Early Work on Dial Telephone Systems

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The first commercial telephone exchange, employing one operator, was opened for service at New Haven, Conn., in January, 1878, and within a short time exchanges had been established in a number of cities throughout the country.* Almost immediately, and, of course, long before the requirements of the switching art were clearly envisioned, inventors in many walks of life began devising schemes for performing the switching operations by machines instead of by operators. The patented art in any new development is usually well in advance of the commercial art, and in the early work on dial exchanges, many of the fundamental ideas came from inventors who were without technical training or practical telephone experience, and whose mechanical arrangements for embodying their ideas were apt to be impractical or unworkable.

Dial telephone systems derive their name from the use of a dial, or equivalent device, operated by a subscriber or operator to produce the interruptions of current that direct or control the switching process at the central office. The use of a dial for such purposes, however, is much older than the telephone. It was suggested by William F. Cooke in 1836 in connection with telegraphy, and was first used in Professor Wheatstone's dial telegraph of 1839. During succeeding years, it was the subject of many improvements, and was employed not only in dial telegraph systems, but in fire alarm and district messenger systems. Figure 1 shows Froment's telegraph transmitting and receiving dials of 1851. When the pointer P of the transmitting dial (a) is moved to the letter D, for example, four teeth of wheel R will be moved past spring M, and four makes and breaks of the battery current will take place. These will attract the armature, a, of electromagnet b, at the distant station (b) four times, and, by means of pawl F, will give four movements to ratchet wheel G, thus advancing the pointer of the receiving dial (c) to letter D. In this way, the telegraph message was spelled out, letter by letter. The modern type of finger-wheel dial — an important mechanical improvement over the pointer type of dial — did not appear until 1896.

The first dial telephone exchange patent, No. 222,458, was applied for on September 10, 1879, and issued on December 9, 1879, jointly to M. D. Connolly, of Philadelphia; T. A. Connolly, of Washington, D. C.; and T. J. McTighe, of Pittsburgh. Although this first system was crude in design and limited to a small number of subscribers, it nevertheless embodied the generic principle of later dial systems. At each station, in addition to the telephone, battery, and call bell, were a reversing key, a compound switch, and a dial (Figure 2a) similar to that employed in dial telegraph systems, and bearing on its face the numbers corresponding to the different stations of the exchange. At the central office (Figure 2b) were ratchet wheels: one wheel for each station, mounted one above the other on a common vertical shaft and carrying wiper arms which moved with the ratchets. Actuated by the circuit interruptions made by the calling subscriber dial, an electromagnet stepped the wiper arm around to engage the contact of the called subscriber line.

Although the switching mechanism was relatively simple, various manipulations of the reversing key and compound switch

* RECORD, *February*, 1931, *page* 265.

were required by both parties to a conversation to make the necessary circuit shifts at the station, to reverse the current on the line, to operate the call bells, and to restore the switching apparatus to normal when the parties were through talking.

The Connolly and McTighe system, with eight stations connected, was exhibited at the Paris Exposition in 1881, and various modifications were made in it by its inventors in subsequent patents. It was never employed in commercial service.

Between 1879 and 1900, a great many patents covering dial switching systems were issued, but except for the Strowger patent (No. 447,918) of 1891 and subsequent patents pertaining to the Strowger system, none resulted in a successful commercial system. A list of the patents falling within the Patent Office classification "Automatic Telephone Exchanges," is given in Table I. Several other patents covering automatic village, house, and factory systems, not included in the above list, were also issued during this period.

The twenty-six patents on the list that were issued between the Connolly and McTighe patent of 1879 and Strowger patent No. 447,918 of 1891 all related to the operation of small exchanges, and for the most part employed complicated electromagnetic step-by-step arrangements, constantly running synchronized clockwork mechanisms, reversals of current direction, changes in current strength, and the like. None of them can be said to have advanced the automatic switching art in any practical manner, nor did any of them, so far as is known, go into commercial use.

Patents Nos. 223,201 and 223,202, issued to George Westinghouse, Jr., in December, 1879, were the first to provide for the operation of a number of suburban, or satellite, exchanges connected to the main manually-operated exchange in a city.

