the architectural design.

Floor plans have been developed representing for typical conditions the best arrangements of the various types of central office equipment both manual and dial. The use of these uniform floor plans greatly facilitates the engineering, manufacture and installation of the equipment, and results in savings of both time and money. A uniform floor plan applying to a step-by-step dial office is illustrated in Fig. 25. The relative location of the different frames and aisle space as well as the unit size of the frames is fixed but the number of frames is varied to meet the requirements of individual cases.

Except for the smallest buildings, non-combustible construction is used, a steel or reinforced concrete frame and brick or stone curtain walls being employed. The very small buildings, except where severe fire exposures are encountered, are of frame or brick and joist construction.

Rural Service

Surrounding the larger cities and towns there is in general a sparsely settled district developed on a multi-party basis. Service is given on common battery lines where the distances are not too great and either semi-selective or code ringing is used. These lines usually serve not more than six or occasionally eight parties and the common battery signaling requirements limit the range to about seven or eight kilometers.

One of the most difficult service problems of the Bell System is that of providing service to farming districts where the distances between successive farms as developed in the United States is often great. At the present time service in such farming areas is usually provided by multi-party lines with magneto signaling. These rural lines carry from six to as many as fifteen parties and may be as much as sixty-five kilometers in length.

In the past the demand for service from rural districts of this nature has generally been limited almost wholly to local service between the rural customers and shorter haul toll service, and the present development is a response to that point of view.

The extent of development of rural service is illustrated by a census made in the State of Iowa in 1920, showing that of 213,000 farmers 86 per cent have telephone service. This percentage is doubtless materially higher at the present time. There were in 1928, in the Bell System, 6,000 offices which served lines that might be classified as rural. Of these rural lines about 12,000 were on a common battery basis and about 43,000 on a magneto basis. These figures do not include the rural lines which were served by connecting companies, the addition of which would increase the above figures many times. The development of this type of service has to a very considerable extent been in the hands of local groups of small local companies because of the nature of the service.

With the present rapid development in the use of a nation-wide toll service, there are a rapidly increasing number of stations where rural customers will accept a higher grade of service designed for general connection to telephones throughout the Bell System. The development of improved rural service of this type is an important feature of the present telephone program in the United States.

Toll Service

Service between telephones which are not in the same local exchange area is called "Toll Service." With the exception of less than one per cent of the telephones which are not connected to the Bell System, toll service is offered in the United States between any two telephones in the country and to a very large extent the toll plant is adequate to provide good service between any two of these telephones.

An outstanding feature of the last few years has been the rapid growth of the toll service. This is indicated in the appended statistical summary which shows that during the last five years the completed toll messages have increased by 67 per cent. During this same period the number of telephones in service have increased by about 28 per cent. These figures show that in spite of the continued increase in the number of telephones in service, the number of toll messages per telephone have increased by about 30 per cent for this period.

One important cause of the rapid increase in toll usage has been the material improvements in toll service.

Figure 26 shows the increase in the speed of toll service since 1920 expressed in terms of the average time required from the placing of a call to the response of the called party, or until the operator gives

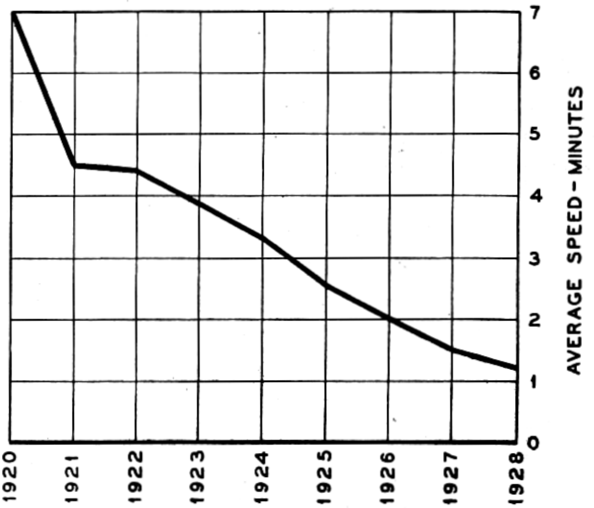

Fig. 26—The average time required from the placing of a toll call to the response of the called party, or until a definite report is made by the operator.

a definite report regarding the call. The service is sufficiently fast so that on 95 per cent of the calls, the subscriber stays at the telephone. This makes possible still more rapid service and simplified operation.

There have also been very great improvements during this period in the clearness of speech transmission. The maximum permissible transmission loss between two subscribers on a toll connection has been materially reduced. The toll plant and subscriber plant are now so designed that most of the messages are handled with a maximum transmission equivalent for the longest subscriber lines of 20 to 25 decibels overall referred to the standard transmission reference system.

Short Distance Toll Service

General

To a large and increasing extent the toll messages are completed and supervised by the local exchange operators who first answer the subscriber's call, providing in this way toll service with the same methods which are applied to local service and with comparable

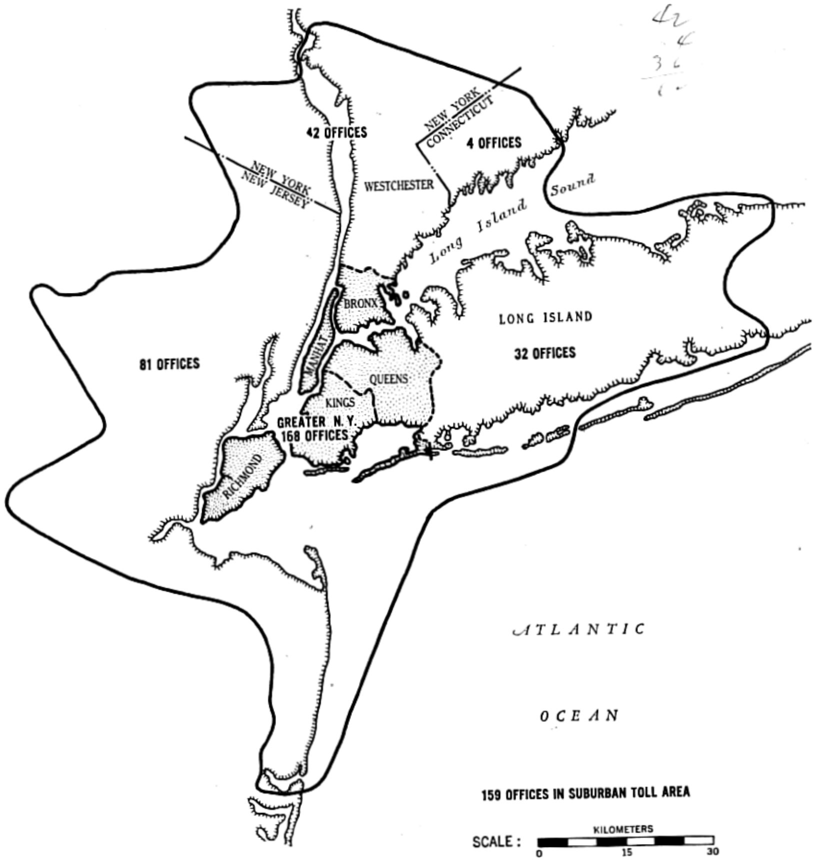

Fig. 27—New York suburban toll area indicating the number of offices in Metropolitan and suburban districts. Population in the area 10.5 millions. Telephones in the area 2.5 millions.

speed. This method of operation is used for most of the toll business up to a distance of 50 kilometers and to a considerable extent up to 100 kilometers. The use of this method includes the extensive suburban areas around the large cities. Calls handled by this method now amount to 650 million messages a year and its increasing use has been one of the important ways in which increased speed of service has been brought about.

The handling of this suburban telephone traffic adds greatly to the complexity of the transmission, trunking and operating problem of the larger cities. This is illustrated by Fig. 27 showing the suburban toll area surrounding New York City. It will be noted that the city itself includes 168 central offices and in the suburban areas in the metropolitan district there are in addition 159 central offices.

In many cases of the shorter haul toll service, the volume of traffic between two offices is sufficient to warrant direct trunks and the calls are completed over these direct trunks by the usual local traffic methods. In order to provide an efficient trunking arrangement for the smaller volume of traffic between widely separated offices, however, tandem trunking arrangements are provided, by which the calls are routed through a central switching point and from that point distributed to the terminating offices. Either manual or dial central office equipment is used as outlined below, each type having its field of application depending upon the amount of traffic and the portion of traffic to and from manual and dial central offices. The trunks to the central switching point, or tandem office, are in general of somewhat larger gauge than interoffice trunks because of the greater distances involved and the correspondingly more severe transmission requirements. In some of the longer trunks telephone repeaters are used. It has not been found generally economical to use repeaters at the tandem switching point although this is done in certain instances and it is possible that in the near future the more general use of repeaters in this way may become an economical means of meeting the transmission requirements.

Manual Straightforward Tandem

The manual straightforward tandem is used in those medium sized areas in which most of the suburban calls are between manual switchboards. The arrangement of the equipment is shown in Fig. 28. The tandem trunks from the originating office terminate on the plugs located at the rear of the keyboard and the tandem completing trunks to the various terminating offices appear in jacks in the face of the switchboard. The completing trunks are provided with lamp signals indicating idle trunks. When a call comes in on a tandem trunk the operator is advised by a flashing lamp signal on that trunk and her telephone set is automatically connected to it. The work of the tandem operator is limited to making the connection at the tandem board and making the disconnection when advised by lamp signal that the conversation is over. Her work is thus greatly simplified and the operation of the board is extremely rapid.

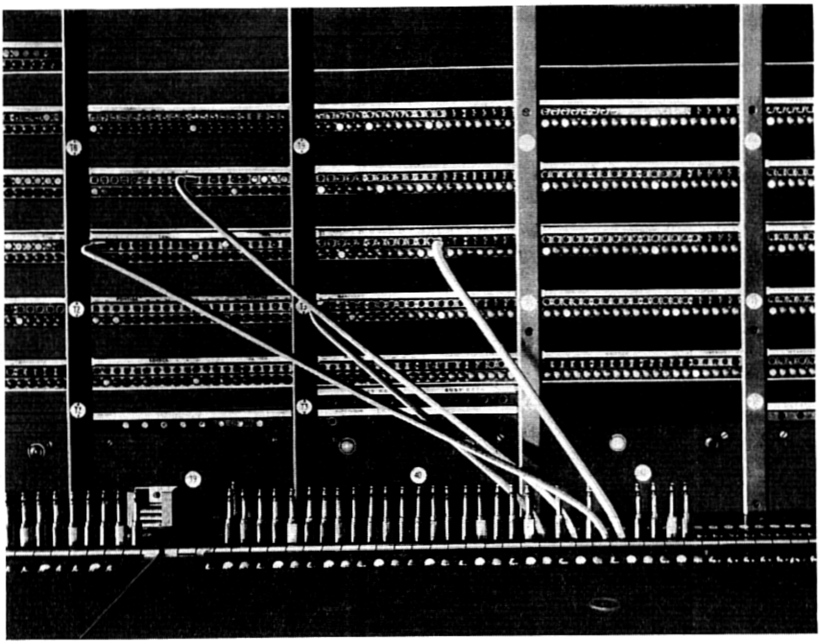

Fig. 28—Manual straightforward tandem board for handling suburban toll calls. Trunks from originating offices terminate on plugs at the rear of the keyboard. Tandem completing trunks appear in jacks in the face of the switchboard. Incoming calls indicated by flashing of lamp associated with trunk cord.

Dial Tandem

Dial tandem systems have been designed for handling suburban toll traffic in areas where a large proportion of the central offices are of the dial system and also to facilitate handling the complex suburban traffic around the large metropolitan areas, such as New York, Boston, Chicago and Philadelphia. The type of dial equipment, in general, corresponds with the type used for the local traffic in the same area.

For use in connection with calls from dial offices, the dial tandem usually requires no operators at the tandem office. The originating operator in the dial office who handles the short haul traffic controls the selection of the trunk to the terminating office.

In some of the large metropolitan centers, dial tandem apparatus of the panel type is employed also for handling calls from manual

Fig. 29—Panel type dial tandem office in New York City.

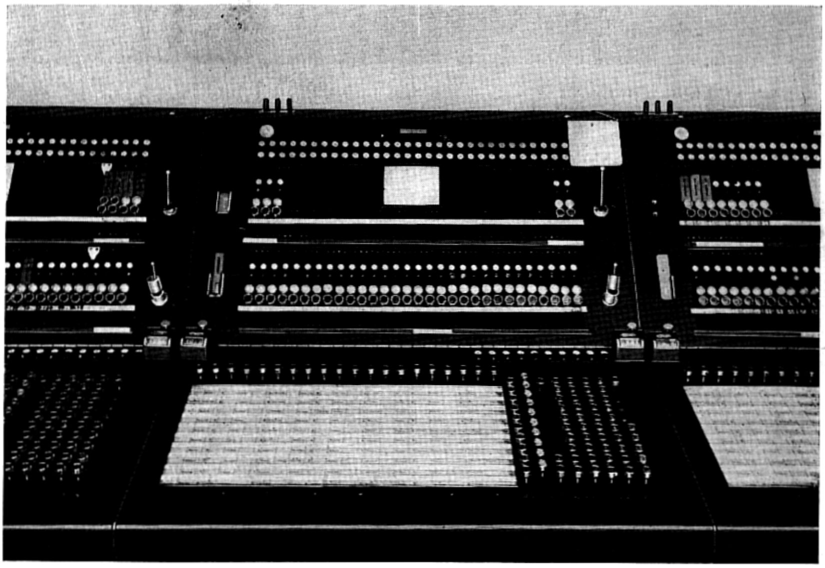

Fig. 30—Panel type dial tandem office. Arrangement of keyboard at tandem positions. Incoming trunks appear as lamps and associated keys on upper sloping part of keyshelf. Calls are completed by setting up the called office and called number on keys on lower part of keyshelf.

offices. With this arrangement operators are, of course, required at the tandem board. The tandem operator receives a request from the originating operator for the office and number called and by means of keys establishes the connection by dial switching apparatus to the called subscriber in case he is in a dial office or transmits the required information to the terminating office operator in the case of a manual office. Figure 29 shows an installation of panel tandem operators' equipment and Fig. 30 shows one section of this equipment in greater detail.

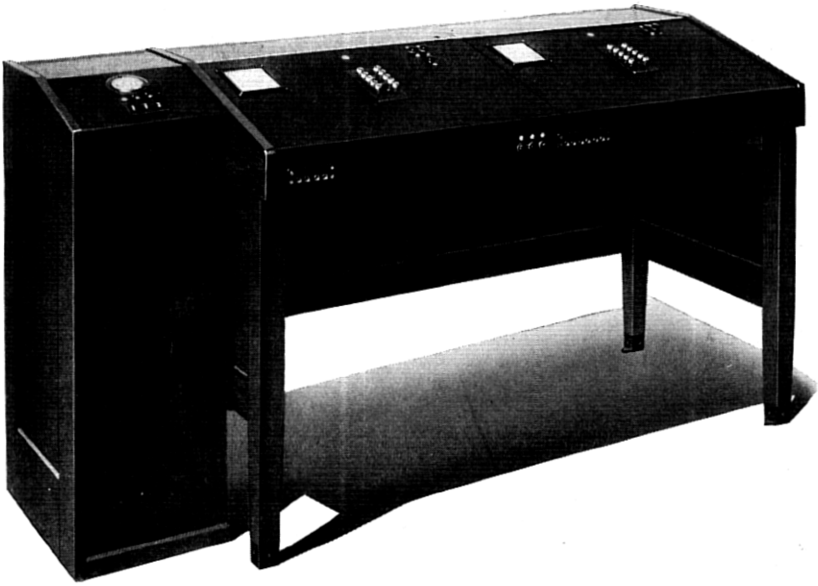

Fig. 31—Step-by-step dial tandem board. Calls completed to the terminating dial subscriber station by means of the 10 button key set shown on the keyboard. Incoming calls automatically distributed to an idle operator.

A modified form of step-by-step tandem equipment using operators has been installed in step-by-step areas for handling calls from manual offices to dial offices in cases in which it was not advisable to equip all the subscriber operators' positions with dials. This equipment includes, in addition to the selectors, a simplified type of switchboard as shown in Fig. 31.

Long Distance Service

General

For the longer hauls the subscriber is connected to a toll board operator who completes and supervises the toll message. This method is called the toll board method of operation, and is used for most all the messages over about 100 kilometers. For the purpose of this paper this service will be referred to as long distance service. The messages handled by this method total about 300 million messages a year. The amount of long distance business at New York City, for example, requires the use of 1,275 operators' switchboard positions.

During the past three years an important change has been generally applied in the methods of handling long distance service. Formerly the toll operator first receiving the call recorded the necessary information on a ticket and forwarded this ticket to another operator provided with facilities for completing calls to the particular part of the country involved in each case. An increase in speed has been brought about by providing the operators with arrangements both for recording calls and for completing calls to all points so as to avoid, in a large proportion of the cases, the necessity for transmitting the information to a second operator.

By means of this change in method and other improvements, the average speed of service for all long distance messages has been decreased from 6.9 minutes in 1925 to 2.6 minutes in 1928. Also in 1928, 90.7 per cent of the calls made by the customers resulted in completed messages.

In placing a long distance call, the telephone subscriber in the United States may give simply the telephone number and city desired. This has some advantages in speed of service. At present, 50 per cent of the long distance messages are handled in this way and this per cent is increasing. About 15 per cent of the messages are handled in this same way, the called telephone number, however, being supplied by the operator. In addition, the telephone system offers, for a somewhat greater charge, what is called a "particular person" service. This means that the subscriber may, if he wishes, ask to talk with a specified person at a distant point, giving such information as he can regarding how that person may be located. The telephone operator then undertakes to complete this message by locating the desired party, following him up to points other than that designated, if necessary, and if the calling subscriber wishes. The percentage of messages handled on this basis increases with the length of haul.

