DISCUSSION ON "MODERN AUTOMATIC TELEPHONE APPARATUS,"
NEW YORK, FEBRUARY 11, 1910

Chairman Maver: It may be of interest to note that in telegraphy two general systems are employed, namely, manual telegraphy, and automatic telegraphy. The first relates to the hand transmission of messages and the second to the machine transmission of messages. In telephony we also have manual and automatic systems, so called, but these relate to the manner in which subscribers' circuits are coupled into one metallic circuit at the exchange and have nothing to do with the transmission per se of communications, which is of course effected by the subscribers' voice. It is of course well known that in the present day practice of telephony each subscriber in a given district is connected with central by two wires, the terminals of which, in the manual system, are led into a switch board in the exchange and normally end there. There is in the circuit of these wires a relay which closes a circuit containing a small incandescent lamp which lights up when the subscriber lifts his telephone receiver from the hook, thereby indicating to the attendant operator in the exchange that a connection is desired. Upon listening in and ascertaining the number of the desired subscriber the operator by means of jacks and cords performs the operation of placing the lines of these subscribers in a through metallic circuit, ready for intercommunication. In a large exchange one operator can attend to the calls of about two hundred subscribers. In automatic telephony on the other hand the operation of coupling up the circuit of a calling subscriber with any other subscriber is performed automatically in the exchange by selecting and connecting apparatus controlled by impulses of electric current established primarily by the calling subscriber.

The question of automatic telephony is perhaps not a very active issue with us in the East at present, but it is decidedly so in the western part of this country, where it is in quite extensive operation, and also to a smaller extent in the eastern part. For instance, New Bedford and Fall River, Massachusetts have automatic telephone exchanges that have been in successful operation for the past eight or ten years.

I am sure, that we all feel under obligations to Mr. Campbell and to the company with which he is associated, for their courtesy, in not only presenting the paper, but also in bringing before us this model working exhibit of the apparatus, and on behalf of the Telegraphy and Telephony Committee, I desire to express our hearty appreciation of this courtesy.

Before calling for discussion, I will ask Mr. Campbell to kindly show us the manner in which the ringer arrangement acts in this apparatus and also to point out the location of the Keith line switch.

(Mr. Campbell then briefly described the apparatus and gave further demonstrations.)

Ralph W. Pope: A discussion of a system of this kind naturally brings up a comparison with other systems. We have been through various discussions of that kind in this room, that have sometimes raised the temperature appreciably. This is a case, however, where we are not called upon to discuss the question of whether or not the apparatus works, because we know that it does work. I think that our vision can be cleared sometimes by taking a reverse view of the conditions. There is always some doubt as to whether an automobile is better than a horse, but if we always had had automobiles, would we use horses to supersede them? So, if we had always had the automatic telephone system in use, would we be talking about introducing the manual system as an improvement.

I have been much gratified, in reading over the paper, to see the modest claims made by the author, and to note that he has refrained from saying that the automatic system will answer in every place and under all conditions. In a certain sense, I am quite familiar with it, so far as lapse of time is concerned. I was Chairman of the Committee on Telegraphy and Signalling at the World's Fair in Chicago in 1893, when we examined the Strowger system which was at that time on exhibition. I believe that it did not receive an award, because of its crude construction, and it was felt that it did not appear equal to the claims made for it; and I think I am safe in saying that it was not then in use to any great extent. Rather curiously, we considered at that time the question whether it was really adapted to large cities, and it seemed to be the opinion that it was better adapted for the smaller cities and the question of its suitability for the larger cities had not been proved. Since 1893 its utility has been proved, and here in New York, where we are supposed to be able to get the best of everything there is, and to see everything that is worth seeing, it remained for the American Institute of Electrical Engineers to have a working exhibit of this automatic telephone system for the public to come and examine.

Last summer I visited the Pacific coast, and there, for the first time since my experience in Chicago some seventeen years ago, I had the opportunity of examining the automatic system in operation in Portland, Oregon. It was rather a novel experience to be in that exchange of about eight thousand lines, and to see the connections, or rather hear them, being made throughout the room, with practically no one in attendance at all; and another thing I learned there in Portland, from our own members, who were simply subscribers to the automatic system, was that from their experience they preferred the automatic system to the manual system, on account of its certainty of conveying the signals, and not giving the wrong numbers. Another point, which was new to me, and which was first made known to me by a subscriber who was an electrical man and had an automatic exchange system connected with his residence, was

that occasionally a lineman came looking for trouble on the circuit before the subscriber knew that there was any trouble. It appears that in the exchange, instead of waiting for trouble to be reported from the outside, they can locate the trouble on the line from the exchange and remove it promptly before the subscriber is aware that there is any trouble.