The Village system invented by E. T. Gilliland, of the American Bell Telephone Company, and covered by patent No. 306,-238, of October 7, 1884 (not included in Table I), with subsequent improvements, enjoyed a limited commercial use. It employed a number of main lines which entered all of the subscriber stations, thus eliminating the central office altogether. To make a call, a subscriber pushed in a knob corresponding to the line on which the desired station was located, which connected his telephone to that line. If, on listening,

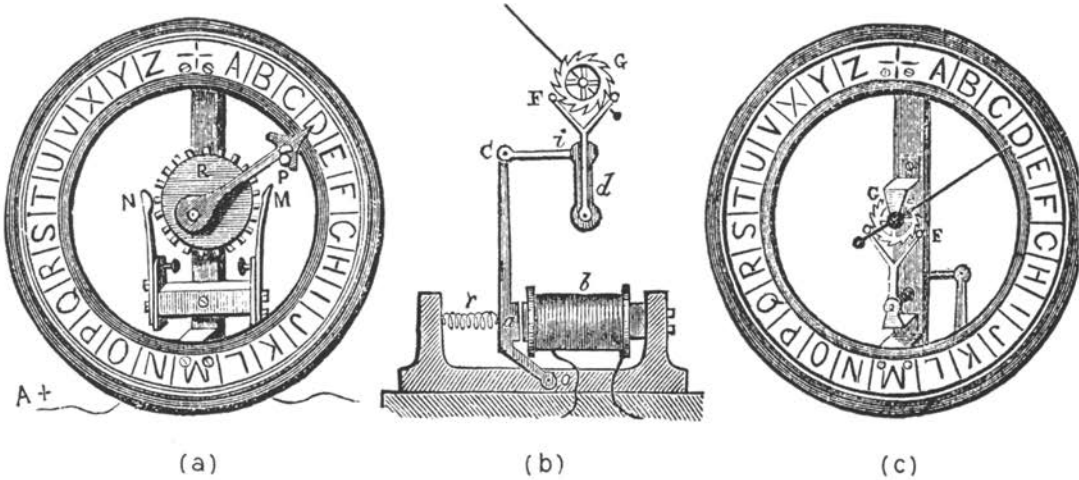

Fig. 1—Transmitting dial (a) and receiving dial (c) used with Froment's alphabetical telegraph system of 1851 (from Shaffner's Telegraph Manual) together with the electromagnet, ratchet, and pawl arrangement used with the receiving dial (b).

he found that the line was not in use, he rang the wanted subscriber with his magneto generator, and conversed with him. This Village system, which was first installed at Leicester, Mass., in 1885, and was afterward employed in a number of small towns, was exhibited at the Chicago World's Fair in 1893.

In 1886, Gilliland also patented an "Automatic Circuit Changer," patent No. 334,014, whereby the operator at Worcester could pulse a rotary selector at Leicester, six miles away, selecting and ringing any desired line of the Village system. This might be considered an embryonic form of operator dialing. It was placed in actual commercial use in 1885.

Foreshadowing the complexity of later switching systems was another patent, No. 435,295, issued to Dr. William H. Ford, of St. Louis, in August 1890. It was the result of several years' work by its inventor, and contained twenty-seven sheets of drawings and twenty-two pages of specification.

Thomas D. Lockwood, manager of the American Bell Company's Patent Department, also entered the dial switching field, and was granted two patents, Nos. 335,708 and 372,378, issued in 1886 and 1887, respectively.

In 1889, H. V. Hayes and H. D. Sears, of the American Bell Telephone Company, devised a dial system for small exchanges, which was afterward covered by patent No. 457,477, issued in 1891. It employed at the central office a motor-driven rotary commutating mechanism for each line, which could be set in motion, through a polarized relay and other intervening appliances, by plus or minus currents sent out over the line by the subscriber magneto generator. The method of operation was quite complicated, and the system never passed the laboratory stage. It represented, however, the first work of American Bell engineers on true dial exchanges.

The real advances in the dial exchange art prior to the Strowger patent of 1891 came from inventions not directly related to automatic telephone systems.

On November 2, 1889, for example, J. G. Smith, of New York City, applied for a patent on a dial switching system for telegraph lines, which was issued on August 23, 1892, as patent No. 481,247. This was the first patent to clearly disclose the use of trunks* between groups of selectors, including the automatic selection of an idle trunk, which later became an essential feature of all but the smallest dial telephone exchanges.