When a subscriber wishes he may transmit to the telephone company in advance information regarding a number of calls which he wishes to have completed in sequence, beginning immediately or at a specified time. These sequence calls, as they are termed, are used particularly in connection with selling by long distance telephone. At the present time at the New York long distance office, for example, about five per cent of the business is in the form of sequence calls, some of the sequence lists including as many as 1,000 calls.

Except during times of emergency conditions, it is not the practice

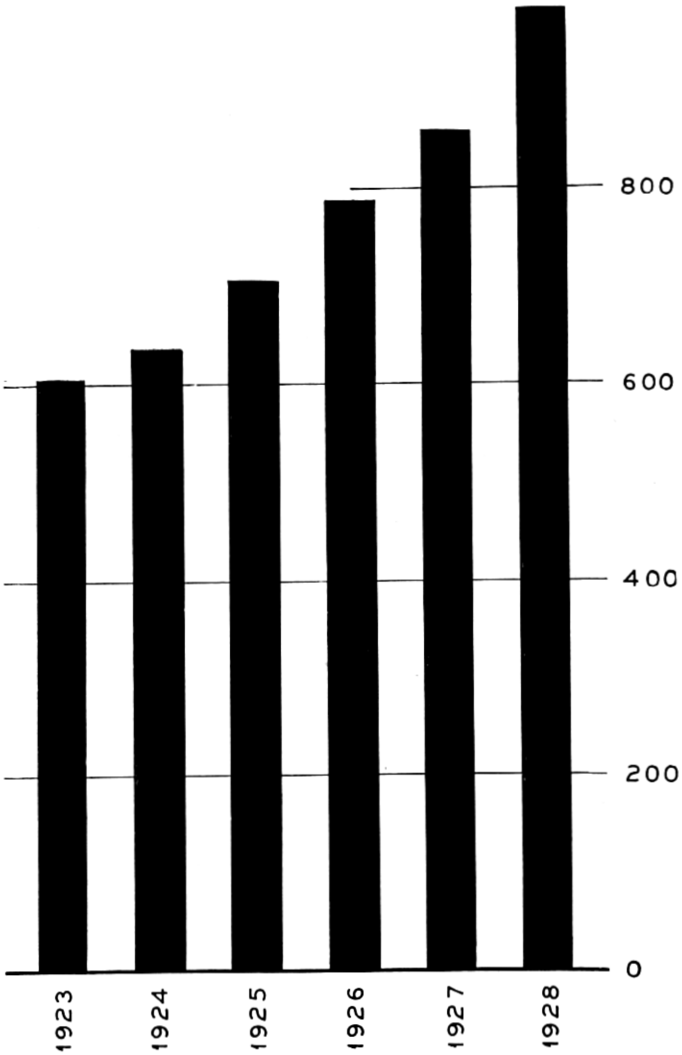

Fig. 32—Toll board messages per year in thousands, New York–Boston.

in the United States to limit the length of conversations on toll connections. As a result it is very general for conversations, particularly on longer hauls, to exceed the initial three-minute period, the average length for transcontinental conversations being, for example, six minutes. Conversations which run one half hour or an hour are not unusual, and in one case a transcontinental telephone conversation was eight hours in all.

A striking feature of the long distance service is the more rapid

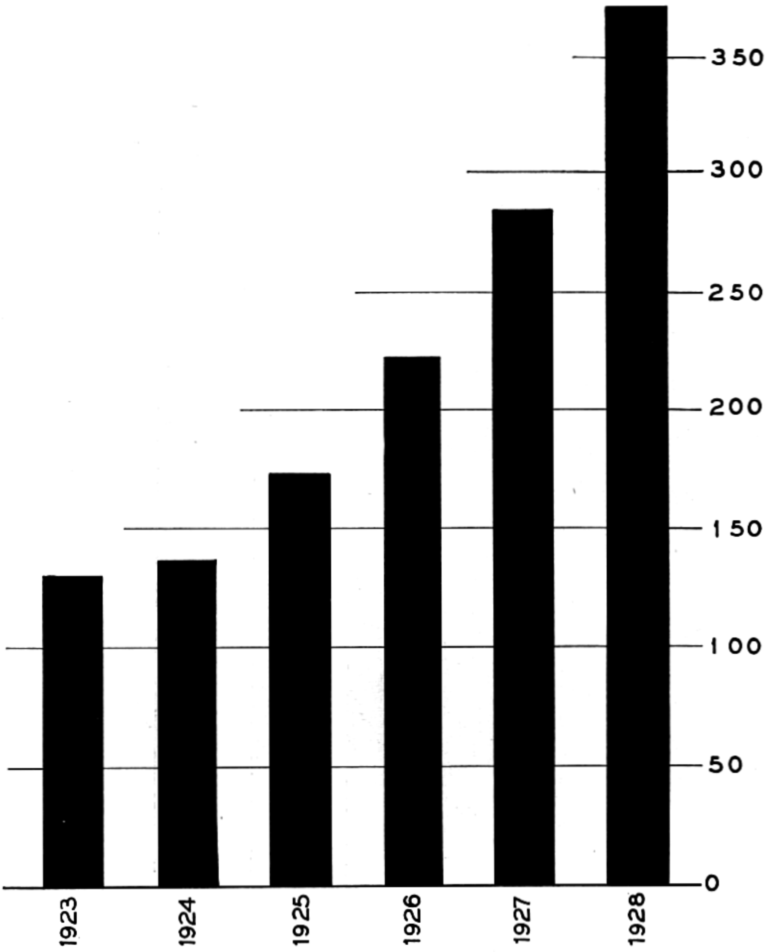

Fig. 33—Toll board messages per year in thousands, New York–Chicago.

growth of very long haul business than business of moderate length. Figures 32, 33 and 34, for example, show respectively the growth in messages for the last five years between New York and Boston, 370 kilometers, New York and Chicago, 1,380 kilometers, and the transcontinental business between New York and Chicago at one end and

Los Angeles and San Francisco at the other end, an average of 4,700 kilometers. It will be noted that while the toll business as a whole has increased as noted above, 67 per cent in this period, the New York-Boston business has increased 62 per cent, the New York-

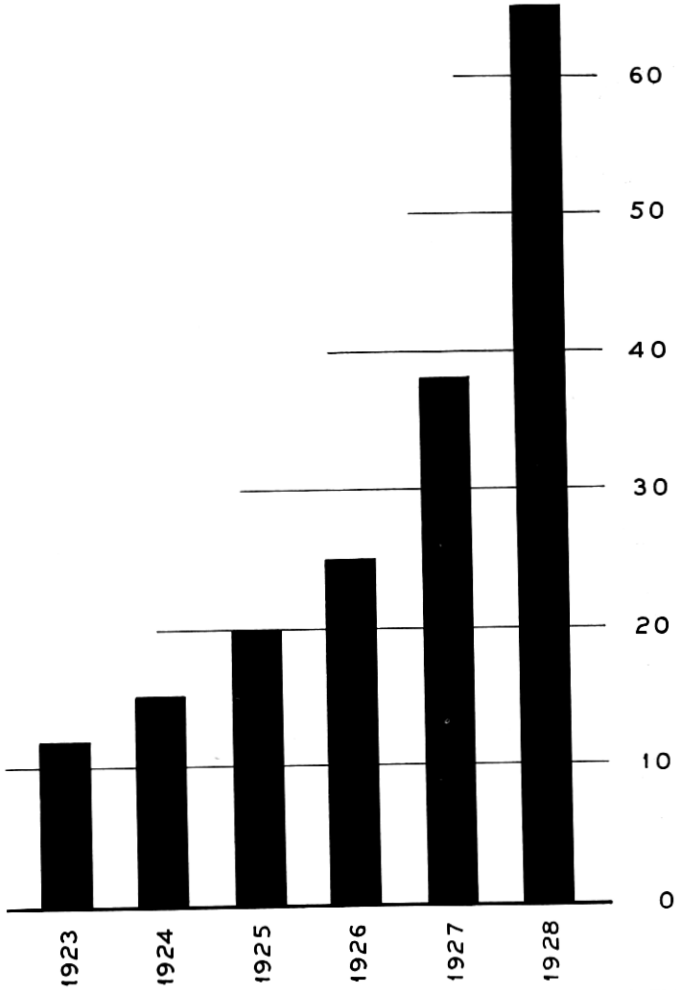

Fig. 34—Toll board messages per year in thousands, New York and Chicago to Los Angeles and San Francisco.

Chicago business 194 per cent and the transcontinental business 430 per cent.

In the attached statistical summary is given the basis used for determining long distance toll rates, including the practices in the

United States in the offering of reduced rates in evening and night hours. The effect of these reduced rates is in some cases temporarily to slow down service at the hours when the reduced rates first go into effect, because of the large demand for long distant business at those hours.

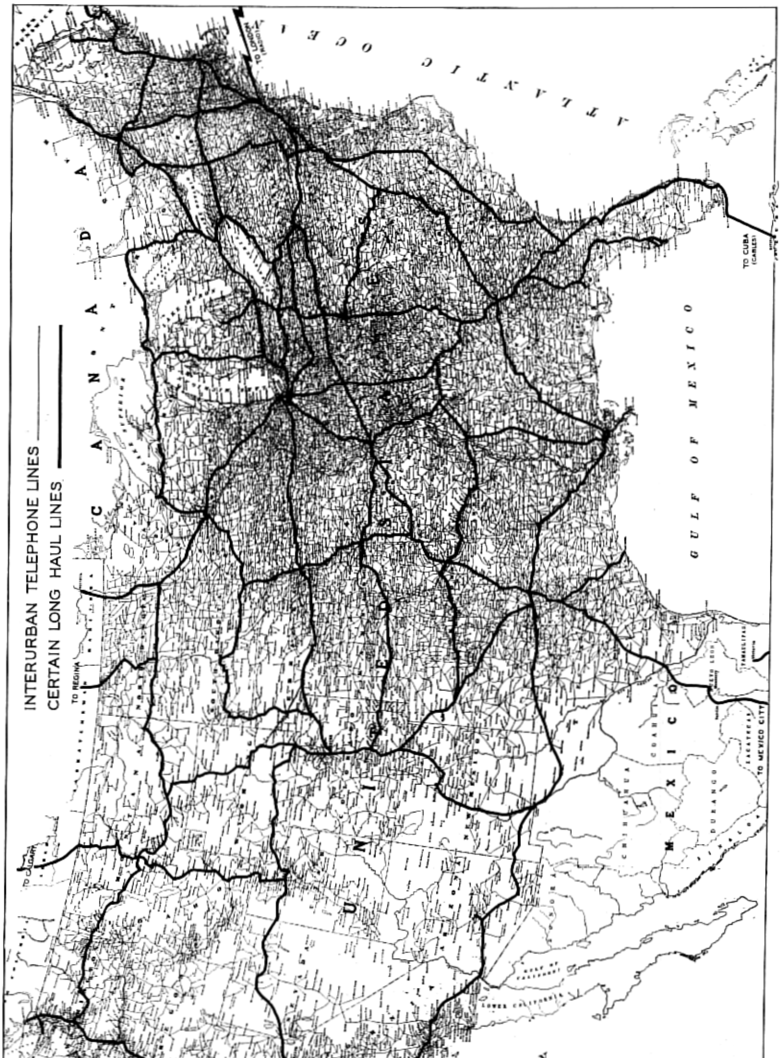

Fig. 35—Toll lines of the Bell Telephone System.

Telephone Toll Lines

To handle the toll business of the United States has required completing a network of toll telephone lines completely covering the country. This network is shown in a general way in Fig. 35. It

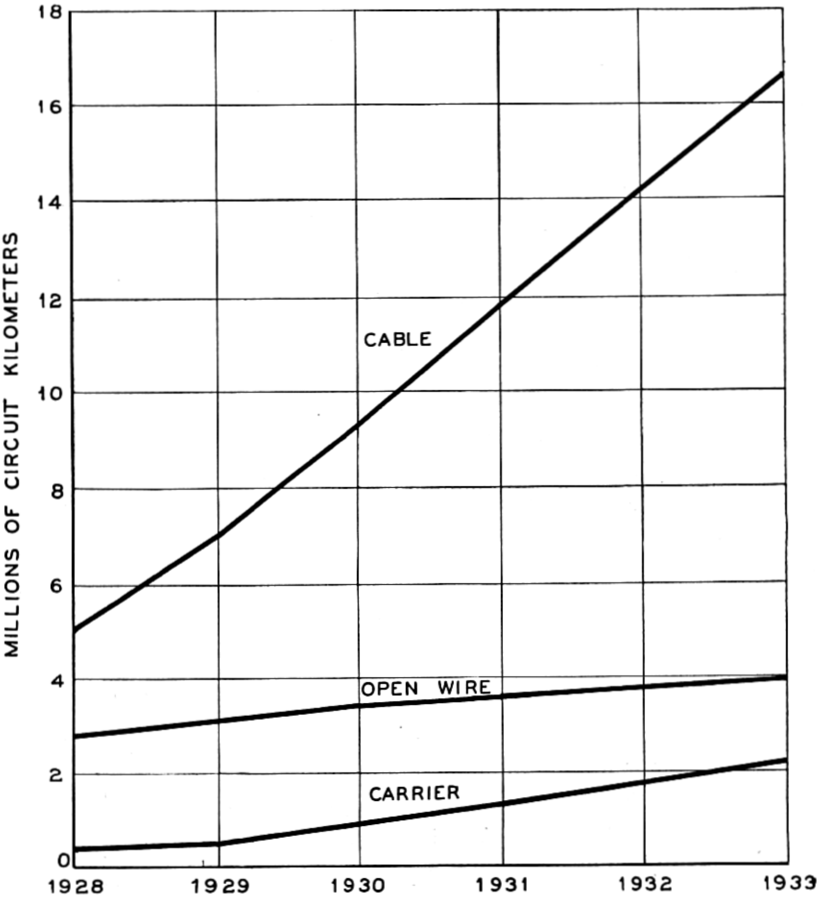

Fig. 36—Estimated toll circuit kilometers in plant Bell Operating Companies.

consists at the present time of about 14 million kilometers of wire on about 300,000 kilometers of toll route. The toll circuits are partly open wire, supported on insulators and are partly in cable. Both the open wire and cable circuits are, in general, phantomed, giving three independent circuits for each two pairs of wires, and in addition on the open wire is superposed a considerable amount of carrier current telephone circuits. The distribution at the present time between cable, open wire and carrier and the expected increase of each during the next four years is shown in Fig. 36.

Open Wire and Carrier Circuits

The standard construction for open wire telephone circuits in the United States is indicated by the diagram of Fig. 37 and a typical pole line built in accordance with this construction is shown in Fig. 38.

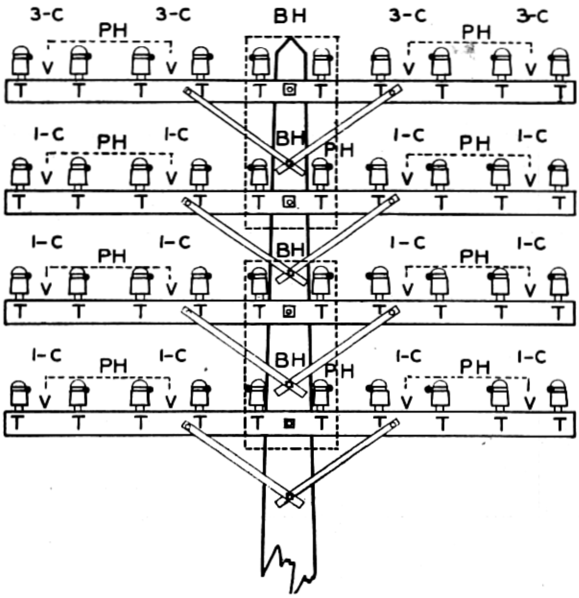

Fig. 37—Pole Line Configuration, phantomed construction, 12 inch spacing between wires of non-pole pairs.

Symbol	Facility	Total Circuits	
V	Voice frequency-physical	20	
PH	Voice frequency-phantom	10	
3-C	Carrier system furnishing 3 telephone circuits	12	
1-C	Carrier system furnishing 1 telephone circuit	12	
T	D-C telegraph	40	
BH	Carrier telegraph (10 channel)	40	
	Total telephone		54
	Total telegraph		80

The wires are of copper and the sizes and weights are shown in the following table.

Diameter—mm.	Weights—kg. per km.
2.6	47
3.2	74
4.2	118

Bronze and aluminum are not, in general, used in the United States for telephone lines, being not as economical or as generally satisfactory as copper, taking into account transmission efficiency and construction conditions.

The wires are placed on 10 pin cross-arms and supported, in general, by double-petticoated glass insulators. The grouping of wires to form phantoms is indicated in Fig. 37. This arrangement has been found desirable for conditions in the United States and transposition systems have been designed by which are obtained satisfactory operation of the phantoms and side circuits, the mutual induction between the various circuits being sufficiently neutralized to prevent mutual interference.

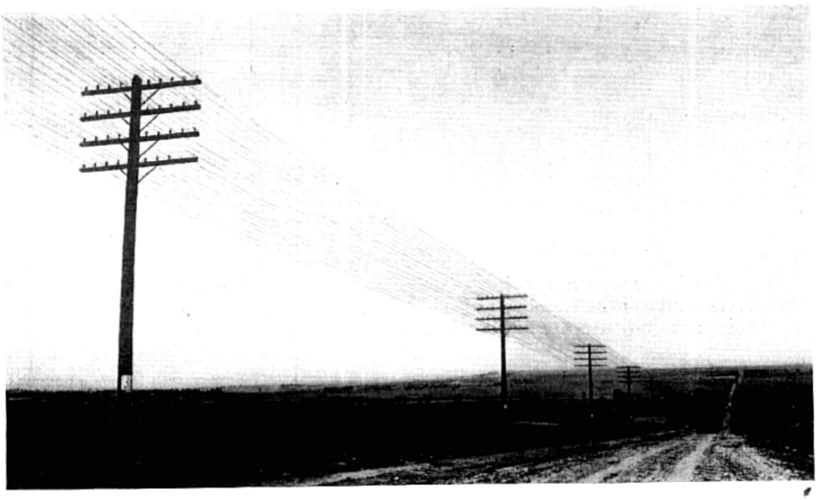

Fig. 38—Open wire pole line construction. Four 10-pin cross arms.