Another interesting device connected with the system, which was called to my attention, was the meter for registering the calls. It appears that in some of the cities on the coast the franchise requires that the telephone exchange system must be on a meter basis, that is, that the subscriber must pay by the number of calls. The result is that the companies are obliged to meter the system, and the meter not only registers completed calls, but it discards "service" calls and discards calls that are not completed, so that the meter actually registers only the calls that are to be paid for.

From Portland, Oregon, I went to San Francisco, and there the Home Telephone Company's system was in process of construction. I visited the main exchange and several of the branches, and it is quite certain and evident that the people who are building that system have faith in the automatic telephone exchange, for the reason that it is one of the best and most expensively constructed systems that I have ever visited—all the exchanges are fire-proof, the wires are underground, led up in lead-covered cables, and as far as I could see no expense has been spared to make the installation first-class in every particular.

It must be remembered that the manual system may be properly divided into two classes, so far as the subscriber is concerned—the subscriber may work direct with the exchange or he may work through a private branch exchange. In the course of my experience I have found that the perfection of the manual system depends very largely on the disposition, the voice and the attention of the particular operator that has charge of the section with which one is connected. I feel that with the introduction of a private branch, while the operator usually has less on her mind, that we do not receive the short and petulant answers, and the impression that we are trespassing on the time of somebody, and we had better be quick about it, that we get when we are connected with the main exchange. Right here, while this has no bearing particularly on the paper, I think it is well for all of us to remember, and I presume we have criticised it—that when the operator at the exchange repeats back the number wanted, we can rarely understand what the number is, and if you wish to correct it, the operator has gone, so that that time is practically lost, and I understand that the practice has been abandoned in some of the exchanges for that reason. It may have been due to Mr. Campbell's Chicago voice that he brought with him to-day, but when he undertook to make a telephone connection from my office, he succeeded twice in getting the wrong number, and we began to think that the

number was wrong in the book, but I believe he finally succeeded in getting connection with the subscriber. I am free to confess that this was a rather bad exhibit to make of the manual system to a gentleman who came here with this exhibit we see to-night.

Chairman Maver: I will make some additional remarks, and read one or two communicated discussions, to one of which Mr. Pope has referred. As Mr. Pope has said, Mr. Campbell is quite modest in his claims, and therefore, even if one were disposed to be critical, not much opportunity is afforded. Mr. Campbell presents his apparatus almost as though it were on trial, whereas it is in actual operation on a large scale in over fifty cities and towns in this country, embracing a total of 250,000 subscribers.

Mr. Campbell refers to the somewhat crude apparatus first employed in the system which he has described in his paper, in which the calling subscriber pushed buttons corresponding to the call number of the called subscriber. There were, however, more cumbersome ways than this employed in some of the early automatic telephone systems, to one of which (the Callendar automatic telephone) I may refer, as it may help to show the manner in which our predecessors sometimes groped about to reach a desired point; just as our successors will no doubt observe that we of 1910 have only been groping in many things, where we imagine we have reached the acme of perfection. The Callendar automatic telephone was, I believe, in limited use for some time in this country. By reason of its awful and wonderful design it is worthy of passing mention. Each subscriber's wire was led into the central exchange in such a manner and so arranged with regard to certain mechanism that when a subscriber called he was first connected with a "numerical receiver." This numerical receiver had a movable grooved arm, in the form of a rail, which was adapted to make contact with certain other rails as required. In a suitable receptacle were kept a number of metallic balls, which were allowed at the proper moment to roll into the traveling rail from which they were delivered to the subscriber's rail. The subscribers' rails were placed across certain conductors normally not touching. At each point on a rail, where it crossed a conductor, a trap was placed in the rail. When any one of these traps was opened a metallic ball coming down the rail fell through the trap and made contact with the conductor below. Each subscriber was allotted a rail and a cross conductor. When, then, a certain subscriber desired a certain other subscriber, he would give the necessary impulses of current which would bring the traveling rails into position with the rails of the desired subscriber, and the metallic ball would then pass from this receptacle on to the subscribers rail up to the point where a trap was found open, when the ball fell through and made connection with the subscriber's cross-connected conductor. In short, by the mechanism employed in this system, the subscribers, by a process of selection, were finally automatically

connected and they were isolated from other subscribers while thus connected. When through, one or other of the subscribers pressed a release button; the traps were closed and the balls were returned automatically to their receptacle, ready for other calls.

It is to be feared that if automatic telephony depended on a system involving contact by movable rails and rolling balls it would be within bounds to predict that hopes of its ever attaining commercial usefulness would be meagre.