For the purpose of reducing the cost of giving private wire service to brokers and others who desired telegraph connection between their offices in different cities, the inventor provided only enough trunk lines to serve the maximum number of subscribers who would be telegraphing at any one time. To prevent two or more subscribers from being connected to the same trunk, he devised a mechanism for hunting for the first trunk that was not in use. At each subscriber station was a dial, with holes bearing the numbers of the distant local circuits with which communication might be desired, and means for setting in motion the central office mechanism. At the local central office, each subscriber line terminated in a switch, or selector, whose function was to select an idle trunk. The trunk lines were multipled to the bank contacts on each selector, so that each subscriber line could connect with every trunk. Each trunk line terminated, at the distant central office, in a switch, or connector, which made the connection with the desired subscriber line. All of the subscriber lines at the distant central office were multipled to the banks of all of the connectors. Power for actuating the switches was supplied by a constantly rotating shaft driven by a small motor.

The apparatus and method of operation of this system were far too complicated for an adequate description here. Briefly stated, a subscriber desiring a connection inserted a brass plug in the proper hole in his dial plate, and, by operating suitable hand switches, caused his selector clutch to engage a constantly rotating disc, which advanced the selector brushes over the trunk terminals until the test brush encountered an idle trunk, whereupon the clutch was disengaged and the brush stopped. This connected the calling subscriber line, through the selected trunk, to a connector switch at the distant central office, whose brushes ad-

* In manual switching, trunking had been employed for many years.

vanced over the terminals of the subscriber lines, one step at a time. For each of these steps, the calling subscriber dial arm made a corresponding advance until it encountered the brass plug which had been inserted in a hole, whereupon a change in the current strength took place, which stopped the distant connector on the proper terminal, and the desired connection was completed.

Although the important feature of the Smith patent was the adoption of the trunking principle, the invention also employed the principle of reverse impulse control which, in a different form, is a feature of the Bell System panel dial system.

In two later patents, Nos. 550,728 and 550,729, issued in 1895, J. G. Smith applied the features of his dial telegraph exchange to telephone exchange operation.

Patent No. 329,874, issued to Thomas Ahearn, of Ottawa, Canada, in 1885, covered a watchman's signal. In order to compel a watchman, in making his rounds, to be at each station at the proper time, the inventor provided at the central station a constantly rotating brush, driven by clockwork, which slowly wiped over the contacts of the lines to the various signal stations and closed the circuit of each for a definite period of time. If the watchman did not arrive at a station within the appointed time interval, he was unable to send in his signal, as the circuit through the central station indicator was destroyed. Instead, an alarm sounded at the central station. This patent was only a partial disclosure of the line finder principle, since no provision was made for stopping the rotating brush on a particular line. It is mentioned here because it was cited by the Patent Office in connection with the Van Size invention referred to below.

Patent No. 393,529, issued to W. B. Van Size, of Plainfield, N. J., on November 27, 1888, and subsequently reissued, disclosed an arrangement closely analogous to the line finder method of operation. To simplify the equipment at a manual operator's position, and to eliminate the annunciator drop, the