On the longer circuits telephone repeaters are installed at an average distance of about 175 to 300 kilometers, providing in that way for adequate transmission efficiency.

The number of circuits which it is practicable to provide by means of open wire lines has during the past decade been very greatly increased by the extensive use of carrier telephone for superposing on the telephone circuits additional channels of communication carried by currents above the voice range of frequencies. These systems now form a network covering the entire country and in some areas a large proportion of the circuit growth on open wire lines is taken care of by carrier systems. The systems range in length from a minimum of 75 kilometers to a maximum of 3,800 kilometers.

Two types of carrier telephone systems are standard for use in the United States. One of these, designed for the longer hauls, provides on one pair of wires three telephone circuits in addition to the voice frequency circuits. These three carrier circuits are provided by the modulation of frequencies between about 6,000 and 28,000

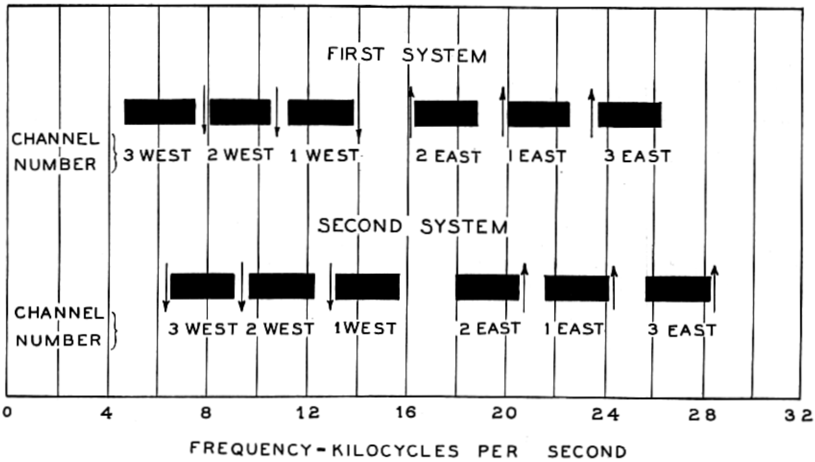

Fig. 39—Frequency allocation of two long haul carrier systems. The blocks indicate the range of the transmitted side band. The arrows are located at the carrier frequencies and indicate the direction of transmission.

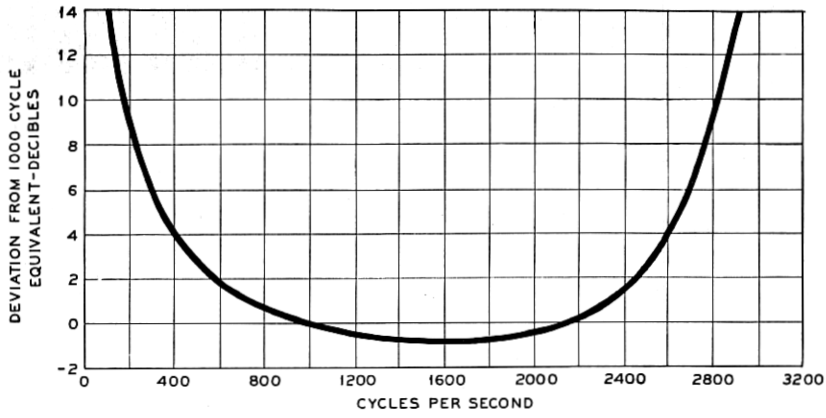

Fig. 40—Average overall transmission-frequency characteristic of Long Haul Carrier telephone system.

cycles, different frequencies being used for transmission in the two directions. The different conversations are amplified together in a common repeater at intermediate points and at the terminals separated by electrical filters providing for each circuit a band of approximately 3,000 cycles. The frequency allocation for two varieties of the long haul system in common use are shown in Fig. 39 and typical transmission characteristics for a carrier channel are shown in Fig. 40.

The long haul carrier systems give very satisfactory service and form a part of some of the longest circuits in the country. For example, the direct circuits between New York and Los Angeles, California, 5,100 kilometers in length, are made up of cable circuits from New York to Pittsburgh connected permanently to a Pittsburgh-St. Louis carrier system, and a St. Louis-Los Angeles carrier system. These two carrier systems connected together total 4,550 kilometers in length with 13 intermediate repeaters. Similarly the New York-San Francisco circuits are in cable from New York to Chicago and there permanently connected to the Chicago-Sacramento carrier system 3,800 kilometers long with 10 intermediate repeaters.

The short haul carrier system is similar in its general characteristics but is simplified and provides a single carrier circuit for each pair of wires. In the case of both systems, single side-band carrier suppression circuits are used.

In Fig. 37 showing the standard arrangement of open wires on pole lines are indicated the carrier telephone channels and also the carrier telegraph channels which can be superposed on these circuits without mutual interference, after the installation of suitable transpositions which have been designed to neutralize the mutual induction between the circuits. It is noted that with this arrangement it is possible to obtain from 40 wires 54 telephone circuits. Also 80 telegraph circuits are obtained, used for special contract service as described later in this paper.

On a number of the open wire toll routes carrying very long circuits, it has become important to provide arrangements for using a larger number of long haul carrier telephone systems, thus obtaining a larger number of circuits. Whereas a number of arrangements using the standard spacing of wires have been tried out, it is found extremely difficult to continue the use of phantoms and to so transpose the wires as to provide adequate freedom of interference between the higher frequency carrier channels if these are used on all pairs. The difficulty of doing this is evident in considering that in order to avoid overhearing it is necessary that the power transfer between different circuits should not exceed one part in a million even though they are parallel to each other for long distances.

In order to make possible the maximum use of long haul carrier systems where desired, trials have been made with the arrangement of wires shown in Fig. 41 and these trials have shown very satisfactory results. With this arrangement the spacing of the two wires of each pair except the pole pairs is reduced to 23 centimeters and the phantoms on these wires are abandoned. Type "C" systems can then be used on all of the pairs with this spacing. The result as indicated on the diagram is that a 40 wire toll line provides 70 telephone and 80 telegraph circuits.

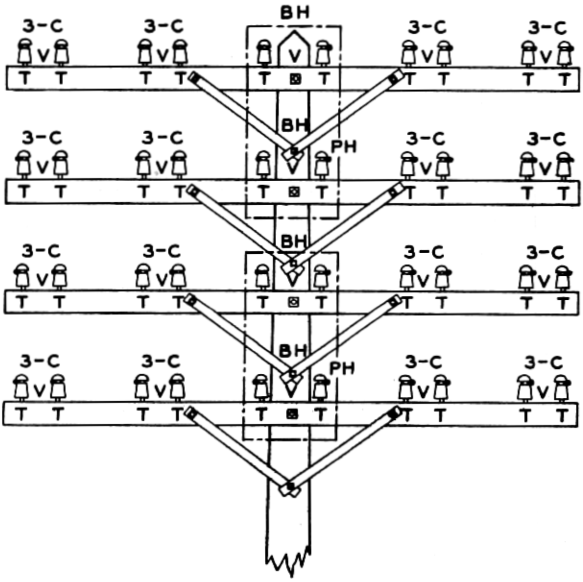

Fig. 41—Pole Line Configuration, non-phantomed construction, 8 inch spacing between wires of non-pole pairs.

Symbol	Facility	Total Circuits	
V	Voice frequency-physical	20	
PH	Voice frequency-phantom	2	
3-C	Carrier telephone	48	
T	D-C telegraph	40	
BH	Carrier telegraph (10 channels)	40	
	Total telephone		70
	Total telegraph		80

Toll Cables

In spite of the great extension in the use of open wire circuits brought about through the application of carrier systems, as indicated above, it would be extremely difficult with the present rapid growth in toll business to provide by open wire toll lines the large numbers of telephone toll circuits now required on many routes. It is very fortunate that the development of means for providing satisfactory long distance circuits through telephone cables has matured in time to enable this method of construction to be widely used to meet the present demands. Also, the toll cables provide practical immunity from the effects of storms, including the sleet storms, which are a hazard to open wire construction in nearly all parts of the United States.

The first long distance toll cables in the United States were placed in service in 1906 between New York and Philadelphia and between Chicago and Milwaukee. These cables were both placed underground in multiple duct and are each about 150 kilometers long. The next step in the extension of toll cables was the completion in 1914 of an underground toll cable route between Boston, New York, Philadelphia and Washington, a distance of 730 kilometers. Cable running west from New York was completed to Chicago, a distance of 1,380 kilometers, in 1925 and to St. Louis, a distance of 2,150 kilometers, in 1926. This permitted placing in service circuits entirely in cable between New York and St. Louis.

The present major toll cable routes together with the extensions which it is expected to complete during the next five years are indicated in Fig. 42. It is to be seen that in accordance with these plans toll cable will, within five years, extend entirely across the continent and up and down the length of both Atlantic and Pacific Coasts, will extend north into Canada and south almost to Mexico. In the northeastern portion of the country where the development is the heaviest, there is already a multiplicity of toll cable routes and on some of these routes the rate of growth is high enough to require additional cables at successive intervals of one or two years. The amount of toll cable added to the network this year will be about 8,000 kilometers and this amount is expected to be increased materially in the following years.

In the early toll cables before the extensive development of telephone repeaters, it was necessary, in order to provide satisfactory transmission, to use relatively large conductors and conductors up to a maximum size of 2.6 mm. diameter (No. 10 B and S gauge), were provided in the Boston-Washington cable.

With the perfection of telephone repeaters for use with toll cable circuits, the transmission limitations on the extension of toll cable were removed and the economy of such circuits greatly increased by making it possible to use small conductors. The longest toll cable circuits at the present time are carried over conductors of 0.9 mm. diameter (19 B and S gauge). For the shorter circuits each path is used as a two-way circuit, while the longer circuits use separate paths for transmission in opposite directions. In order to improve the transmission characteristics, the circuits are provided with loading coils

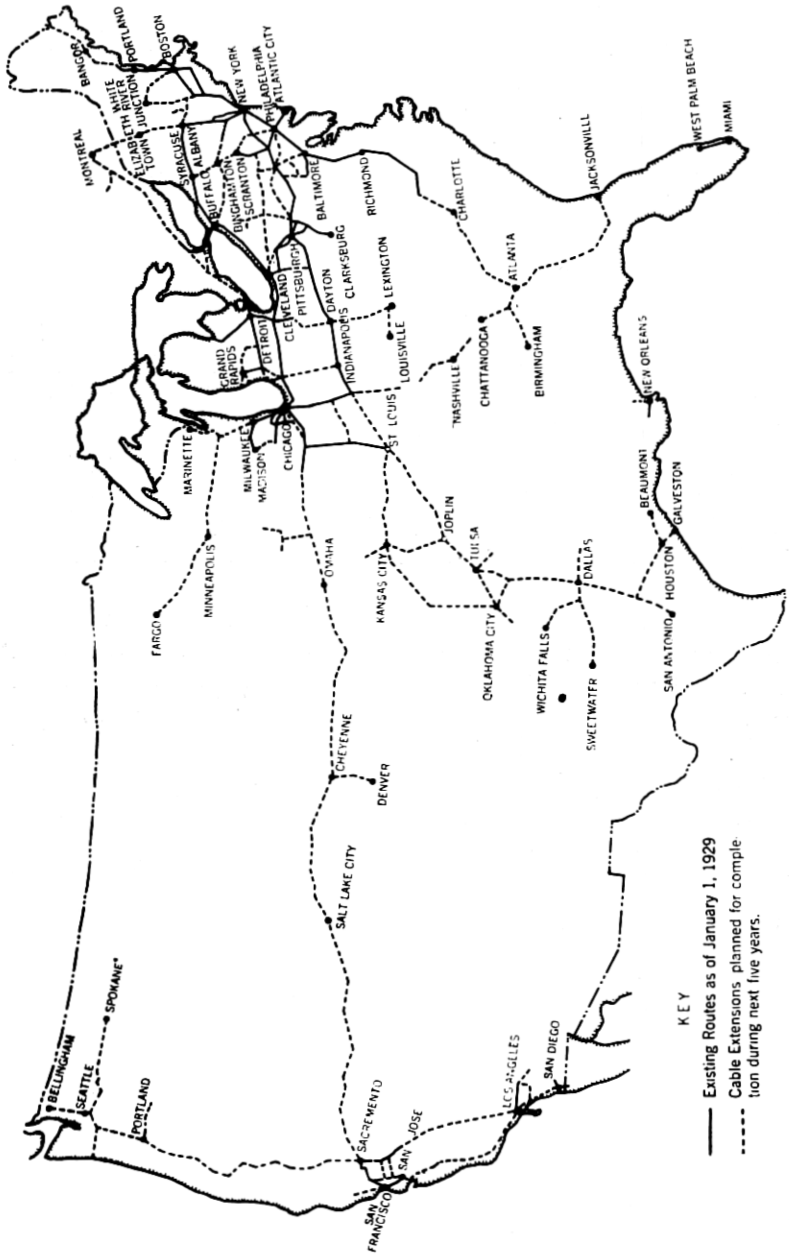

Fig. 42—Main toll cable routes of the United States.

at intervals of 1,830 meters and at an average interval of about 70 kilometers are provided with telephone repeaters which renew the power of the attenuated voice currents. A single standard full size cable 6.7 cm. in diameter when so equipped is capable of providing between 250 and 300 long distance telephone circuits.

The toll cable system includes various types of construction. For the routes having the most rapid growth, multiple duct subway is used. At the present time with the development of very heavy toll demands in many parts of the country, this type of construction is

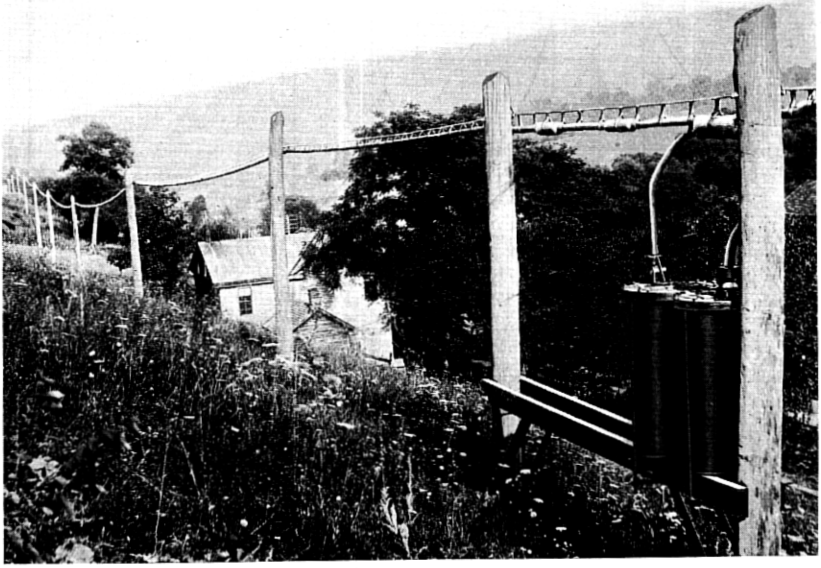

Fig. 43—Typical aerial toll cable construction showing loading point.

being extended very rapidly on a number of important routes. Multiple tile duct with small splicing manholes located at intervals of 229 meters and large manholes for loading coil pots at intervals of 1,830 meters are generally used.

For routes on which the growth is relatively light, for example, 40 or 50 circuits a year and where underground construction is desirable, two other types of construction have been used to a limited extent. In one type the cable is placed in a single duct of fibre and in the other type of construction cable covered with a double layer of steel tape is placed directly in the earth. With both of these types of construction, manholes are built only at loading points.

In many places the character of the country is such that underground construction would be very expensive. In such cases, and in other cases where it seems desirable, aerial toll cable construction has been used extensively in the United States. With this type of construction the cable is suspended from a steel messenger wire supported on poles. Figure 43 shows typical aerial cable construction, including a loading point, the pots of loading coils being supported on an angle iron pole fixture.

Long circuits in toll cables have some extremely interesting electrical characteristics. Figure 44 shows the net transmission charac-

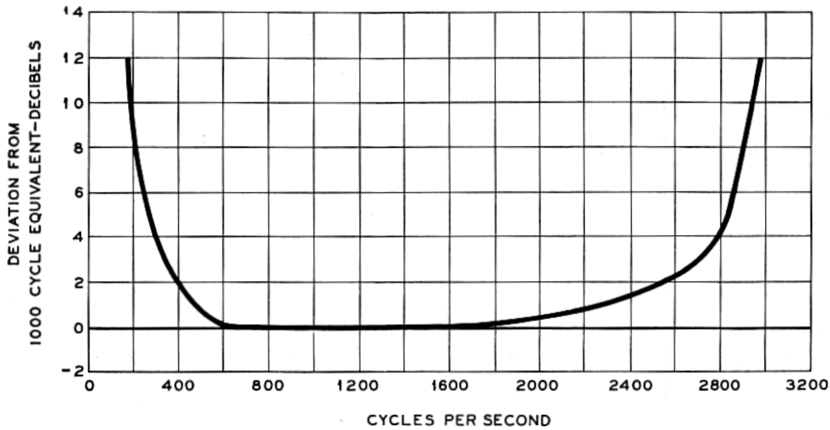

Fig. 44.

teristic over a range of frequencies of a New York-Chicago toll cable circuit 1,380 kilometers in length. It will be seen that the voice frequencies are transmitted with nearly the same net efficiency over a sufficiently wide band to give a high grade of telephone transmission. The net characteristic indicated, however, is obtained by almost wholly neutralizing with telephone repeaters the very large transmission loss in the circuit. The New York-Chicago circuit, for example, would have an attenuation loss at 1,000 cycles of about 470 db, which means that without amplification the ratio of output power at one end to input power at the other end of the circuit would be 10^{-47}. The combined gain of the 19 telephone repeaters in the circuit is about 461 db, giving about 9 db net equivalent. Under these conditions, it is evident that a careful regulation of the circuit is essential. For example, variations in the temperature of a circuit in the course of a day could make as much as 30 db or 1,000 fold difference in the electric power received at the end of the circuit. To prevent such variations affecting the net equivalent the long circuits are all provided with automatic regulators which adjust the gains of the telephone repeaters to compensate for the effect of temperature variations on the equivalent of the circuit.