One of the most frequent objections that was offered to automatic telephony in its early days was that the multiplicity of contacts necessarily employed would prevent its successful operation, and it used to be pointed out that whereas in a manual exchange for 5,000 subscribers there are, for instance, something like 133,000 pairs of contacts, in an automatic exchange for 5000 subscribers there might be 1,000,000 pairs of contact in the first selectors alone. The introduction of the Keith line switch, however, has reduced the number of such contacts in the automatic exchange by perhaps eighty per cent. Even, however, before the introduction of the Keith switch, comparatively little trouble was experienced by the great multiplicity of contacts in the automatic exchange; and from actual observation it is my experience that such troubles are quickly indicated by supervisory signals.

Another point that may be mentioned is that the wear and tear on the automatic apparatus is inconsiderable. This is partly due to the fact that much of the apparatus is not in operation more than 2 to 5 per cent of the time. Apart from this fact, actual experiments with certain automatic apparatus, where the mechanism was operated by machinery over 1,000,000 times, shows that the wear of the parts was not perceptible.

There is no doubt that the large amount of apparatus and the multiplicity of contacts employed in the automatic coupling of subscribers circuits tends to the occurrence of troubles that are unknown in the manual systems. An instance of these troubles of comparatively frequent occurrence is the "off normal" troubles, due to a failure of some part of the apparatus to complete its full function or to return to normal position. This for example may be due to sticking of the wipers in the bank contacts, to imperfect contacts, etc. In the common battery system of the manually operated exchange there are numerous delicately adjusted relays operated automatically, and in the multiple switchboard of the same system there are countless contacts, jacks and cords, subject to handling in no delicate manner, and all conducing more or less to the production of defects, but it may fairly be assumed that the occurrence of contact and apparatus troubles in the manual system is less frequent than in the automatic system.

It is, however, a fact that while the occurrence of such troubles is comparatively frequent in the automatic system, nevertheless the methods adopted to promptly announce or indicate the oc-

currence of defective operation to the attendants, by supervisory lamps and other signals, are so efficient that in the large majority of cases the defects are discovered and rectified before the subscribers concerned are aware that such troubles have existed. Further, the attendants become so accustomed to the rhythmic sounds of the apparatus in the process of making normal connections that their ear detects any abnormal operation of a piece of apparatus almost before the supervisory signal can indicate the defect. By reason of this ability of the attendants to recognize non-completed calls they are frequently able to assist in completing a call. This is done by cutting in on the calling subscriber's line to inquire the number of the called subscriber, on learning which the attendant rotates the various parts of the apparatus manually as required for the proper connection. I believe that a daily average of about 16 such "assist" calls has been noted in one large automatic exchange. In consequence also of this ability of the attendants to forestall and to quickly rectify apparatus troubles in the exchange, the disadvantage of the occurrence of such troubles loses much of the weight it might otherwise possess. Obviously, in this as in many other systems, electrical and mechanical, constant vigilance is the price of good service.

The advantages rightly claimed for automatic telephony are numerous. Of course the most important one is that of dispensing with the need of operators at the exchange, not only in effecting a large saving in operating expenses, but also by solving the "girl" problems in the exchanges, which involve training the girls, their leaving the service abruptly when trained, the necessity for resting rooms in the exchanges, etc. These problems, together with the difficulty in obtaining operators suitable for the work in certain localities, have frequently been the deciding factors in determining the adoption of an automatic exchange. There is also the further important advantage that, in the aggregate, much time is saved in the automatic method of connecting, and more especially of disconnecting, subscribers, which admits, among other things of the use of a lower percentage basis of apparatus and of trunking circuits.

It is also evident that the percentage of "wrong number" calls is, in the nature of things, much higher in manual than in automatic exchanges, the difficulty in hearing numerals by telephone, and the repetition from voice to voice accounting for much of this confusion. There is perhaps no greater single cause of annoyance to subscribers, and of loss of valuable time in effecting connections to a telephone company, than this matter of "wrong number" calls. The claim for secrecy in the automatic system does not have much weight with me although it appears to do so with the general public. It is my experience that the operator in a busy manual exchange has little time and less inclination to listen to the subscribers conversation.

As the result of a wide investigation of automatic telephony

in the United States and Canada, I can confirm the claims made for automatic telephony by its advocates as to its popularity with the general public where it is established, especially that basic feature of the art which enables the subscriber to make his own calls without the intervention of an operator.

E. A. Mellinger: A field for further development of the automatic system is suggested by Mr. Campbell's reference to small exchanges. Since a very large proportion of the telephones in use in the country are in exchanges of 500 lines or less, the development of a simple inexpensive switchboard designed especially for use in the small town exchange would go far toward making the telephone universal.