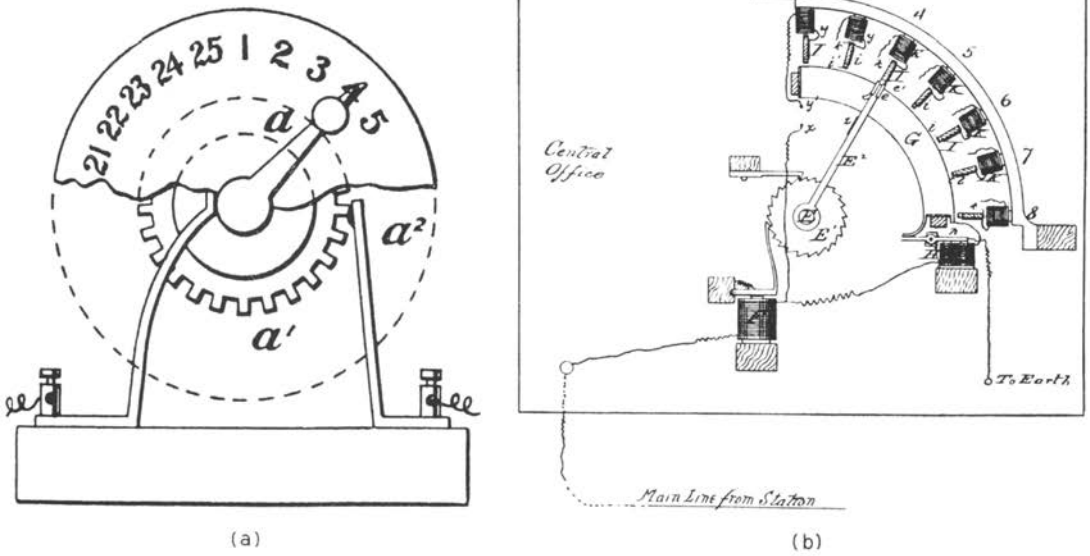

Fig. 2—Dial arrangement (a) and switching elements (b) for one subscriber's line illustrated in the Connolly and McTighe patent of 1879. Similar switching equipment, mounted on a common shaft E, was provided for each line of the exchange.

inventor provided at each position a constantly revolving radial arm or brush, connected to ground through an electromagnet and the operator's head telephone, which wiped over the circularly arranged contacts of the subscriber lines assigned to that switchboard position. When a calling subscriber operated a switch, connecting his battery to the line, it actuated the electromagnet as soon as the revolving brush reached his line terminal and, by means of a ratchet and pawl, stopped the brush on that terminal, thus connecting the operator's telephone into the circuit. The subscriber could then pass his call verbally to the operator, who completed it in the usual manner. Although the Van Size arrangement could hardly be called a simplification of the manual method of operation employed at that time, it did represent an interesting patent disclosure.

All dial switching systems prior to the early 1890's were severely handicapped by the lack of a reliable power plant. Primary cells, such as LeClanché, were the best available, and the voltage varied widely.

By 1900, only two general types of automatic telephone systems had been developed, although both had various subdivisions. In the first, and earliest, type, there was a direct connection of the calling and called line. Each subscriber line ended at the central office in the movable arm of an individual switch capable of making connection with the fixed terminals of any other line in the exchange. All of the subscriber lines were connected, or multipled, to the fixed terminals of each switch. Figure 3 illustrates this principle for an automatic exchange of eight subscriber lines. For the sake of simplicity, the multiple connections to only four of the eight lines are shown. As long as the number of lines in the exchange was small – not more than one or two hundred – this type of system was practicable. In large exchanges – several thousand lines, to take an extreme case – it is readily seen that the switches, with the necessary multiple connections, would be prohibitive in size and cost. The Connolly and McTighe system and the early Strowger installations were examples of this type.

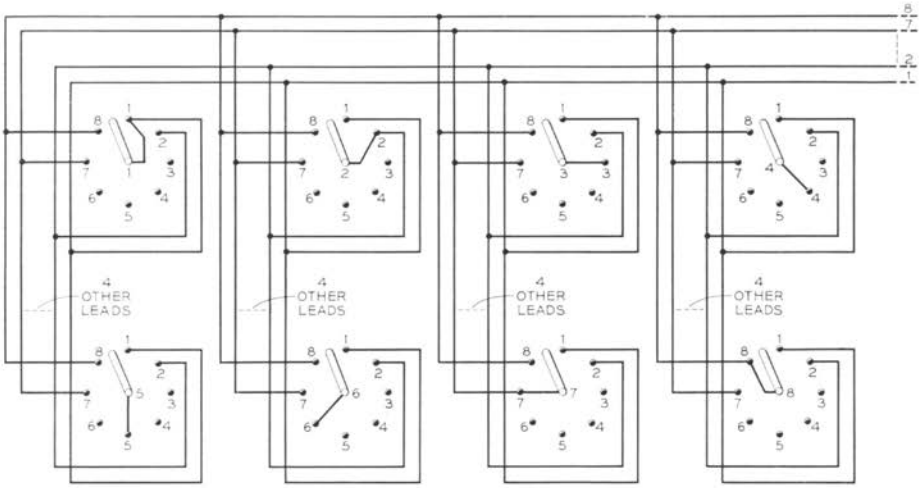

Fig. 3–Diagrammatic representation of the earliest type of automatic telephone exchange. At the central office there was an individual switch for each subscriber, to the wiper arm of which his line was permanently connected (center numbers). Each of the lines (eight shown in diagram) was also connected, or multipled, to its own peripheral contact on every switch.

The second, and later, type of automatic exchange employed the trunking, or transfer, principle, in which the direct connection between the terminals of the calling and called lines is discarded, and instead such connection is established through an office trunk, the function of the central office switches being, first, to unite the calling line to one end of an idle trunk, and then to unite the other end of the trunk to the called line. This method greatly diminished the first cost and complexity of the central office apparatus in large exchanges, since it permitted the use of switches of relatively small capacity. Only enough trunks had to be provided to handle the maximum number of calls made at any one time.