The effects of transmission delay are also very interesting and important. Voice waves travel considerably more slowly over cable circuits than they do over open wire circuits. For example, the velocity is about 30,000 kilometers per second for "long distance" type cable circuits as compared to nearly 300,000 kilometers per second for non-loaded open wire circuits.

One important result of delaying the speech waves is the "echo" effect. The transmitted currents are in part reflected at the distant terminal due to variations in the impedance of the receiving circuit. If the reflected currents transmitted back to the other end are delayed enough they may be heard by the talker as echoes of his voice. They may be again reflected at the sending end of the circuit and returned to the listener as an echo following the directly transmitted speech. The effects of these echoes are largely eliminated by devices known as "echo suppressors" by means of which the transmission of voice waves in one direction over the circuit causes interruption of the path over which the echo currents are transmitted in the opposite direction. However, the effectiveness of echo suppressors is limited by the necessity that they shall not be operated by noise currents of extraneous origin as this would interrupt conversations. The echoes, therefore, are an important factor to be taken into account in determining the type of toll cable circuit to be provided to meet the transmission limitations imposed on the long distance circuits.

In cable circuits introducing considerable transmission delay, the fact that the delay is not exactly the same for waves of different frequencies is also important, tending to give rise to what have been sometimes referred to as "transient" effects. In loaded cable circuits the waves of higher frequency are delayed more than those of lower frequency because of the fact that the loading is applied in lumps. The coils and condensers in the repeaters and auxiliary apparatus, on the other hand, tend to delay the waves of lower frequency. The result is that the waves of intermediate frequency arrive first, followed by the waves of higher and lower frequency. Devices known as "phase compensators" can be used to reduce the effects, particularly those caused by the line. To improve the situation at the low end of the frequency scale special attention has been given to the design of the repeaters and auxiliary apparatus.

Still another effect of the transmission delay is to somewhat slow up and perhaps otherwise interfere with conversations due to the delay which is added to the ordinary time elapsing between question and answer. For example, if a cable circuit is 5,000 kilometers long

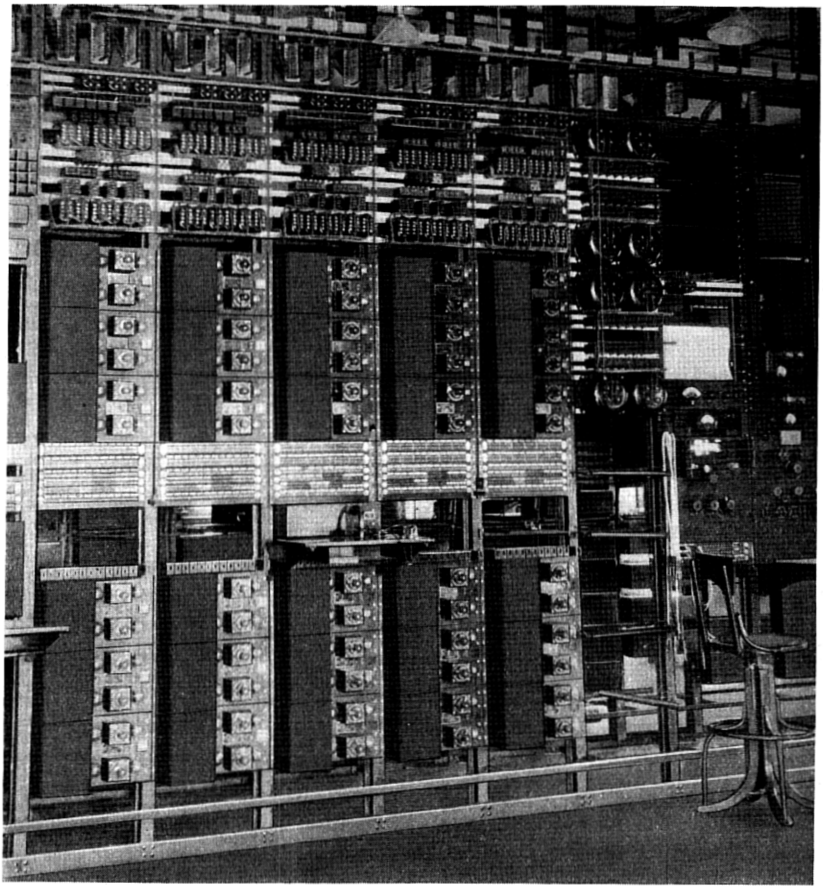

Fig. 45—Thirty 4-wire repeaters and associated testing equipment. The repeaters are arranged in groups of 3 with a minimum of cabling, each group being associated with a phantom circuit and its 2 side circuits.

and the voice waves travel 30,000 kilometers per second, the time required for the waves to travel from one end of the circuit to the other is $\frac{1}{6}$ second and to make a complete round trip, $\frac{1}{3}$ second. This $\frac{1}{3}$ second delay is evidently added to the ordinary time which elapses between question and answer. In the United States cable connections somewhat longer than 5,000 kilometers will be used in the future, while for international connections, of course, very much longer distances than this will be involved. In the United States considerable study is, therefore, being given to the effects of transmission delay and to methods of avoiding difficulties on the very long connections including the development of cable circuits of higher speed.

The toll cable circuits today include two principal types, one, discussed above, for the longer distances having a transmission speed of about 30,000 kilometers a second, and the other for the shorter distances, transmitting a narrower band of frequencies and having about one-half the transmission velocity. In view of the superior transmission characteristics of the long distance type circuits it is the present practice in the design of new toll cable circuits in the United States to limit the use of the short distance type facilities to circuits about 160 kilometers in length if they are to be used for switched business, and about 280 kilometers in length if used only for terminal business.

Toll Circuit Equipment

The apparatus required for the operation of toll circuits has been developed in the form of panels mounted on standard bays of angle iron, thus bringing about a great reduction in the space required compared with earlier forms of mounting. Figure 45 shows a bank of 30 four-wire repeaters arranged in groups of three, each group being associated with a phantom and its two side circuits. Figure 46 shows the panels containing complete terminal equipment for two type "C" carrier telephone systems (six circuits) with associated testing apparatus.

The equipment is housed in fire-proof buildings. Figure 47 shows a typical telephone repeater station, this one being located at Princeton on the cable route between New York and Philadelphia. This building now contains 1,100 repeaters. Some of the telephone repeater stations now being built are designed for ultimate capacity with extensions of 10,000 repeaters.

An interesting feature of the long telephone circuits is the use of 1,000-cycle current for signaling rather than the lower frequencies which have been general in the past. This higher frequency has the advantage of being efficiently transmitted by the telephone circuit without change in the amplifying apparatus and hence does not require intermediate ringing apparatus. At the terminals it is rectified and caused to operate relays which actuate the desired signal.

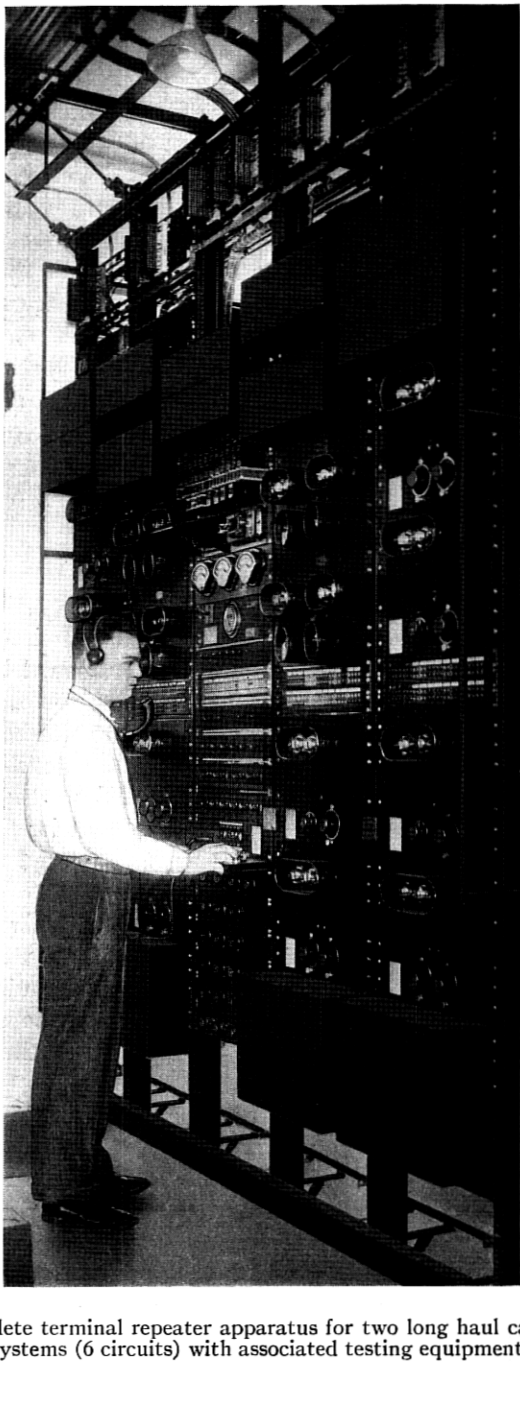

Fig. 46—Complete terminal repeater apparatus for two long haul carrier telephone systems (6 circuits) with associated testing equipment.

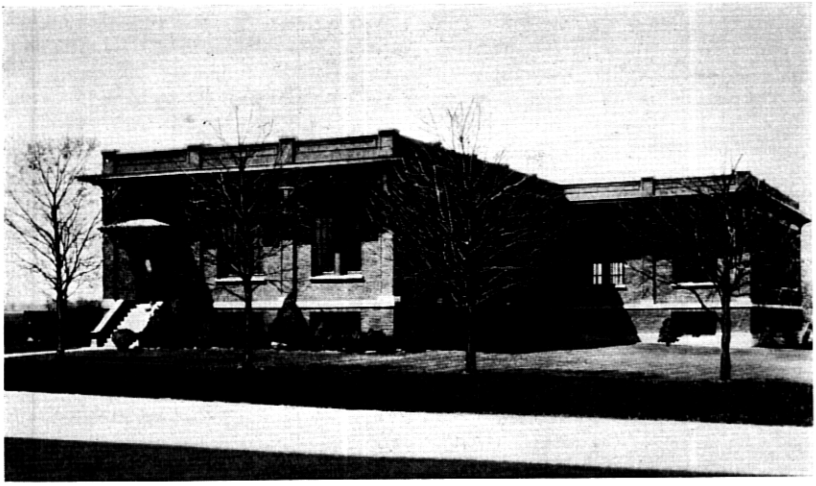

Fig. 47—Telephone repeater building at Princeton, New Jersey on New York–Philadelphia cable route. Building now houses 1100 repeaters. Ultimate capacity 2200 repeaters.

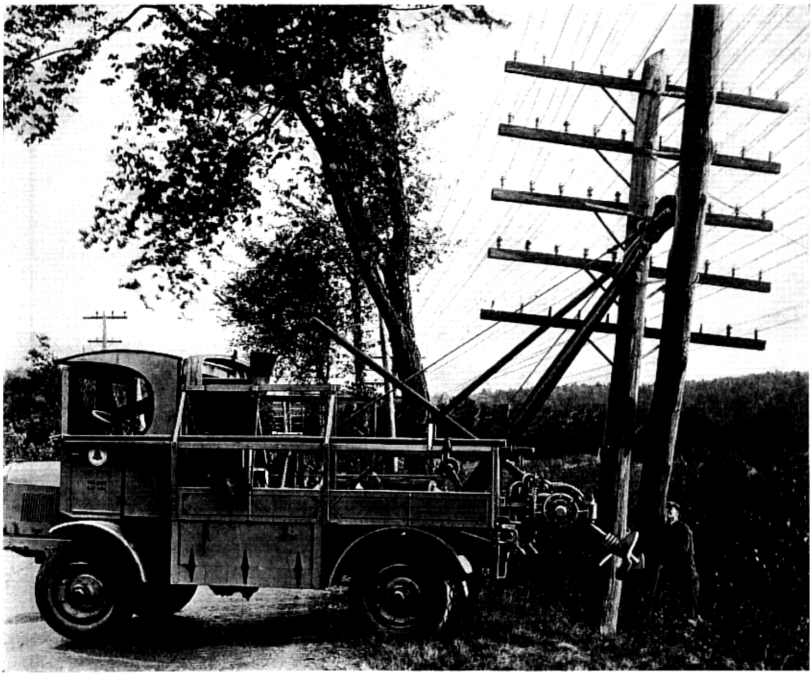

Fig. 48—Earth boring machine and derrick. Will bore 60 centimeter hole 2 meters deep in loam or clay soil in about one minute and in stone or frozen soil in 5 or 10 minutes. Derrick operated by power driven winch for setting poles. Truck provided with four wheel drive.

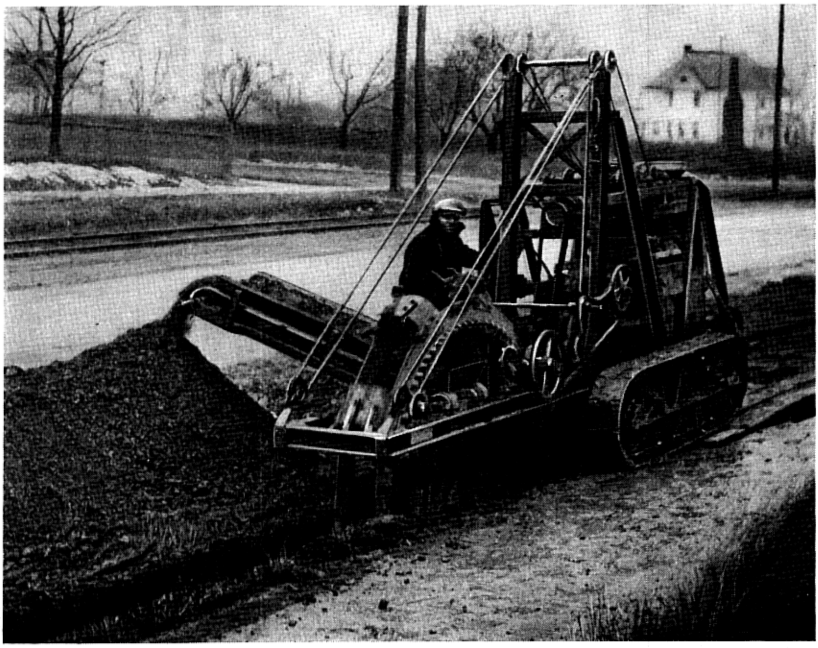

Fig. 49—Trenching machine. Digs trench 1.7 meters deep and 55 centimeters wide, at speeds varying between 0.2 and 1.2 meters per minute, and is carried from job to job upon a trailer drawn by 2½ ton truck.

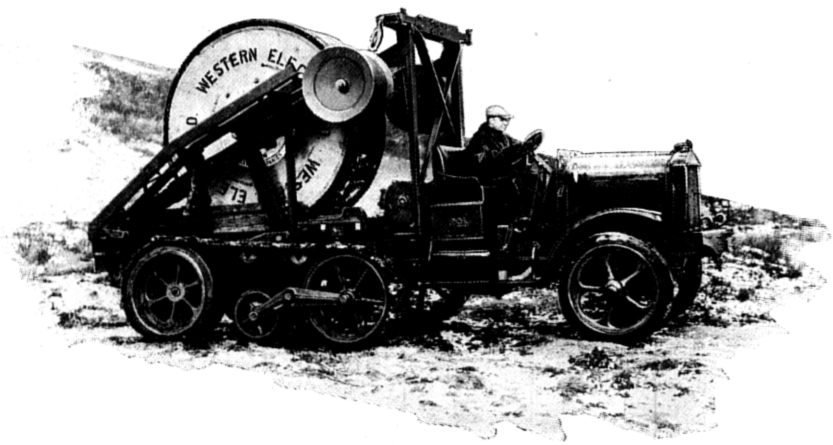

Fig. 50—Automobile truck equipped with tracks for hauling cable on private right of way. With tracks, speed about 16 kilometers per hour. Can carry 4500 kilogram reel up 40% grade. Tracks can be removed using special equipment provided for that purpose; without tracks speed 27 kilometers per hour.

Toll Line Construction

The construction of toll lines under a wide variety of conditions has required the solution of many interesting problems. The relatively high cost of labor in the United States contributes to the extensive use of labor saving machinery, a large amount of which has been developed to meet the particular conditions of telephone construction. Figures 48, 49 and 50 illustrate some of the more interesting types of labor saving machinery used extensively for both open wire and toll cable construction.

Numerous special construction problems are, of course, met in specific situations. One of the interesting river crossings is illustrated in Fig. 51.