Aside from the economic consideration pointed out by Mr. Campbell, the chief problems which present themselves as affecting the practical operation of small automatic exchanges using the present type of equipment are the maintenance of the battery supply and the care of the apparatus. These problems are successfully solved in the case of private installations, as is indicated by the number of these exchanges in use in government and state institutions, industrial plants, mines, etc.; but in these instances ample facilities exist for charging storage batteries and a competent electrician is usually at hand to attend to trouble which might arise, or to make needed adjustments or changes. The average town exchange of one hundred lines or thereabouts is at a serious disadvantage with respect to these items, which it would appear might be at least partially overcome by the use of simple equipment constructed especially for this kind of service.

Concerning the economic disadvantages of small automatic exchanges, it would be of interest to some to know how large an exchange must be to justify the use of automatic equipment as now installed, and what factors are to be considered in making a comparison. A consideration of the data available from a number of both manual and automatic exchanges indicates that the automatic begins to show an economy at about 500 lines. In a typical modern manual plant of this size there are employed eight operators at an annual expense of \$2,160. As against this, an automatic plant of 500 lines has one operator or clerk and a switchman, totaling \$1,100.00 per annum, thus showing a net average in operation over the manual exchange of \$1,060.00.

Assuming that the automatic equipment, telephone and switchboards, will cost \$8,500.00 in excess of the manual equipment, and allowing on this excess investment six per cent interest and six per cent for depreciation, we find that these annual charges amounting to \$1,020.00 are just about equivalent to the saving effected in maintenance and operation. The other factors entering into consideration total about the same in each case, and would not appreciably affect the result, except that the smaller floor space required for the automatic switchboard would be an item in its favor.

Local conditions in small exchanges vary so greatly that this figure of 500 lines cannot, of course, be taken as authoritative. Public automatic exchanges of fewer than 200 lines have been operated satisfactorily and economically, but it is probable that under present conditions the average exchange of less than four or five hundred lines cannot afford to install automatic equipment except that the greater popularity of automatic service might be considered as an economic advantage as it undoubtedly is in most instances where competition exists.

E. L. Lehman: Mr. Campbell's description of the working of the automatic telephone appears to be well set forth, but what about the apparatus that does not work or cannot report when out of order? After all, it is the efficiency of repairs and cost of maintenance that satisfies the subscriber and lowers the rental charge. The fundamental requirements of operation to be met in maintaining both the manual and the automatic systems may be briefly summed up as follows: The "busy" and "trouble back" signals, "don't answer," "receivers off," and line and trunk troubles. In the manual switchboard any trouble occurring with the "busy" or "trouble back" signals would be noticed instantly a connection was put up. "Don't answer" reports are given to the calling subscriber if the called subscriber does not answer. In the case of a business subscriber or the calling subscriber insisting that the called subscriber is within hearing of his telephone a report of "can't raise" is given to the wire chief who makes a test on the line and quite often finds the line in trouble, in which case repairs may be quickly made.

Another important item in maintaining telephones is the loss of incoming calls to subscribers who have left their receivers off the hook. In a manual exchange of about 6,000 stations, a percentage of about 1.5 per day is comparatively small, and the percentage to total calls outgoing and incoming would amount to one-quarter of one per cent. Yet if these stations had their receivers off all day the loss in outgoing and incoming calls would amount to the considerable sum of 1,200, or three per cent of the total calls for the day. It is safe to say that, with the present system of plugging out on the manual system, very few calls are lost, as the subscriber is reminded to hang up his receiver by a high frequency tone thrown on the line.

Relative to lines in trouble; operators are quick to report swinging grounds, receiver circuits open due to tips out, etc., poor transmission, etc., while the plugging-out system takes care of a large percentage of instrument, line, cable and office trouble, such as shunts, grounds and open circuits. Trouble on trunk lines, office to office, may be intermittent yet are quickly noticed by an operator.

One more comparison occurs to me, namely, the calling of private branch exchange numbers or any subscriber that has two or more lines, generally numbered in consecutive order. In the manual operation, if such a subscriber is called, and the number

called is busy, the connection will be put upon the next available trunk line, while the automatic subscriber would probably have to look up the number and call until a trunk line not busy was found.

Query: Can the automatic system be controlled to such an extent that a subscriber's station may not be out of order over a period of two or three hours before the fact is known by the switchman?

H. W. Pope: Some fourteen years ago I met Mr. Campbell at Augusta, Georgia. One of the first systems of automatic telephony was introduced in that city, with one selector, as I recall it, to each line. It was a very crude affair, and the wonder to me was that it worked at all, and I presume it was very largely due to the care of the man in charge of it that it did work.