This second type of automatic system comprised two distinct classes. In one class, there was an individual switch for each subscriber line which, when operated, selected an idle trunk of a group leading to the bank of terminals in which the called line was located, and then, by means of another switch, connected that trunk to the terminals of the desired line. In Figure 3, for instance, the peripheral contacts, of which there would be 100 or more for a large exchange, are now the terminals of trunk circuits leading to the switch arms of selectors which make the final connection. In this class were included the later Strowger installations.

In the other class of the second type, the subscriber lines were not provided with individual selecting switches, and there was no such apparatus normally connected with their lines. Instead, the several trunk circuits assigned to a group of subscriber lines were each provided with a suitable selecting switch, or "line finder," at their calling circuit ends, adapted to seize upon and connect with the terminals of a calling line, to unite those terminals with an idle trunk, and then by means of suitable switching devices to join the other end of the trunk with the terminals of the called line. This "line finder" method of operation was first employed in the Lorimer and Faller systems. As there used, a constantly operating mechanism brought a switch common to a group of lines into successive contact with the terminals of the lines and detected the changed electrical condition produced when any line had originated a call. A path was then provided from the calling line to an idle selector, which the calling subscriber could actuate to complete his call. Line finders of forms not requiring continuous scanning were used in later Western Electric and Strowger Systems.

During the first twenty-five years of the telephone, up to the beginning of the twentieth century, the attempts to devise a dial switching system had been made primarily by inventors without practical telephone experience, as has already been noted. The problem was interesting in its theoretical aspects, and all over the country men of an inventive turn of mind and with some knowledge of electricity tried their hand at solving it. Some of the many bizarre proposals have already been described in the Record*. As a matter of fact, however, there was very little need for a dial system in these early years of the telephone art.

The objective in the minds of the many inventors was probably to save the cost of operators, but for the most part they knew too little about the telephone system and its requirements to realize that with an adequate dial system the saving in salaries of the operators would be largely if not entirely offset by the greatly increased maintenance expenses of the more elaborate switching apparatus and by the carrying charges on the much greater investment required. The real need for dial switching is due primarily to other and much more complex technical and economic factors, and did not arise in any appreciable intensity until well after the turn of the century.

The engineers of the Bell System had been closely following the dial system patents from the very beginning, and had carried on a little development along these lines as early as the late 1880's. They recognized the difficulties, however, and knew how little would be gained from dial switching under existing conditions. There was far greater need for developments along other lines — in instruments and station apparatus, in transmission systems and methods, and in underground distributing systems. During the 1890's and early 1900's, for example, they were very much occupied in developing and

* Record, *March*, 1929, *page* 265.

Table I — List of United States Patents on Automatic Telephone Exchanges Issued During the Years 1879-1900, Inclusive.*