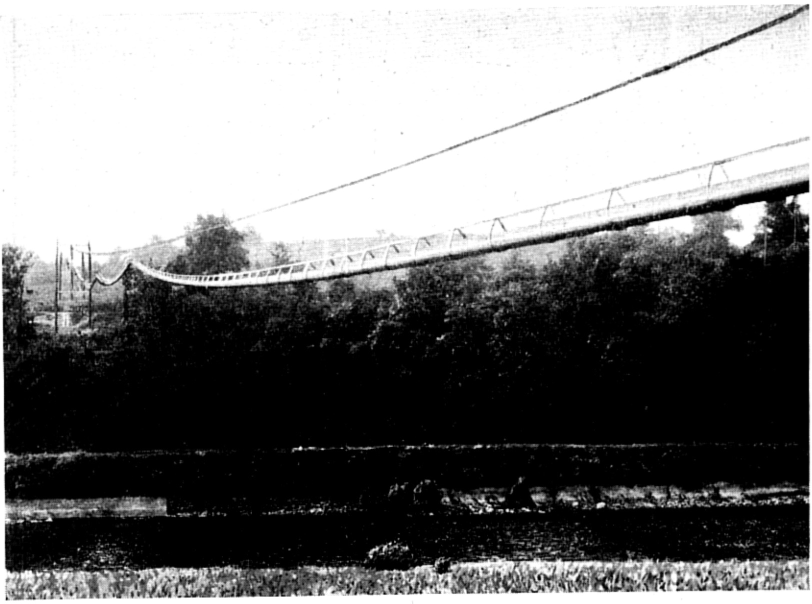

Fig. 51—Special aerial cable construction across a river. Cable and messenger secured to a catenary suspension wire. 2-spans each about 180 meters long.

Switching of Toll Circuits

As far as is economically practicable the toll business is handled by direct circuits without intermediate switching. At the present time this includes 80 per cent of the toll messages. Of the remaining 20 per cent, 17 per cent have one intermediate switch and 3 per cent more than one intermediate switch.

It is the purpose of the Bell Telephone System to design the toll

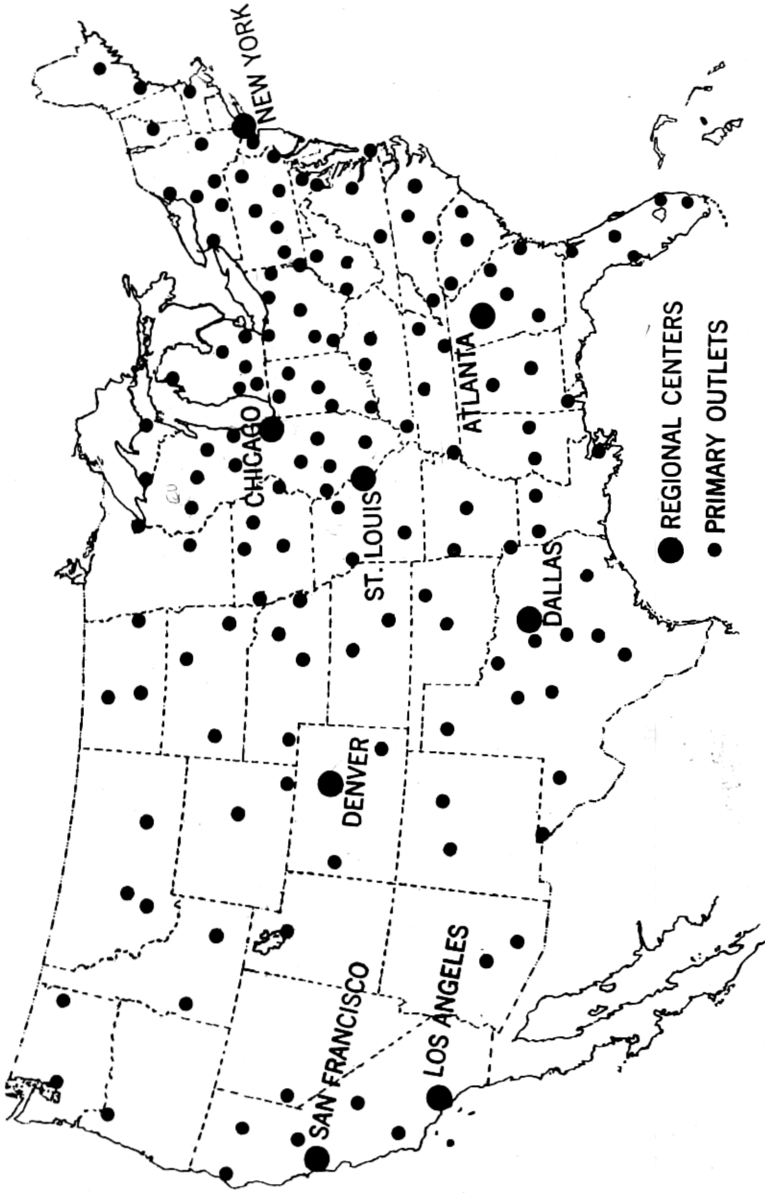

Fig. 52—General toll switching plan. Map showing location of important switching points in Bell Operating Companies.

telephone system in the United States to give satisfactory service between any two points in the country. In order to accomplish this it is necessary to make arrangements for a minimum number of switches between any two points. Also the toll circuits which will be used as parts of the built-up connections must be designed for a very high standard of transmission so that the overall efficiency of the built-up connection will be satisfactory.

Arrangements have recently been worked out in the United States for meeting requirements of switched traffic more satisfactorily than has heretofore been possible. These arrangements may be briefly described as follows:

At different points in the country there have been selected a group of eight very important switching points shown in Fig. 52. These eight regional centers will all be interconnected by high grade groups of circuits directly, that is, without intermediate switch. Throughout the country there are selected about 147 important switching points known as primary outlets also indicated in Fig. 52, each of which is directly connected to at least one of the regional centers. Each of the remaining 2,576 toll offices in the country will be connected to at least one of these important switching points. Furthermore, within limited areas, such for example as a State, all important switching points will be directly interconnected. Within such an area, therefore, any two toll offices can be connected together with not more than two intermediate switches. Also, every toll office can be connected to a regional center with not more than one switch and through that center can reach any other toll office in any part of the country with a minimum number of switches.

To insure adequate transmission on the switched connections, each of the important switching points will be provided with means for automatically inserting gain in the connection when two toll circuits are switched together so that the overall connection may be operated at the highest possible efficiency. This will, in general, be done by automatic adjustment of the gain of terminal repeaters permanently installed in circuits which must, in general, because of transmission limitations be operated at a lower efficiency when used for terminal business than when used as parts of a built-up connection.

Maintenance of Toll Service

With the present network of long distance lines in the United States, it is common to have 20 or more repeaters installed on each of the longer circuits and this number will increase greatly with the further extension of toll cable. The maintenance of service over these long and complicated circuits is a very considerable problem both from the standpoint of technique and of organization. In this paper, these problems will not generally be discussed, but certain features will briefly be indicated.

The service maintenance of the circuits includes periodic tests of transmission efficiency with transmission measuring sets designed for rapid and efficient use by the plant maintenance forces. The frequency of tests varies according to the requirements of each circuit group.

To expedite the testing and adjustment of the circuits the longer cable circuits are subdivided into circuit units, these units usually being in cable about 160 to 240 kilometers in length, including the conductors and equipment involved in one section arranged for the automatic compensation of temperature variations. When trouble occurs on a long circuit, the circuit unit in which the trouble is located is immediately replaced and the location of trouble within the circuit unit then can be carried out without further interruption of service. The responsibility for establishing and maintaining each circuit group is given to a control office which is provided with private communication channels to all parts of the circuit.

An important feature in the maintenance of long toll circuits is the physical relations between the telephone circuits and circuits for the transmission or distribution of electric power. The Bell Telephone System and the power companies of the United States as represented by the National Electric Light Association are very actively cooperating in a study of the best means of so coordinating the plant of telephone and power companies as to avoid interference under the various types of conditions important in practice. By means of this work it has been possible to find in every case a satisfactory solution permitting each utility to extend and increase its service along natural lines and providing proper protection of the telephone service.

International Connections

General

The connections between the telephone systems of the United States and the telephone systems of other countries are indicated in Fig. 53.

The territory of the United States has direct contact with only two other nations, Canada on the north and Mexico on the south. The common language and the close commercial relations between Canada and the United States have naturally resulted in a well developed arrangement of lines connecting the telephone systems of the two countries. Telephone connection between the cities of the United States and Mexico was not made until 1927, due to the unsettled political conditions which obtained for some years in Mexico.

The many close commercial, political and social relations between the peoples of Europe and America have naturally drawn the attention of telephone men for many years to the possibility of establishing

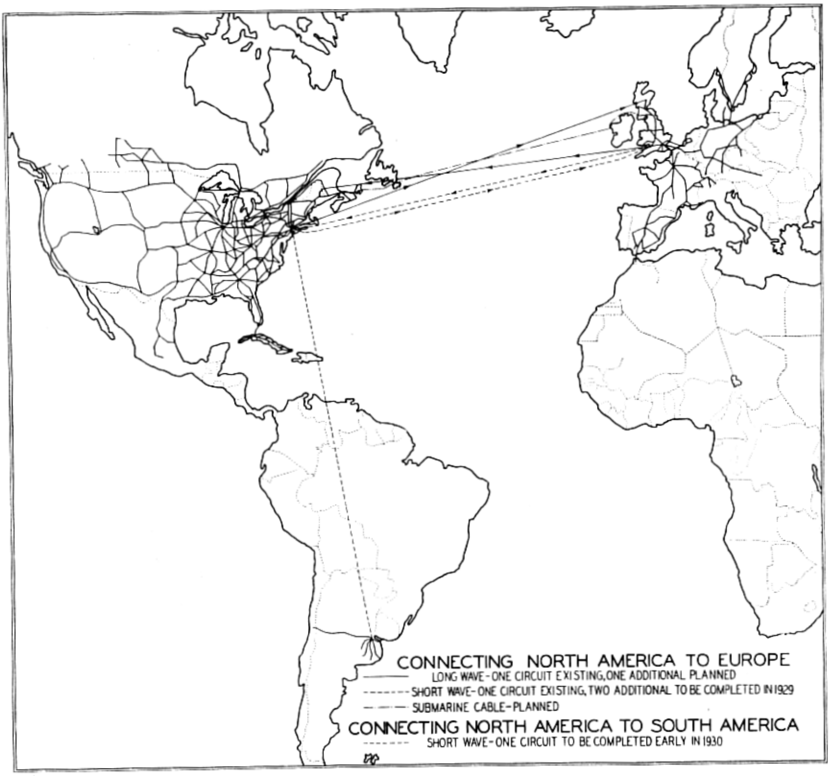

Fig. 53.

telephone communication between these two continents. It was a great satisfaction, therefore, to be able to inaugurate such a service in 1927. The transatlantic telephone circuits already connect over 20,000,000 telephone stations in North America to over 7,000,000 telephone stations in Europe, thus joining together over 85 per cent of the total telephone stations of the world.

In somewhat more detail, the present status of the connections of the United States telephone system to the telephone systems of other countries is as follows:

Connections in North America

Practically all the telephone stations in Canada have communication to the telephone stations in the United States. There are approximately 100 long distance circuits extending from cities in the United States to important Canadian centers, including Halifax, St. Johns, Montreal, Toronto, Hamilton, Winnipeg, Regina, Calgary and Vancouver. The remaining cities are reached either directly or by switching through the important centers. In addition to long distance circuits there are, of course, many short distance circuits connecting points on opposite sides of the boundary which have local relations with each other. The various companies and provinces in Canada cooperate very closely with the Bell Companies in the United States in the maintenance of international service and, in general, telephone practices are very similar or identical in the two countries.

Telephone communication is extended from the United States to Mexico by means of a telephone line crossing the border near Laredo, Texas. Direct long distance circuits extend from points in the United States to Mexico City, Tampico and Monterey and through these centers to about one-half the telephone stations in Mexico. Local toll circuits cross the border at a number of places.

Telephone communication was established between the United States and Cuba in 1921 by the placing of three telephone cables between Key West and Havana. Each of these cables furnishes one telephone circuit and a maximum of four telegraph circuits. The requirements for the cables were exacting since a length of about 190 kilometers is combined with a depth of water having a maximum of 1,860 meters. Each cable consists of a central conductor magnetically loaded with a wrapping of fine iron wire and insulated with gutta percha compound. A metallic return path for the telephone currents is furnished by heavy copper tape wrapped outside of the insulation and, therefore, in contact with the surrounding water. Three of the telegraph circuits in each cable are obtained by using "carrier currents" at frequencies slightly above the voice range. The fourth is obtained by using frequencies below the voice range.

Connections to Europe

In 1915 the Bell System experiments on radio reached the point where telephone messages were transmitted by radio from the United States and were successfully received by engineers sent for the purpose to Paris and to the Hawaiian Islands. While the Great War delayed technical and commercial development, in 1923 the Bell Companies were able to carry out a successful demonstration of radiotelephone transmission from a group of telephone officials in New York to a group of people interested in communication assembled for the purpose in London. The success of these experiments led to cooperation with the British Post Office and the establishment in 1927 of telephone service between New York and London. This service has now been extended to include the greater part of the telephones of North America and Europe.

As indicated in Fig. 53 there now exist one long-wave and one short-wave telephone circuit between the two continents. A second short-wave circuit will be placed in service about June 1 of this year and a third in December. By the end of 1933 it is expected that there will be in service between New York and London a group of six circuits consisting of three short-wave radio circuits, two long-wave radio circuits, and one cable circuit. Our best information indicates that the short-wave circuits will be suitable for service at least 60 per cent of the time, the long-wave, 90 per cent, and the cable, 100 per cent.

Since the beginning of 1929, the average number of messages handled per week has been 275. For this period the average number of messages per day, omitting Saturday and Sunday, has been 44. Eighty-nine messages were handled on Christmas Day, 1928.

Certain technical features of these circuits are particularly interesting. The long-wave circuit operating at a frequency of approximately 60,000 cycles employs the "single side-band carrier suppression" method. This appears to be the only use of this method in radio, although it is widely used in "carrier" circuits over telephone wires. The energy saved by the suppression of the carrier and the increased selectivity permitted by the narrow band of frequencies which is transmitted gives this system a transmission effectiveness as great as a system of three or more times as much power using the ordinary transmission method. At both ends the receiving stations are situated as far north as can conveniently be reached and use is made of highly directive receiving. It is estimated that at the United States end these two factors represent an improvement equivalent to an increase in power of five thousand times as compared to a non-directive receiving station located at the same latitude as the transmitting station.

The short-wave transmitting and receiving stations located not far distant from New York and London employ highly directive antenna systems. The design of such antennas must take into account economic factors and possible reactions on receiving effects other than power efficiency such as fading. The improvements effected by such systems depend on wave-length and transmission conditions. Under favorable conditions the improvement effected at each end is approximately equivalent to a transmitted power increase of 100 times. The most useful wave-lengths for this service have proved to be in the vicinity of 16 meters, although wave-lengths of about 22 and 33 meters are also provided to increase the amount of time these circuits are satisfactory for service because at certain seasons and times of day they are more effective than the 16 meters wave-length.

Service over the transatlantic facilities is carried on from 6.30 in the morning to 10.00 at night in New York, corresponding to 11.30 in the morning and 3.00 A. M. London. During the winter months the long waves give nearly continuous service over this period. Under summer conditions considerable difficulty is frequently experienced in maintaining the long waves during the afternoon period in New York, corresponding to the evening period in London. At these times, however, the short waves are usually effective.

The projected transatlantic telephone cable will use new magnetic loading materials and new insulating compounds for submarine cables recently developed by the Bell Telephone Laboratories. It will have at least one intermediate repeater point at Newfoundland. A circuit of this kind, differing radically from radio circuit in its characteristics will add both to the message capacity and to the reliability of the transatlantic service.

Connections to South America

Figure 53 indicates a short-wave radiotelephone circuit from New York to South America which, it is expected, will be in service early in 1930. The South American transmitting and receiving stations, which will be in the vicinity of Buenos Aires, will be owned and operated by the companies who operate the local telephone service in Buenos Aires and the wire lines extending to other points in South America.