There are some things that this paper hardly touches upon—in fact, you would hardly expect it to—and these are the questions of maintenance and of depreciation. Now, I have an idea that the cost of maintenance is a very large item in connection with the automatic system. I am laboring under the impression that it requires a skilled man for every thousand telephones, which would be quite an item in a large exchange, for skilled men do not work for nothing, and this system is particularly applicable to large exchanges. Of the matter of depreciation, I have no reliable knowledge. I understand there has been a system in operation in Fall River for something like ten years, which has shown a depreciation not to exceed, I think that of the manual board. Mr. Campbell has refrained from saying anything in this connection that would lead to any argument or criticism.

Another thing which occurs to me is this; a good system, whether manual or automatic, should be one that is available for all people, for the illiterate and for the blind, or for any person that can speak the language of the country in which the telephone system is operated. Now, the automatic system especially as regards the requirements for the placing or transmitting of the call, does not meet these conditions as easily or as simply as the mere act, in the manual system, of lifting the telephone from the hook. I do not know how you could handle this automatic system in the dark, unless you were very familiar with the transmitting apparatus, and that is quite an essential thing, so far as its use in residences is concerned. In case of danger, fire, burglary, or anything of that kind, the mere fact that if, in the manual system, you take the telephone off the hook, attention is called to the fact that something is the matter, is of very great advantage. I read only yesterday or the day before of a case of suicide, where the information was gained from the telephone; the woman who committed suicide left the telephone off the hook and they heard her groan. That is a newspaper story, but I can imagine cases where emergencies might arise whereby attention would be called in this manner. Of course, it is a small thing, but it is worth considering in

connection with automatic systems. A blind man is certainly prevented from using the automatic telephone, and we have many blind people who use the telephone.

I do not think there is much in the contention as to the rapidity of the signalling to the central office. Of course, the subscriber in working the automatic system is busily engaged in whirling around the transmitting device to the proper point, and he does not realize the time he is consuming. While he is doing that, in the City of New York you put in a call and get an answer. That may not apply everywhere, but it applies here. Mr. Campbell says in his paper that "generally speaking" it is more profitable than the manual system. I infer from that that sometimes it is not, and I think that is quite a question. From what I have learned and seen, and I have seen quite a good deal of it, I have always considered it an expensive system to maintain; but I do find that it gives great satisfaction to the subscribers and it eliminates a good deal of difficulty in connection with the wrong number. Of course, with the automatic system, the wrong number comes right back to the customer every time. In the manually operated system the subscriber looks in the book and finds 3700 and gives 3800; he does not realize that he is making the mistake and is prone to blame it on the operator; but the fact is that the customers probably make more mistakes than the operators do.

Charles A. LeQuesne, Jr.: I ask Mr. Campbell to explain if this system can be adapted to the use of private branch exchanges in connection with city exchanges; and also, what provisions is made for handling pay station calls, and whether in using a pay station telephone, it is necessary to first deposit your coin before being able to operate the calling mechanism, and, having done so, is the coin returned if you do not get the connection?

A. R. Sawyer: In 1904 when I became connected with the Michigan Agricultural College I found a campus of 25 acres or more with about 18 buildings scattered over it and no method of communication between them. I recommended to the Board of Control the adoption of a system of communication that would facilitate intercourse between the heads of the departments and save much time, the arguments for which need not be repeated. I saw that what we needed was a telephone system which would be intercommunicating for every office on the grounds and would be cheap enough in maintenance cost so that everybody could have one. I also soon realized that most of the offices should have connection with one or both of the Lansing exchanges.

After studying the matter I decided to recommend the automatic system, which was adopted by the Board of Control after due investigation. The outcome was that we put in an automatic telephone system sufficient to accommodate one hundred telephones, with three trunk lines connected to the city exchange in Lansing. The automatic system was selected because, once

installed, the management would hear virtually nothing more of it in the way of running expenses. A manual system would necessitate adding to the college pay roll at least three operators as well as at least part of a man's time to keep the exchange in order, whereas the automatic system would need only part of a man's time to keep it in shape and we would have good service twenty-four hours a day and seven days in the week. At that time neither of the exchanges in Lansing gave us satisfactory service and it was my desire if we were going to put in a system that the outcome should be satisfactory telephone service. As a result, we shortly found ourselves in possession of an automatic system with three trunk lines to Lansing and a telephone in every office on the grounds as well as in the residences of those who wished to pay the college a small fee for the privilege.

The Lansing Citizens' exchange was under the management of the Grand Rapids Telephone Company which employed an automatic system and an up-to-date automatic exchange was shortly afterward installed in Lansing. At that time the automatic company did not claim that its system was best for a small exchange, but in the light of the experience we have had, we are satisfied that by all odds the automatic exchange was the best for us.

The college electrician calls up the Lansing exchange every morning over the trunk lines to make sure that they are working satisfactorily, and spends perhaps a half hour in looking over the system; the rest of the day he is free for other duties. This test over the trunk lines is necessary because of line troubles that may have occurred and not because of defective apparatus.