Number	Date Issued	Patentee	Application Date
222,458	Dec. 9, 1879	Connolly & McTighe	Sept. 10, 1879
223,201	Dec. 30, 1879	Westinghouse, G. Jr.	Oct. 11, 1879
223,202	Dec. 30, 1879	Westinghouse, G. Jr.	Oct. 13, 1879
224,565	Feb. 17, 1880	Westinghouse, G. Jr.	Oct. 27, 1879
237,222	Feb. 1, 1881	Westinghouse, G. Jr.	Feb. 7, 1880
248,138	Oct. 11, 1881	Buell,C. E.	June 15, 1881
255,766	Apr. 4, 1882	Buell,C. E.	Dec. 12, 1881
262,645	Aug. 15, 1882	Connolly & McTighe	Aug. 29, 1881
262,646	Aug. 15, 1882	Connolly, M. D.	Nov. 29, 1881
262,647	Aug. 15, 1882	Connolly, M. D.	Nov. 8, 1881
263,862	Sept. 5, 1882	Connolly, M. D.	Oct. 29, 1881
269,130	Dec. 12, 1882	Snell, F. H.	Sept. 6, 1882
281,613	July 17, 1883	Cardwell, G. A.	July 7, 1882
282,791	Aug. 7, 1883	Snell, F. H.	Feb. 28, 1883
283,806	Aug. 28, 1883	O'Donel, I. M.	June 5, 1880
290,730	Dec. 25, 1883	Bartelous, J. V. M.	June 15, 1882
295,356	Mar. 18, 1884	Connolly, T. A.	Apr. 10, 1883
310,282	Jan. 6, 1885	Jackson & Cole	Mar. 5, 1884
335,708	Feb. 9, 1886	Lockwood, T. D.	Sept. 26, 1885
349,975	Sept. 28, 1886	Bickford, J. H.	Nov. 25, 1885
349,976	Sept. 28, 1886	Bickford, J. H.	Jan. 18, 1886
367,219	July 26, 1887	McCoy, J. A.	Jan. 29, 1887
372,378	Nov. 1, 1887	Lockwood, T. D.	Apr. 11, 1887
381,938	May 1, 1888	McCoy, J. A.	July 6, 1887
408,327	Aug. 6, 1889	Smith, J. R.	Feb. 16, 1888
435,295	Aug. 26, 1890	Ford, W. H.	Dec. 31, 1889
442,734	Dec. 16, 1890	Smith & Childs	Sept. 27, 1889
447,918	Mar. 10, 1891	Strowger, A. B.	Mar. 12, 1889
457,477	Aug. 11, 1891	Hayes & Sears	Feb. 3, 1891
486,909	Nov. 29, 1892	Strowger, A. B.	Feb. 19, 1892
498,236	May 30, 1893	Clark, E. A.	Apr. 5, 1892
498,289	May 30, 1893	McCaskey, A. S.	July 29, 1892
498,291	May 30, 1893	McCaskey, A. S.	Aug. 25, 1892
499,748	June 20, 1893	McClaren, A. E.	June 13, 1892
510,195	Dec. 5, 1893	Serdinko, J.	Apr. 22, 1893
511,873	Jan. 2, 1894	Callender, R.	Apr. 24, 1893
511,874	Jan. 2, 1894	Callender, R.	May 12, 1893
511,875	Jan. 2, 1894	Callender, R.	Aug. 13, 1892
515,108	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
515,109	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
515,110	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
520,246	May 22, 1894	Simoneau, L. E.	July 11, 1893
528,590	Nov. 6, 1894	Childs, W.	May 12, 1891
528,591	Nov. 6, 1894	Childs, W.	May 27, 1890
530,324	Dec. 4, 1894	Callender, R.	Dec. 18, 1893
533,893	Feb. 12, 1895	Hey & Parsons	Mar. 30, 1893
535,806	Mar. 12, 1895	Nissl, F.	Feb. 17, 1894
537,603	Apr. 16, 1895	Decker, W.	May 14, 1894
538,975	May 7, 1895	McDonough, J. W.	May 21, 1891
540,168	May 28, 1895	Keith, Lundquist & Erickson	Nov. 7, 1894
543,160	July 23, 1895	Shibata, W. Y.	Oct. 11, 1894
543,708	July 30, 1895	Shibata, W. Y.	Nov. 24, 1893
546,725	Sept. 24, 1895	†Berditschewsky et al.	Mar. 27, 1895
547,755	Oct. 8, 1895	Hutchins, G. K.	May 6, 1893
550,728	Dec. 3, 1895	Smith, J. G.	Feb. 18, 1893
550,729	Dec. 3, 1895	Smith, J. G.	Feb. 20, 1893
551,391	Dec. 17, 1895	Lounsbury, W. F.	Apr. 23, 1895
554,125	Feb. 4, 1896	Houts, W. A.	Dec. 24, 1894
556,007	Mar. 10, 1896	Freudenberg, M.	Jan. 10, 1896
561,377	June 2, 1896	Dean, G. Q. & J. Jr.	Aug. 3, 1895
562,064	June 16, 1896	†S. Berditschewsky	Mar. 23, 1896
570,840	Nov. 3, 1896	Brooks, M.	Jan. 26, 1895
573,859	Dec. 29, 1896	Callender, R.	Mar. 19, 1896
573,884	Dec. 29, 1896	Keith, A. E.	Sept. 16, 1893
574,245	Dec. 29, 1896	Houts & Nilson	Aug. 25, 1896
574,707	Jan. 5, 1897	Bowman, L. G.	July 18, 1896
582,578	May 11, 1897	Clark, Ellacott & Johnson	Sept. 28, 1893
584,384	June 15, 1897	Macklin, A. B.	Aug. 7, 1896
586,529	July 13, 1897	Davis, W. W.	Sept. 5, 1896
587,435	Aug. 3, 1897	Freudenberg, M.	Oct. 22, 1896
588,511	Aug. 17, 1897	Van Wagenen, A.	Apr. 30, 1896
589,798	Sept. 7, 1897	Strowger & Keith	Feb. 19, 1896
591,201	Oct. 5, 1897	Strowger, Lundquist & Erickson	July 17, 1895
597,062	Jan. 11, 1898	Keith & Erickson	Aug. 20, 1896
604,373	May 24, 1898	Decker, W.	Mar. 25, 1895
604,434	May 24, 1898	Stillwell & Barneck	Nov. 10, 1896
606,764	July 5, 1898	Lundquist, F. A.	May 19, 1897
611,974	Oct. 4, 1898	Nilson, L. G.	Mar. 9, 1896
612,681	Oct. 13, 1898	Snow, H. P.	Nov. 1, 1897
616,714	Dec. 27, 1898	Lundquist & Erickson	Mar. 28, 1893
624,666	May 9, 1899	Lundquist, F. A.	Sept. 20, 1897
626,983	June 13, 1899	Decker, W.	Aug. 3, 1896
632,759	Sept. 12, 1899	Slater, J. C.	May 23, 1898
638,249	Dec. 5, 1899	Keith & Erickson	Dec. 16, 1895
639,186	Dec. 12, 1899	Seligmann-Lui, G.	May 27, 1898