Special Services

Telegraph Circuits

While the Bell System handles practically no commercial telegraph message business, it plays an important part in meeting the communication needs of the United States by furnishing a large mileage of telegraph circuits for the private use of individuals and institutions, and for the use of governmental departments. Over two million kilometers of such circuits are now in use. One-third of this amount is used by newspapers and press associations. The greater part of

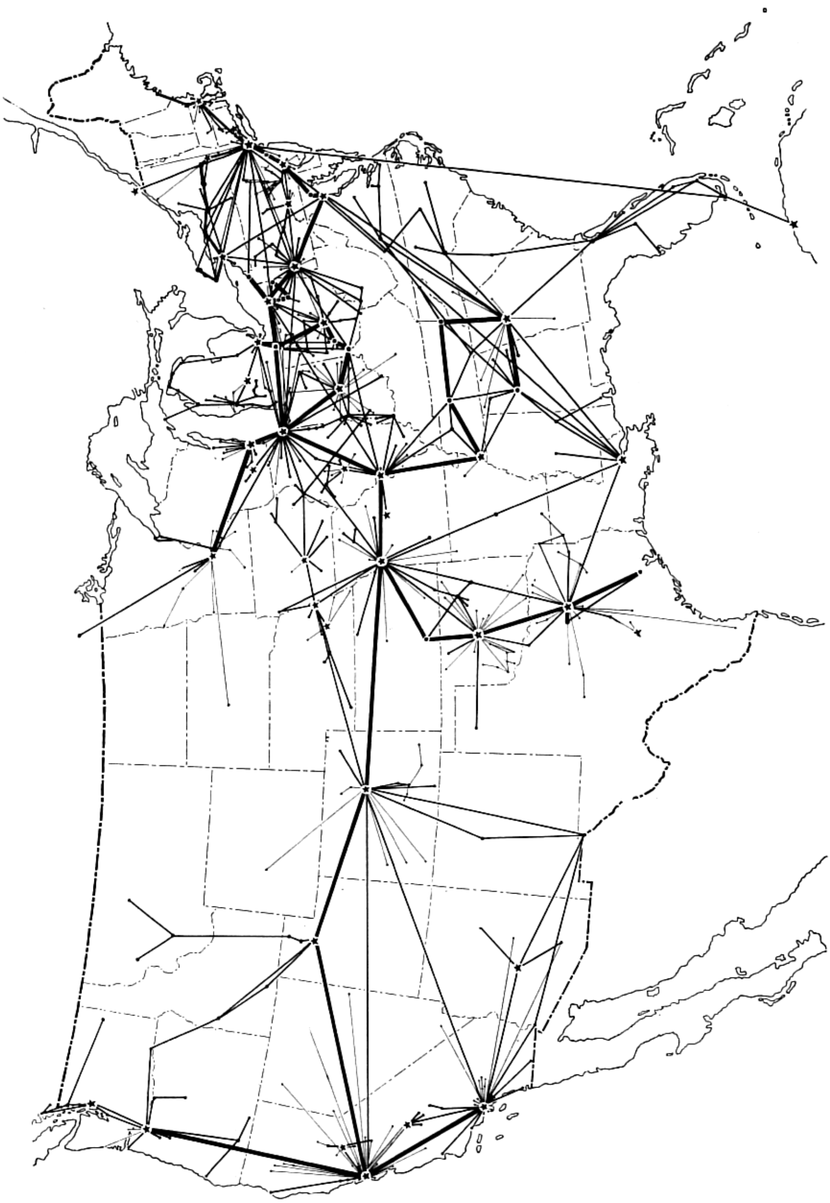

Fig. 54—Special contract telegraph service furnished a press association. 53 circuits totaling 124,000 kilometers, are used exclusively by the press association for distributing news to its customers.

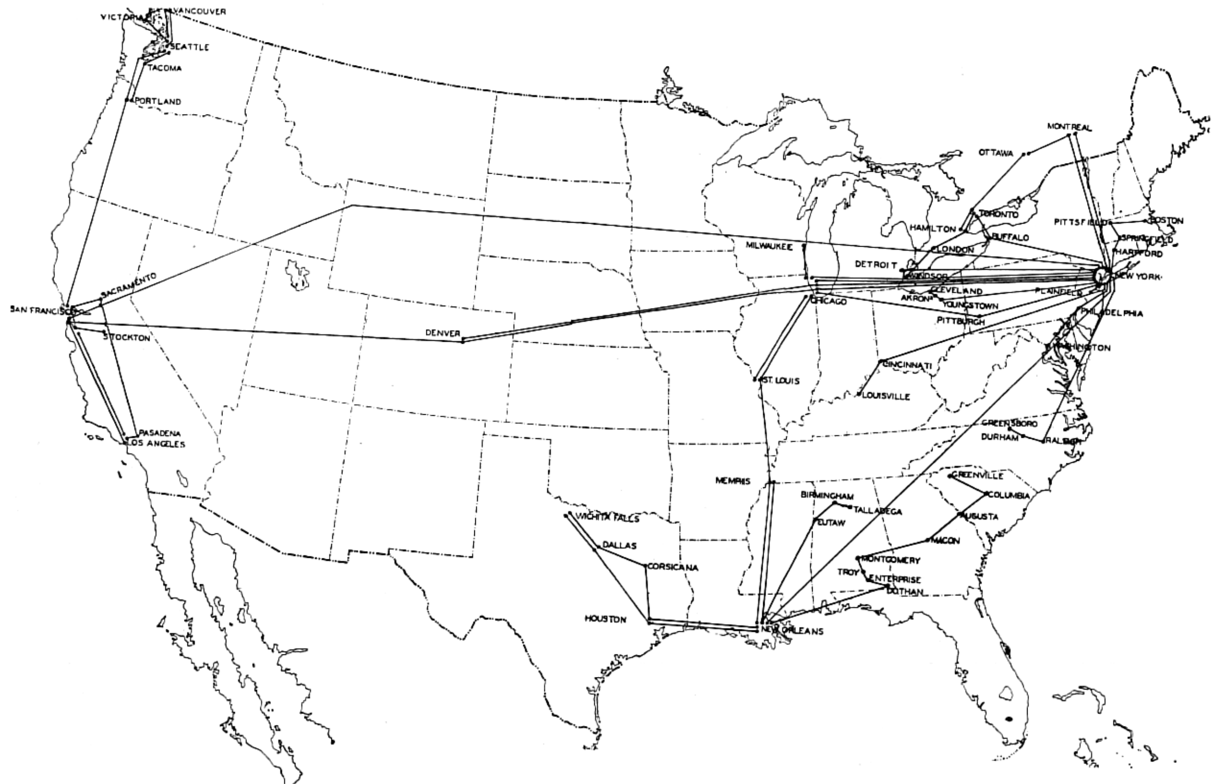

Fig. 55—Special contract telegraph circuits furnished to a brokerage company. 30 circuits totaling 38,000 kilometers with 95 stations.

the remainder is used by commercial, financial and other organizations. Between New York and Chicago, a distance of approximately 1,400 kilometers, there are slightly over 300 such circuits now in operation.

Figure 54 shows the system of telegraph circuits furnished by the Bell Companies to one of the press associations. An indication of the importance of private communication systems to commercial and financial institutions is given in Fig. 55 which shows the telegraph circuits furnished by the Bell Companies to a single brokerage company.

The greater part of such telegraph circuits have in the past been operated by hand-speed Morse telegraph. At the present time, however, nearly a third of the mileage is operated with telegraph printers and this method of operation is rapidly increasing. Two speeds of service employing printers are offered, one operating at 40 words per minute and the other operating at 60 words per minute. At the present time, in view of the use to which this service is put, no demand has arisen for multiplex operation, but this method of operation is possible and will be used if it should become desirable.

The telegraph circuits were originally all obtained as a by-product of the telephone business by compositing or otherwise superposing them on the telephone wires, using direct current for the telegraph circuits. At the present time approximately two-thirds are obtained in this way. The remaining third are obtained by "carrier current" methods. The carrier current system of open-wire lines uses frequencies above the voice range and provides ten duplex telegraph circuits on each pair of wires. The carrier current system used on cable circuits employs frequencies within the voice range, the currents being transmitted over an ordinary telephone four-wire cable circuit. This system gives twelve duplex telegraph circuits on each such circuit.

Telephone Circuits Provided for Private Use

In addition to the usual telephone message business, the Bell Companies furnish telephone circuits for the private use of individuals and organizations.

So-called "special contract" telephone circuits are set up between particular parties for their private use at definite times specified in the contract. Approximately 2,000,000 circuit km. hours of such facilities are now in use during each complete business day. This is the sum of the figures obtained by multiplying the length of each such special circuit by the number of hours per day it is continued in use.

About three quarters of this total is accounted for by circuits where the contract calls for 12 hours operation per day, nearly all the remainder is accounted for by circuits which remain in service 24 hours per day. A remaining small fraction is made up of shorter period contracts which are permitted to be as short as 30 minutes per night one night per week, or 10 minutes per day five days a week.

As an illustration of the extent of use of this service, there are at present 158 full-time special contract circuits between New York and Philadelphia and 89 of such circuits between New York and Boston.

Foreign Exchange Service

Closely related to the above is the furnishing of what is called foreign exchange service. This consists of an arrangement whereby a customer in one exchange area is provided with a circuit for his exclusive use to another exchange area, this circuit being associated with a telephone number in a distant exchange so that other telephone stations in that exchange can be connected to the special line without toll charge. By this means, a business office in Boston, for example, can be given a New York telephone number, all New York calls for that number being treated as local calls but being actually completed over the special line to Boston.

This type of service has a considerable popularity, there being over 1,000 such lines in service at the present time. Most of them are for relatively short distances, but some are for material distances, the longest being between Cleveland and New York, a distance of about 900 kilometers.

Telephone Networks for Program Transmission to Radio Broadcasting Stations

Radio broadcasting has resulted in the development of networks of telephone circuits for transmitting programs from studios or other places at which they are picked up to the radio station or system of stations from which they are broadcast. By such telephone wire systems the ceremonies of the Presidential Inauguration on March 4, 1929, were simultaneously transmitted to 118 radio stations located all over the United States. A statement regarding these interesting telephone networks, the requirements which they must meet and their importance in program broadcasting in the United States is given in a separate paper presented to this Congress (see paper on Wire Systems for National Broadcasting by A. B. Clark).

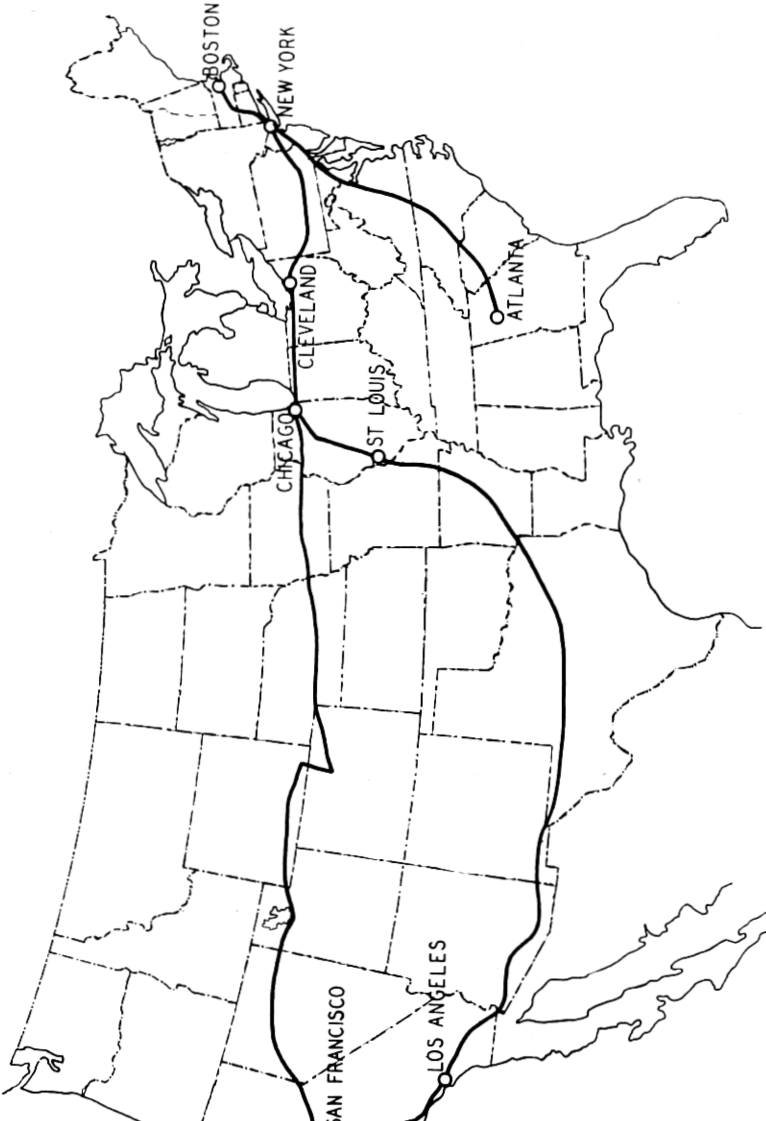

Fig. 56.—Routes of Bell System Telephoto Service in the United States.

Electrical Transmission of Pictures

A commercial service for the electrical transmission of pictures between the cities of New York, Chicago and San Francisco was inaugurated in April, 1925. The eight cities now connected to this service and the routes of the lines used in connecting them are shown in Fig. 56. In addition, a portable transmitter is provided which may be moved to any desired point. At present this is located in the city of Washington, D. C.

The pictures as transmitted are of about twelve centimeters by seventeen centimeters. Any size picture, of course, can be photographed to come within these dimensions. The detail of each picture corresponds to 39.4 lines per centimeter in each direction, that is, each picture is composed effectively of about 300,000 independent elementary areas. The line time of transmission with the present commercial system is about 7 minutes.

Pictures may be sent from any of the cities shown to one or to more of the other cities which are reached by this service. Newspapers use this service for the transmission of pictures of events of national importance or where matters arise in any part of the country of large news interest. For example, pictures of the inauguration of President Hoover were sent in this way to the newspapers in San Francisco. In view of the three hours difference in time between Washington and San Francisco the pictures were published in newspapers sold at a time of day earlier than that at which the event took place.

The majority of the pictures transmitted are for business or social purposes including pictures of legal documents, advertising material to be simultaneously released at a number of separate points, pictures showing new styles in ladies' wearing apparel, personal greetings in the handwriting of the sender and finger-prints of criminals.

The Western Union and Postal Telegraph Companies now have a service in which they will accept telegraph messages for " facsimile " transmission over this picture system between those cities which the system reaches. This service has not yet been offered long enough to show how much it will be used.

Telephony in Connection with Aircraft Operation

Telephony promises to play a very important part in the practice of commercial aviation. The Bell Telephone Laboratories are carrying out a large amount of development work on all phases of telephony for this purpose. One-way receiving sets have been developed permitting an airplane pilot to receive weather reports and to determine the direction of radio beacons. Experimental radio sets suitable for two-way conversations between a moving plane and the wire telephone system have been developed and demonstrated.

Safety of airplane travel depends a great deal on the rapid accumulation and dissemination of meteorological data. An experiment on a promising method of handling such data is being carried out on an airplane route between San Francisco and Los Angeles in the State of California. At each terminal landing field and at two intermediate fields meteorologists are located. At six periods during the day each of these is rapidly connected in succession by telephone to outlying weather observation points varying in number at the different points from three to sixteen. The information thus accumulated and coordinated at each of the four landing fields is rapidly transmitted to the other three fields by means of printer telegraph circuits connecting them. This constant rapid observation of weather conditions along the airplane route and over a considerable territory around it permits very accurate prediction of the weather conditions which any plane will meet in its travel over the route. Such weather predictions may be communicated to the airplanes before starting or by radio during their flight.

Printer telegraph circuits appear to be a particularly convenient means of interchanging information among important landing fields along airplane routes.

Ship-to-Shore Telephony

The Bell System development work on ship-to-shore telephony was originally started with wave-lengths in the neighborhood of 400 meters, which were later taken into the broadcasting range. In 1920 shore transmitting and receiving stations in northern New Jersey were equipped to operate simultaneously three separate telephone channels in this range. Through these radio stations any telephone subscriber could be connected experimentally to the steamships "Gloucester" and "Ontario" which were engaged in coastwise shipping from Boston southward. In October, 1920, a talk to one of these ships furnished an interesting part of a demonstration at a banquet in New York City tendered to the delegates to the "Preliminary International Communication Conference" which was meeting in Washington at that time.

Development of ship-to-shore telephony has been delayed because of uncertainties regarding the commercial situation and wave-length assignments. At the present time the work is again being actively pushed using wave-lengths under 100 meters. A transmitting and a receiving station will shortly be in course of construction near the seacoast of northern New Jersey and a radio-telephone set is about to be installed on the steamship "Leviathan" to operate with these shore stations. As this ship approaches or leaves New York it is expected to be possible to talk from it to any telephone in the Bell System. This is intended not only as a demonstration of the technical features of such a service but to afford an indication of the extent to which such a service will be used under commercial conditions.

Radiotelephony is being used from shore stations to coastal boats in a number of cases in the United States, but not connected to the commercial telephone system. These include particularly certain boats of the U. S. Coast Guard Service. A careful study, including tests, has been made of telephone service to tugboats operating in New York harbor for the purpose of controlling and thus making more efficient the operation of such craft. So far, it is not clear that this service will be commercially justified.

Telephony to Other Mobile Stations

Consideration has been given to telephone connections for types of mobile stations other than ships and airplanes. Communication with moving trains can technically be carried out with facilities now available. Active studies are under way to determine the practicability of providing such service at a cost which would be attractive commercially and with apparatus which can be limited to a reasonable space on the train.

Telephone Services of Railroads and Other Public Utilities

The operation of railway systems requires a large amount of communication service. The dispatching of trains was, until recent years, carried out largely by the use of telegraph. This has been rapidly changed until at the present time on over 60 per cent of the total railway mileage the train dispatching is by telephone. The railroads' telephone service to stations in the Bell System is through P.B.X.'s leased to them by the telephone companies. In addition to this, the railroads frequently own private telephone circuits extending along their rights of way which connect to and are switched through these same P.B.X.'s.

Similar arrangements are provided for meeting the special communication needs of electric power companies, oil pipe-line companies, and other utilities.

Telephone Public Address Systems

Experience in many cases has shown that with the public address system used by the Bell Companies it is possible to amplify speech or other sounds so that they can be heard by an audience of practically unlimited size. Such public address systems as they are called are used very extensively in large auditoriums and at large public gatherings. For example, the ceremonies of inauguration of President Hoover held on the steps of the Capitol in Washington were amplified by the public address system so as to be heard by a gathering estimated at a hundred thousand persons, gathered within a radius of about 300 meters.

Furthermore, by using the public address system with suitable long distance telephone circuits, it is possible to convey the proceedings of such occasions simultaneously to audiences in all parts of the country. The local distribution of such proceedings is, however, now done largely by radio broadcast rather than by use of the public address system.

A use of the public address system which so far has been taken advantage of only on a few special occasions is by providing two-way operation to interconnect two or more meetings held simultaneously in different places. A notable example of this usage is the joint meeting of the American Institute of Electrical Engineers and the Institution of Electrical Engineers in London on February 16, 1928, interconnected by the transatlantic telephone circuit. In this meeting, addresses were heard by both audiences and a resolution made in London and seconded in New York was jointly and unanimously carried. It is possible that this may foreshadow a future important use of a public address system.