I will say that some of the lines to the residences outside of the campus run through a district where wires are numerous and consequently we have had much trouble with those lines, due to imperfect insulation, crosses, etc., and at times the electrician has had to spend a good deal of time on line work. That condition, however, would exist with any system. All our campus phones are connected by means of lead covered cables in tunnels so that we have no line troubles except those mentioned above.

In my recommendation to the Board I predicted that the automatic system would require less attention than any other system, but I was not prepared for the freedom from trouble which we found in the switch room. This system calls for better line work and really puts telephone work on a higher plane.

L. C. Tomlinson: It is very interesting to note the rapid advances that have been made in the past few years in automatic telephony. The large inartistic telephone, in use a few years ago, has been displaced by the small, neat and compact telephone of the present day.

At the same time the central office equipment has passed through a series of changes. By making the units compact, the central office floor space required per 1000 lines, has been greatly

reduced. The apparatus has been simplified and improved with every change. A few years ago an automatic telephone system was considered so complicated, that many telephone engineers considered it quite impracticable and were unwilling to recommend it to their clients, but the ease with which it has adapted itself to all conditions has won the hearty support of most of the progressive telephone engineers.

By the multi-office arrangement of the automatic system a telephone company may reach out and serve the sparsely settled territory, that if served by the manual system, would cause an annual loss to the operating company. Not only do these subscribers receive the same class and quality of service as subscribers whose lines enter the main office direct, but their rates are generally the same, although they are at a greater distance from the main office.

H. A. Robbins: In 1905 an automatic telephone system was installed in the main office building of the Brooklyn Rapid Transit Company, the system being designed for an ultimate capacity of 1,000 lines, but to date only 110 lines have been put in service. The purpose of this installation was

1. To secure quick communication between departments, and the several offices of the departments.

2. To relieve the general switchboard, in order to obtain better service on outside calls.

The results anticipated from the installation have been very satisfactorily realized, and a large proportion of the inter-office communication is handled over the automatic system tests having shown from 80 to 120 calls per hour over this system.

As to the operation of the system, probably 90 per cent of reported troubles, although few in number, have been in the instruments. The selectors and connectors in the exchange which might be expected to give the most trouble being almost free from trouble of any kind.

While we anticipated some trouble from cross talk due to low insulation in the exchange, the system has been free from this trouble, and the talking qualities have at all times been equal to those of our manual system. The maintenance of the system is in charge of the building electrician, and requires not more than 15 to 30 minutes of his time each day, the maintenance being almost entirely labor costs. While this system, consisting of the straight Strowger type of apparatus, has given very satisfactory results, the improvements which have been brought out in the last few years, especially the Keith primary and secondary line switches, should increase materially the possibilities of the system in large installations. I believe that the combination of the present manual system and the automatic system will be the ultimate solution of the telephone problem in our large cities.

W. Lee Campbell: The point has been made that if the "busy back" should get out of order, it would probably not be noticed, for a considerable length of time in the automatic

system. The method of taking care of an automatic system is somewhat different from that usually pursued in taking care of a manually operated switchboard. I can best illustrate, I think, the method of taking care of an automatic system by referring to the method which the locomotive engineer uses in taking care of his engine. He does not sit on the engine and keep going until something breaks or something that has worked loose comes off and wrecks the train. He goes out at the stations where he stops long enough, and goes over the parts that he knows from experience are liable to work loose, or to get too tight, or to get out of order in some way, and cause trouble, and with an experienced touch here and there he keeps all the mechanism in working order. Any good mechanic having the care of a machine pursues that same policy, and any successfully operated automatic switchboard must be run on that plan. The "trouble" reports that are commonly used for recording trouble with automatic telephone switchboards divide the trouble into two classes—detected troubles and reported troubles. If the switchboard attendant does not put down more detected troubles than reported troubles, it is generally taken for granted by his supervisor that he is not giving very close attention to his duty. An automatic switchboard is provided with supervisory signals for the use of the attendant, but many of the disorders he notices simply by the sound of the machines. As you know, an experienced locomotive engineer can tell by the sound of his engine whether it is running properly or not, and an experienced automatic switchboard man, who is anywhere within hearing of an automatic switchboard, can tell instantly if there is a machine which is not working properly. If he should fail to notice it, there is always a complaint clerk, an information operator, or somebody at the office, to which the subscriber can report his trouble, just as it is sometimes necessary to do with a manual plant. If a subscriber leaves his receiver off the hook, his attention is called to it in the same way that it is in the case of the manual plant; there is a device called a "howler" connected to his line, which sends an alternating circuit of high frequency and considerable voltage through his receiver, that causes it to give forth a tone called a "howl" and calls the subscribers attention to the fact that his receiver is left off the hook.