* Excludes village, house and factory systems. † Called "Apostoloff." Note:—No automatic telephone exchange patents were issued during the year 1900.

installing throughout the Bell System the common battery system to take the place of the local battery or magneto system that had been employed since the beginning of the telephone business. This system constituted one of the most important advances ever made in the telephone art, and opened the way for a tremendous expansion in telephone service. It also gave the engineers a much broader and clearer picture of the intricacies, both technical and economic, of the switching problem in large exchanges, together with all of the necessary traffic data to make intelligent plans for future requirements.

During the later years of the nineteenth century, moreover, many features were introduced to save operating effort, such as automatic ringing of a called subscriber when an operator plugged into his jack, and automatic tripping of the ringing when he answered. All of these developments and many others were paving the way for a really satisfactory dial system.

The first real need for dial operation within the Bell System arose in connection with some of the smaller communities where there was not a full time operating load for even one operator, and thus 24-hour service was very expensive. Work was accordingly started about 1900 on the development of a small dial exchange, and during 1902 a 50-line system was placed in experimental operation in Queens, Long Island. During the following year this was replaced by a 100-line system. Other such systems, of 20-line and 100-line capacity, were built during 1904 and 1905, to a total of more than 40. Experience indicated, however, that the operation of dial switching equipment in unattended offices brought in additional requirements that were difficult if not impossible to meet at that time. As a result, these installations were later reconverted to manual operation. It was not until many years later that dial switching for small unattended offices proved technically and economically practicable.

At about this same time, however, it began to become evident that before many years dial switching would be needed to meet the complex conditions in the larger cities, where it was foreseen that there would not be a sufficient number of competent operators available to do all switching manually. As a result, the development of dial switching within the Bell System had expanded into an intensive program by 1905. It resulted in the trial of a semi-automatic system at West Street in 1910, in the commercial installation of a semi-automatic panel system in Newark in 1915 and later in the full automatic panel dial system.

Although many patents had been issued on dial switching systems prior to the Bell System work beginning about 1900, and most of the elementary switching principles had been disclosed, none of the systems that were devised enjoyed any extensive commercial use except that of Almon B. Strowger and his associates. This latter system will be the subject of a forthcoming article.

THE AUTHOR: ROGER B. HILL received a B.S. degree from Harvard University in 1911 and entered the Engineering Department of the American Telephone and Telegraph Company in August of that year. For several years thereafter he was engaged principally in appraisal and depreciation studies. When the Department of Development and Research was formed in 1919, he transferred to it, and since then, until his retirement in 1951, had been largely concerned with studies of the economic phases of development and operation. He had been a member of the staff of Bell Telephone Laboratories since 1934, first in the Outside Plant Development Department and later in the Staff Department. In addition to his work on the economic side of the telephone business, Mr. Hill exhibited a great interest in the early history of the telephone art, and assisted with the preparation of several books and articles dealing with that subject.