Television

The possibility of transmitting pictures of a scene over electrical circuits at so high a speed that the effect is given of seeing at a distance has naturally interested telephone people for a considerable while. However, the large amount of detail which is taken in by the human eye and the resulting broad band of frequencies required to transmit this detail as well as the necessary complexity of the terminal apparatus has, so far, prevented the development of a practical service of this kind.

In 1927 the Bell engineers demonstrated to a large number of interested people a television circuit which extended from New York to Washington, a distance of about 440 kilometers. The television pictures so demonstrated had a detail corresponding to 50 lines in each direction, that is 2,500 elementary areas and 18 such pictures were shown each second. Two circuits especially corrected for volume and phase distortion over a band width of about 20,000 cycles were employed between the two cities. These circuits were, for the most part, in open wire although approximately 13 kilometers of specially loaded cable were necessary at the ends in entering the cities. By means of a separate talking circuit a person at one end of the system could talk to, as well as see, a person at the other end. Systems of approximately twice the detail and also systems adapted to the viewing of larger scenes such as athletes in action have since been developed and demonstrated.

Time Service

Arrangements have been made in many parts of the country to furnish subscribers who desire it, accurate information as to the time of day. A subscriber wishing the information asks for or dials a particular number assigned for this purpose and is connected either to an operator who advises him individually as to the time or is switched across a bus-bar to which is connected the amplified speech of an operator repeating at fifteen second intervals the exact time of day. In the present development of this service it is the practice to localize in one place the time service for an entire exchange area.

By-Products

Certain interesting and important by-products of the telephone development work justify a brief mention. Three arts separate from the telephone art have been radically changed by such by-product developments. These include submarine telegraphy, phonographs and motion pictures.

The changes in submarine telegraphy have resulted from development by the Bell Laboratories of the materials known as "permalloy" and "perminvar" which have unusual magnetic properties at low flux densities. Submarine cables so loaded can transmit approximately 10 times as many words per minute in one direction as compared to cables of the same weight as previously constructed. As such loaded cables are not duplexed the effective increase in speed of transmission is approximately five times.

Development work in connection with the faithful recording and reproduction of sound has greatly improved phonographs and their records. The "Orthophonic Victrola" is an example of such development.

An extension of this work led to the development of the "talking" motion picture. The systems known under the names "Vitaphone" and "Movietone" followed from this work. Great interest has been aroused in such systems in the amusement field in the United States.

Moving picture houses in the important cities and towns are already equipped to show pictures of this type and it appears destined to revolutionize the motion picture art.

A study of speech and hearing in connection with telephone service has led to the development of various devices of value to those having abnormal hearing or speech. This work has been carried out in close cooperation with interested members of the medical profession. One of these devices, the "audiometer," is useful in determining the condition of hearing of individuals by determining the smallest volume of sound at a considerable number of different frequencies which the individual can hear. This device, in rapidly testing large groups of people such as in the public schools, is believed to be of considerable importance. Sound amplifying devices are provided for those hard of hearing.

Another interesting by-product is an artificial larynx for those who have lost their natural larynx as a result of pathological conditions. Apparatus has also been constructed to permit the totally deaf to understand speech sounds by holding their fingers against a moving diaphragm. In one form the individual fingers and thumb are held against separate vibrating bodies and the important range of speech sounds is divided by electrical filters and one part of it applied to each of these five vibrating bodies. This partial electrical analysis of sound appears to be of considerable help in this tactual appreciation of sound.

Other tools of interest to the medical profession include electrical stethescopes and electro-cardiographs. The first of these permits any desired number to listen to chest or other sounds in medical patients. Electrical filters may be interposed in such arrangements to exaggerate or subordinate certain part of the sound. The electro-cardiograph, by permitting the amplification and recording of slight differences of electrical potential between selected points of the skin of a patient give an indication of the condition of his heart beat.

Conclusion

In the above discussion, while emphasis has been placed upon engineering matters, it has naturally been impossible in the discussion of results to separate engineering considerations from many other important phases of the telephone communication problem. While engineering is essential to the results that have been obtained, they are due also to these other factors, commercial and general in their character, and to the policies as regards service and operations which guide the Bell Telephone System. Furthermore, the solution worked out has been designed specifically to meet conditions in the United States, conditions which in many respects are different in the different countries.

It is, of course, not possible in a paper of such broad scope to give technical details of the engineering problems involved. These have, however, been quite fully set forth in numerous articles in the technical press of the United States. For the convenience of those who may wish to refer further to these matters, a bibliography containing a selected list of some of the more important articles is attached to this paper.

In looking forward, there seems to be no doubt that the development of telephone communication in the United States, commercially and technically, will be more rapid than in the past, not less rapid. There are strong indications that in the future very much larger amounts of telephone service, both exchange and toll, will be demanded than at the present time, and in fact that for a number of years at least the rate of growth will continue to increase. The type and extent of services supplied will be modified to meet the broadening and multiplying demands of the changing business and social structure of the country. Finally, it is evident that the rapid advance of science will continue to bring forward new possibilities by means of which new and improved forms of communication systems, apparatus, and materials, can be developed.

These facts all indicate that the engineering work for the telephone communication system of the United States is not complete nor decreasing in magnitude or importance, but on the contrary it is increasing in volume and complexity and in the importance of the problems to be undertaken and solved.

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Statistics of the Telephone Industry of the United States

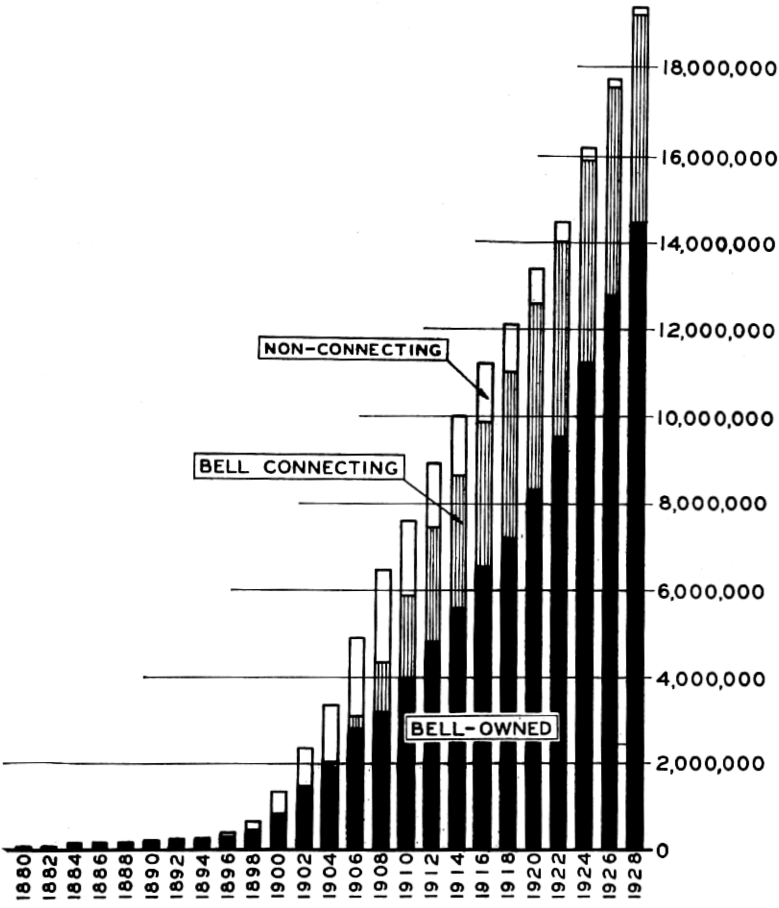

Fig. 57—Number of telephones in the United States.

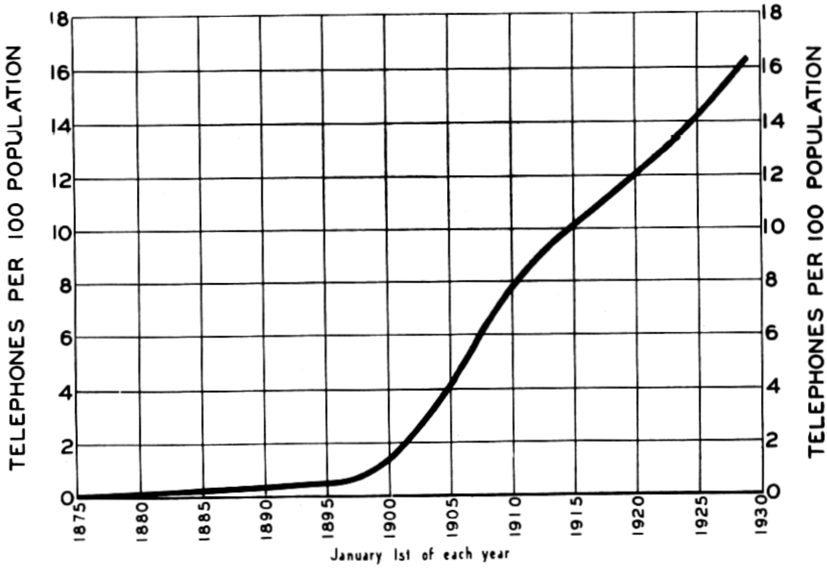

Fig. 58—Telephone development in the United States.

PERCENTAGE DISTRIBUTION OF BELL STATIONS IN FIFTEEN LARGE CITIES IN THE UNITED STATES, JANUARY 1, 1929

City	Population—Local Service Area	Number of Bell Telephones	Per cent. of Total Stations					
			Main		Private Branch Exchange	Extension	Business	Residence
			Individual	Party				
New York	6,310,100	1,702,889	51.3	5.8	34.9	8.0	53.1	46.9
Chicago	3,250,000	942,015	15.6	51.6	26.8	6.0	43.0	57.0
Philadelphia	2,040,200	375,756	25.5	40.6	24.1	9.8	46.6	53.4
Boston	1,821,400	424,781	20.8	49.4	21.4	8.4	41.2	58.8
Detroit	1,678,200	321,439	20.4	46.4	24.8	8.4	40.9	59.1
Los Angeles	1,337,000	357,504	17.4	49.5	25.2	7.9	43.6	56.4
Cleveland	1,135,800	226,186	19.0	46.9	24.4	9.7	40.1	59.9
St. Louis	1,093,500	213,041	20.5	50.6	21.3	7.6	40.9	59.1
Pittsburgh	961,000	215,125	21.9	48.6	20.4	9.1	38.7	61.3
San Francisco	751,500	252,225	27.7	31.3	31.9	9.1	48.6	51.4
Milwaukee	675,000	146,677	20.9	52.4	18.5	8.2	40.3	59.7
Washington	525,500	154,041	31.3	21.0	38.4	9.3	48.1	51.9
New Orleans	519,000	71,844	33.1	39.3	17.1	10.5	43.4	56.6
Minneapolis	492,000	126,888	30.0	40.4	20.1	9.5	33.3	66.7
Atlanta	345,000	64,546	26.8	43.8	19.4	10.0	42.7	57.3

FIG. 59

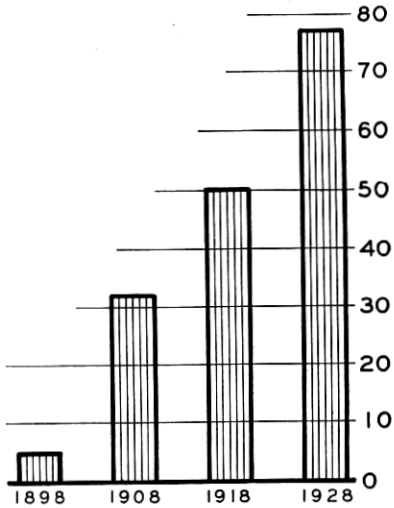

Fig. 60—Telephone conversations—Average number daily in millions in United States.

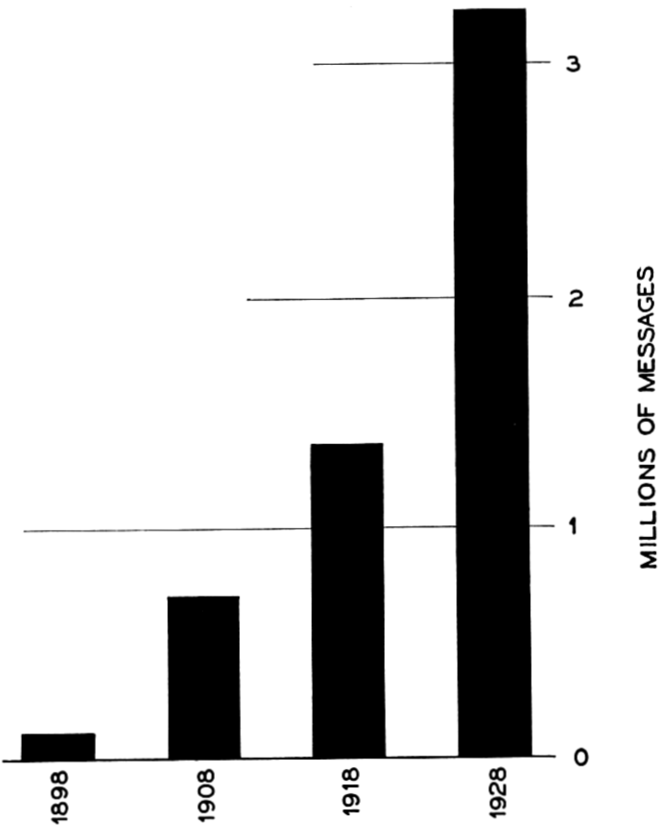

Fig. 61—Average daily number of toll messages in the United States.

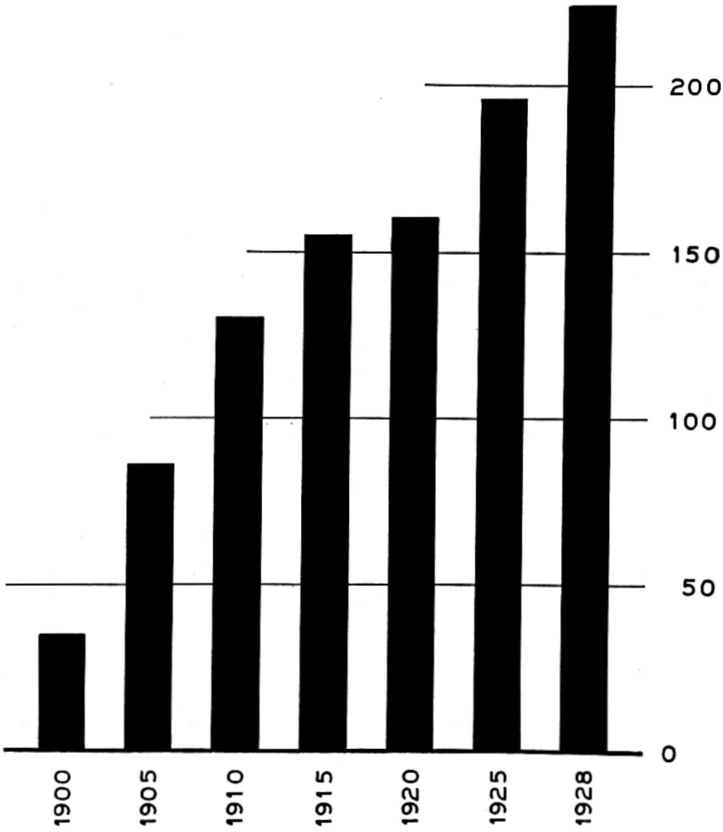

Fig. 62—Yearly telephone messages per capita in the United States.

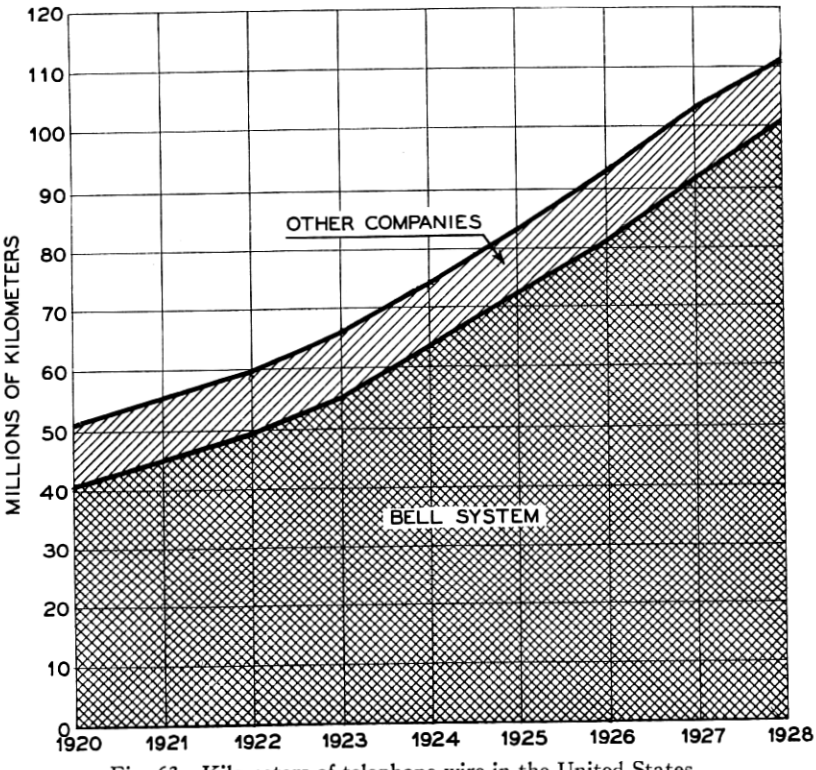

Fig. 63—Kilometers of telephone wire in the United States.