In regard to trunk lines and private branch exchange switchboards, these are handled in a manner similar to that in use in manual practice. For instance, suppose there is a private branch exchange subscriber who has a half dozen trunk lines, for handling calls to and from his place of business; they are all given the same number, just as in manual practice, and any subscriber desiring that private branch exchange simply calls the number shown in the directory. If the first trunk is busy, he is automatically switched to the second trunk, and so on until he finds an idle trunk. The apparatus does automatically what the operator does on the manual switchboard. Of course, if

all the trunks are busy, the calling party gets the " busy signal " just as he does in manual practice.

In regard to the cost of maintenance, the maintenance labor for the automatic system is undoubtedly higher than for the manual system. The cost of maintenance material, however, for the automatic system is considerably less than for the manual system. I am not prepared to say, offhand, that the following is positively true, but my recollection is that the cost of new cords alone on the manual system will more than pay for the cost of all the maintenance materials on an automatic switchboard of the same size. The additional cost of maintenance labor on the automatic system is considerably more than offset by the elimination of the operators' wages, and the elimination of these wages takes care of the higher charges on the automatic system, due to the greater first cost.

With reference to depreciation, the oldest automatic system that I know of in operation to-day is the one at Fall River, Mass., which was installed in 1901, and has accordingly been in operation about nine years. I had a letter from the manager of that system very recently and he says that it is working better now than it worked nine years ago, and that the switchboards and telephones both show very little wear. So far as its wearing qualities are concerned, he sees no reason why the system should not be good for a number of years to come. Of course, the system is considerably out of date and it may be advisable to replace it, before it wears out, with a system more modern, although no plans are on foot to do so yet.

With regard to the method of reporting fires with the automatic system, nearly every automatic system in operation is arranged so that a subscriber by making one turn of his dial can report a fire to the attendant at the central office. This attendant throws a key and simultaneously rings all of the fire alarm stations, or as many as the authorities desire to have rung, and reports the fire. The method is very similar to that in use in manual practice, with the exception that the calling subscriber has to know the number to call, in order to give the alarm. It is very common in cities where the automatic systems are in use to have fire alarms sent in through the automatic switchboards. It may be that the party on whose premises the fire occurs is sometimes too excited to be able to report it, but I have never heard of such a case.

With reference to pay stations, there are very few pay stations in operation in connection with the automatic system, and in fact there are very few pay stations in operation in any independent telephone system. The pay station with an automatic system is operated in this way: The subscriber removes his receiver from the switch hook and calls the party he wants, in the usual manner. If the party answers he then drops his coin. Until he drops the coin he cannot talk to the called party, but he can hear the called party answer him. As soon as he

drops the coin, his transmitter circuit is closed and he proceeds with the conversation. If he wants "long distance," or "trouble operator" or some one to whom he should have free service, the apparatus is arranged so that it is not necessary for him to drop a coin in order to close the talking circuit.

Frank F. Fowle (by letter): Mr. Campbell's paper gives a very good perspective of the principal features of a full automatic system, up to 100,000 subscribers. This limit meets the conditions at present in all but the largest cities, so that it is fair to draw general comparisons with manual systems.

The general question of manual versus automatic systems is a many-sided, complex subject, to which full justice cannot be done in a brief discussion. It is one of those questions which can never perhaps be settled for all persons under all conditions, and for all time. On the whole, the recognition accorded to automatic systems and service is increasing, and they are coming into greater use.

There are to-day three basic systems of telephone operation; the first and earliest of these was the full manual, the next was the full automatic, and the last the semi-automatic or auto-manual. A comparison of these systems should embrace all questions relating to service, economics and rates, along somewhat the following lines:

1. Service.....	{	Transmission.	{	General.
		Reliability.		Operation.
		Accuracy.		Maintenance.
		Speed.		
2. Economics.....	{	Operating.	{	
		Expenses.		
		Fixed	{	Taxes.
		charges.		Insurance.
				Depreciation.
				Interest.
3. Rates.....	{	Exchange.	{	Business.
		Toll.		Residence.
				Special.

The manual system is much the oldest of the three, dating back to the origin of the business. The oldest automatic system in service has been in use about 10 years, only. The auto-manual system is comparatively recent, and the only installation in the writer's knowledge is at Ashtabula, O.