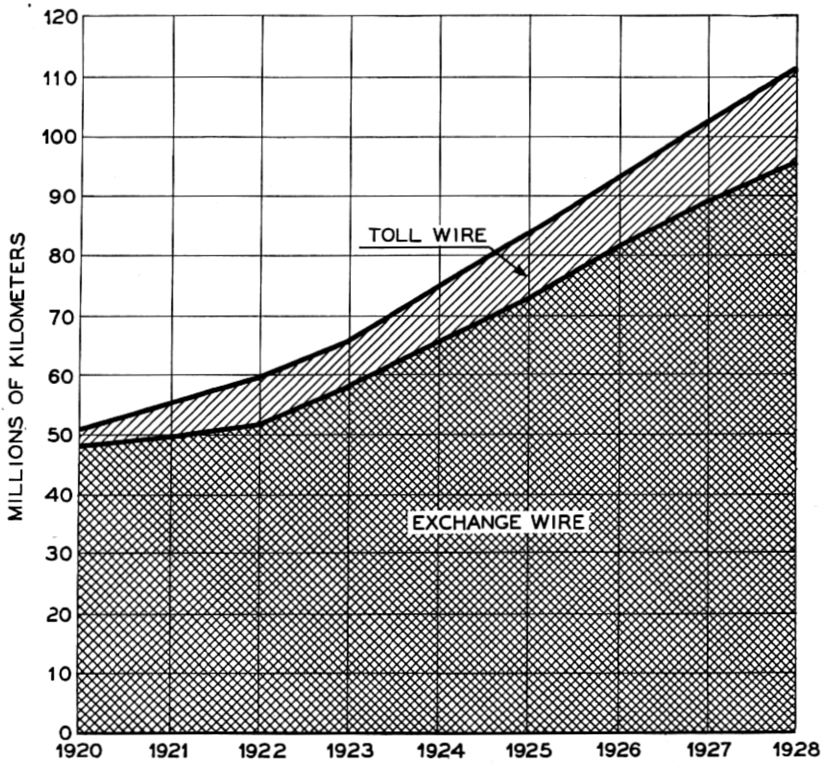

Fig. 64—Kilometers of exchange and toll wire in the United States.

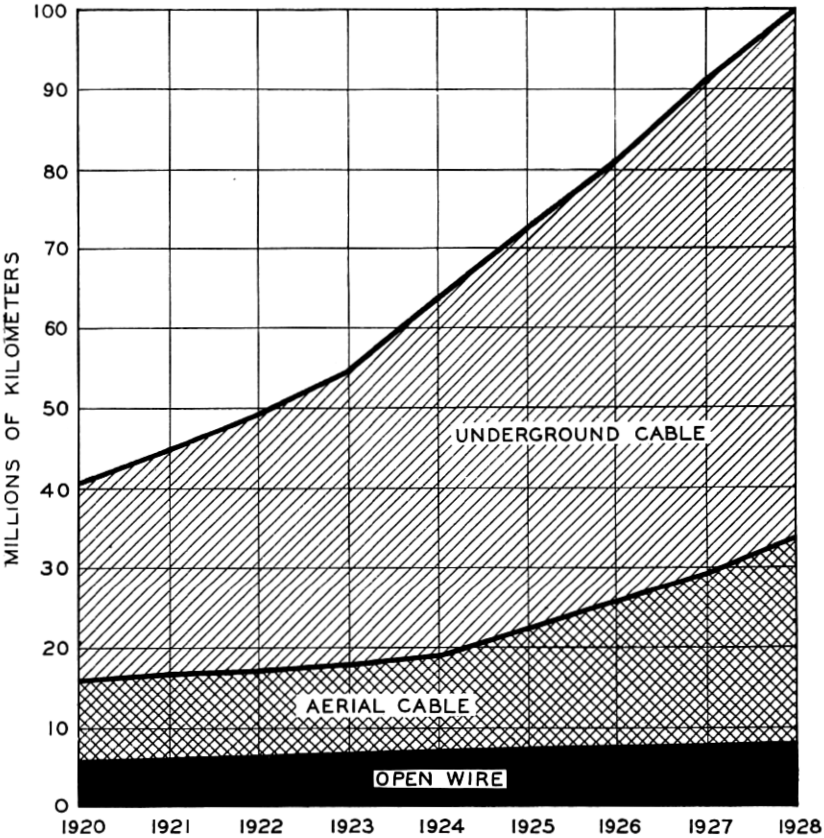

Fig. 65—Telephone wire in the Bell System in millions of kilometers.

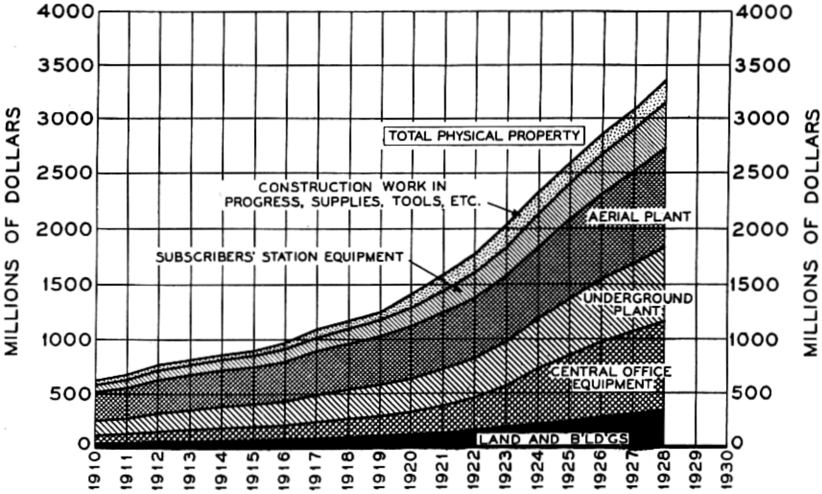

Fig. 66—Growth of various classes of physical property of the Bell System.

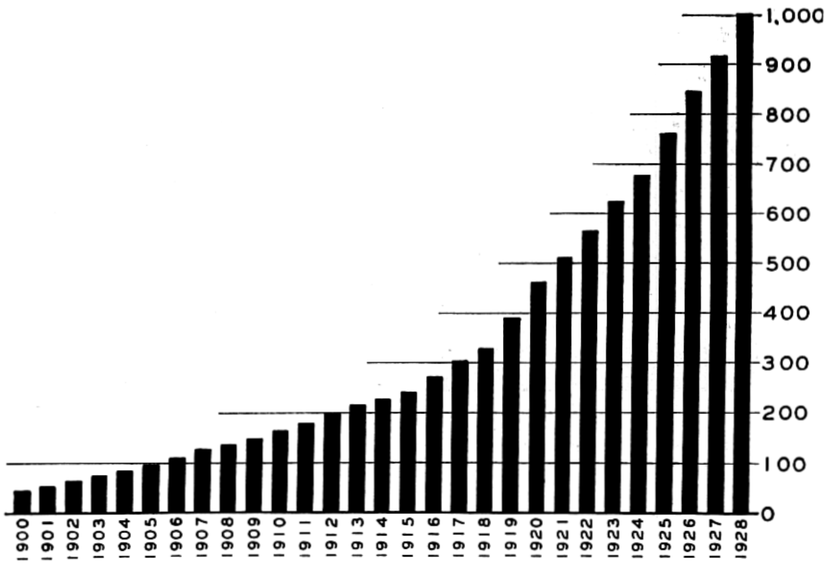

Fig. 67—Bell System revenues in millions of dollars.

TABLE SHOWING INITIAL PERIOD TOLL RATES ...
COMPANY, FEBRUARY 1, 1929

Air Line Kilometers (Fractions Omitted)	Station-to-Station			Person-to-Person All Hours	Report Charge	Air Line Kilometers (Fractions Omitted)	Station-to-Station			Person-to-Person All Hours	Report Charge
	4:30 A.M.–7:00 P.M.	7:00 P.M.–8:30 P.M.	8:30 P.M.–4:30 A.M.				4:30 A.M.–7:00 P.M.	7.00 P.M.–8.30 P.M.	8.30 P.M.–4:30 A.M.		
0– 19	$.10	$.10	$.10	$.20	$.10	711– 763	$1.95	$1.65	$1.10	$2.45	$.50
19– 29	.15	.15	.15	.25	.10	763– 814	2.05	1.75	1.15	2.55	.50
29– 39	.20	.20	.20	.30	.10	814– 866	2.15	1.80	1.20	2.75	.55
39– 48	.25	.25	.25	.35	.10	866– 969	2.35	1.95	1.30	3.00	.60
48– 58	.30	.30	.30	.40	.10	969–1072	2.55	2.10	1.40	3.25	.65
58– 68	.35	.35	.35	.50	.10	1072–1175	2.75	2.25	1.50	3.50	.70
68– 77	.40	.35	.35	.55	.10	1175–1303	3.00	2.45	1.65	3.75	.75
77– 90	.45	.35	.35	.65	.10	1303–1432	3.25	2.65	1.75	4.00	.80
90–103	.50	.40	.35	.70	.15	1432–1561	3.50	2.80	1.90	4.50	.90
103–116	.55	.40	.35	.75	.15	1561–1689	3.75	3.00	2.00	4.75	.95
116–129	.60	.45	.35	.80	.15	1689–1818	4.00	3.25	2.25	5.00	1.00
129–145	.65	.50	.35	.85	.15	1818–1947	4.25	3.50	2.50	5.25	1.00
145–161	.70	.55	.35	.90	.20	1947–2076	4.50	3.75	2.50	5.75	1.00
161–177	.75	.55	.40	.95	.20	2076–2204	4.75	4.00	2.75	6.00	1.00
177–193	.80	.60	.40	1.00	.20	2204–2333	5.00	4.25	3.00	6.25	1.00
193–225	.85	.65	.45	1.05	.20	2333–2397	5.25	4.25	3.00	6.50	1.00
225–241	.90	.70	.50	1.15	.25	2397–2462	5.50	4.25	3.00	7.00	1.00
241–261	.95	.75	.50	1.20	.25	2462–2590	5.75	4.50	3.25	7.25	1.00
261–280	1.00	.80	.55	1.25	.25	2590–2719	6.00	4.75	3.50	7.50	1.00
280–299	1.05	.85	.55	1.30	.25	2719–2848	6.25	5.00	3.50	7.75	1.00
299–319	1.10	.85	.60	1.40	.30	2848–2977	6.50	5.25	3.75	8.25	1.00
319–357	1.15	.90	.60	1.45	.30	2977–3105	6.75	5.50	4.00	8.50	1.00
357–377	1.20	1.00	.65	1.50	.30	3105–3234	7.00	5.50	4.00	8.75	1.00
377–396	1.25	1.00	.70	1.55	.30	3234–3363	7.25	5.75	4.25	9.00	1.00
396–415	1.30	1.05	.70	1.65	.35	3363–3492	7.50	6.00	4.50	9.50	1.00
415–454	1.35	1.10	.75	1.70	.35	3492–3620	7.75	6.25	4.50	9.75	1.00
454–473	1.40	1.15	.80	1.75	.35	3620–3749	8.00	6.50	4.75	10.00	1.00
473–492	1.45	1.20	.80	1.80	.35	3749–3878	8.25	6.75	5.00	10.25	1.00
492–531	1.50	1.25	.85	1.90	.40	3878–4006	8.50	6.75	5.00	10.75	1.00
531–550	1.55	1.30	.90	1.95	.40	4006–4135	8.75	7.00	5.25	11.00	1.00
550–570	1.60	1.35	.90	2.00	.40	4135–4264	9.00	7.25	5.50	11.25	1.00
570–608	1.65	1.40	.95	2.05	.40	4264–4393	9.25	7.50	5.50	11.50	1.00
608–634	1.70	1.45	1.00	2.15	.45	4393–4521	9.50	7.50	5.75	12.00	1.00
634–660	1.75	1.50	1.00	2.20	.45	4521–4650	9.75	7.75	5.75	12.25	1.00
660–685	1.80	1.55	1.05	2.25	.45	4650–4779	10.00	8.00	6.00	12.50	1.00
685–711	1.85	1.60	1.05	2.30	.45	4779–4907	10.25	8.25	6.25	12.75	1.00

FIG. 68

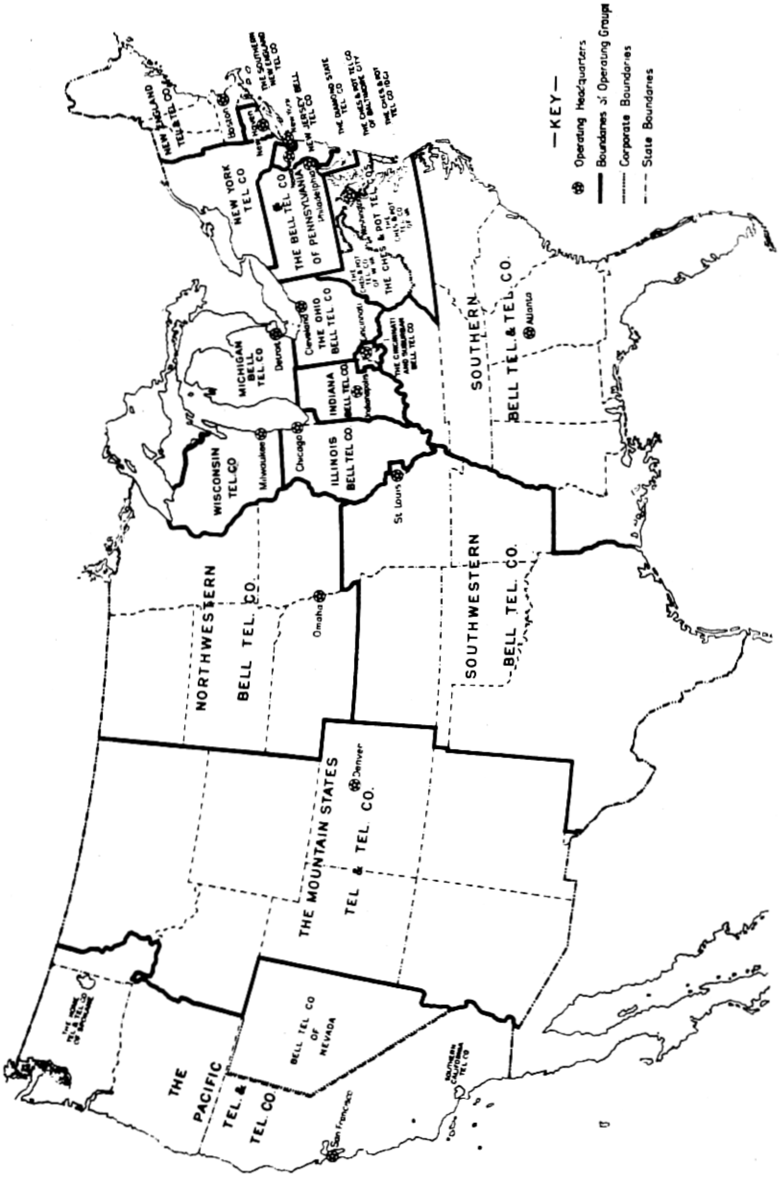

Fig. 69—The Bell Telephone System showing territories of the associated operating companies.

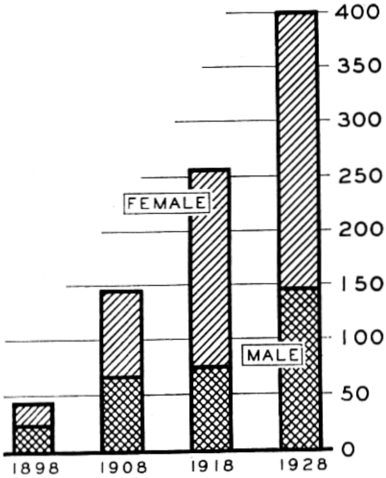

Fig. 70—Thousands of telephone employees in the United States.

Transatlantic Telephone Service

List of places which may be connected with the transatlantic telephone service at the present time. The figures shown both for population and telephones are estimates for January 1, 1929.

	Total Population	Total Telephones	Number Served by Transatlantic Connection: Population	Number Served by Transatlantic Connection: Telephones
England, Scotland, Wales, and Northern Ireland	45,830,000	1,780,000	45,830,000	1,780,000
Germany	64,860,000	3,000,000	64,860,000	3,000,000
Belgium	8,000,000	225,000	8,000,000	225,000
Holland	7,750,000	250,000	7,750,000	250,000
Switzerland	3,990,000	236,000	3,990,000	236,000
France	41,370,000	1,000,000	37,900,000	935,000
Denmark	3,530,000	340,000	782,000	130,000
Norway	2,820,000	180,000	250,000	44,500
Sweden	6,150,000	484,000	760,000	169,000
Danzig	400,000	17,300	400,000	17,300
Spain	22,600,000	156,000	22,600,000	156,000
Austria	6,950,000	175,000	1,970,000	116,000
Hungary	8,620,000	134,000	1,000,000	50,000
Czechoslovakia	14,600,000	140,000	725,000	35,000
Gibraltar	17,000	500	17,000	500
Luxemburg	280,000	9,000	50,000	3,000
Total Europe	237,767,000	8,126,800	196,884,000	7,147,300
Spanish Morocco	1,000,000	600	37,000	300
Total Africa	1,000,000	600	37,000	300
United States	118,500,000	19,197,000	118,500,000	19,197,000
Canada	9,800,000	1,330,000	9,800,000	1,330,000
Mexico	15,500,000	70,000	1,500,000	31,600
Cuba	3,650,000	80,000	3,650,000	80,000
Total North America	147,450,000	20,677,000	133,450,000	20,638,600
Grand Total	386,217,000	28,804,400	330,371,000	27,786,200
World Total	1,930,000,000	32,800,000		
Percentage of Number Served to World Total	17%	85%		

Fig. 71