Full automatic and full manual systems are generally well understood as to their principal features. The auto-manual

system is a compromise between the other two. The subscriber's station equipment and the method of calling the central office are similar to the manual system; after the arrival of the calling signal at the central office the procedure is different. The subscribers' lines do not terminate in front of an operator, but any incoming call is automatically switched to the first idle operator. The operator's equipment consists of a keyboard equipped with numbered plungers or keys much in appearance like the keyboard of an adding machine; there are also lamp signals and selecting keys. There is no multiple of lines before the operator and none of the equipment used in the manual keyboard. The first idle operator receives the calling signal, takes the subscriber's order, sets up on her keyboard the number called for and presses a key which causes that number to be automatically selected. The ringing is automatic and the operator is automatically cut out of the connection, so that full privacy is insured. When the subscribers hang up their receivers, the connection is automatically cleared.

This system avoids the complicated and expensive multiple switchboard, but retains a human agency in its operation. It seems to be especially adapted to the extension of manual systems where a conversion to the full automatic is not desired. A comparison of some of the individual features of these systems will now be taken up.

SERVICE

Transmission. Efficiency of transmission is a matter of electrical design and the selection of equipment. There is fundamentally no reason why the three systems cannot be designed to have equal efficiency in this respect, but both the full automatic and the semi-automatic have an advantage over the full manual system, in avoiding the electrostatic capacity and the resistance of the multiple, including the cable and the jacks. The effect of a large multiple on transmission is an important factor, and the loss occasioned in this way can only be compensated for by selecting more efficient equipment and increasing the size of the talking conductors.

The circuits shown in Figs. 8 and 23 of Mr. Campbell's paper differ somewhat from the common repeating-coil circuit and are probably no more efficient; under some circumstances they may be less efficient; as when ordinary solid-core relay magnets are used for impedances, in place of the more efficient repeating coil or impedance coil, constructed with a properly sub-divided iron core. The effect of such core construction is to increase the apparent resistance and diminish the apparent inductance, due to the energy losses in the core.

Reliability. Full automatic service tends toward greater reliability than manual or semi-automatic service, because it depends on no human agency in its operation; it is equally ready at all times of day or night. On the other hand, it possesses some disadvantage in that it is composed of such complex apparatus and has such a multiplicity of parts and contacts.

It is conceivable, also, that in some of the most recent automatic systems, which employ line switches and substations, a sudden peak in the traffic load might exceed the capacity of the available lines and switches. Insofar as such a condition might exist, it would tend to create a public sentiment against the service. But any such condition should be only temporary, as one of the traffic problems peculiar to automatic systems is that of eliminating the danger of busy line switches and trunks. Reasonably alert supervision should disclose all such faults.

Automatic systems are of course free from interruptions due to strikes of the operators, such as have occurred with manual systems in Chicago and San Francisco. They are also less likely to suffer interruption from neighboring fires, so close as to make it impossible for operators in a manual system to remain at work; instances have occurred where smoke drove the operators from their positions.

The manner in which the upkeep of a plant is taken care of is, of course, a basic factor in the service which it gives. This is particularly true where there are so many moving parts and contacts. It would be very instructive to have a comparison of these systems on the basis of the number of contacts in a complete connection between any two subscribers in the same exchange territory.

The liability of service interruptions increases in some measure with the complexity and multiplication of contacts. This tendency can be offset in part, at any rate, by proper maintenance methods, and in particular by the adoption of the policy of frequent periodic inspections to detect the approach of troubles and faults before they cause actual interruptions. Particularly in large plants, this policy is almost indispensable to good service.

Accuracy. This is one of the important qualities of good service, but rarely attained in perfect degree in manual systems. In fact, the writer has not, in the course of visiting most of the large cities in the country, found manual service that was above criticism. The human element seems to preclude the possibility of 100 per cent of accuracy in service. Under the general head of inaccuracies we should include the following:

1. Wrong numbers.
2. False busy reports.
3. False don't answer reports.
4. False rings.
5. Disconnects, or cut-offs.

All large telephone companies maintain a force to supervise and test the quality of the service. On account of the expense, it has never been the custom to verify more than a very small percentage of the total traffic; the ordinary practice in service testing or supervising does not cover more than one per cent of the whole traffic, and it is usually but a fraction of that figure. When the tests are sufficiently numerous, however, they furnish some index of the general quality of the service. Some results recently given for Chicago are as follows:

	Per cent
Calls completed without trouble.....	78.5
Reported " busy ".....	13.0
Reported " don't-answer ".....	3.0
Cut-offs, double connections etc.....	1.0
Wrong numbers, fault of operators.....	3.0
Wrong number given by subscriber.....	1.5
	<hr/> 100.0

These figures show that nearly one call out of every four is interfered with for some cause, or more than one in five. About one in eight is held up because of busy lines, and one in twelve is interfered with for other reasons. The " don't answer " reports, amounting to three per cent, undoubtedly include some wrong numbers. The writer finds it safe always to verify a " don't answer " by calling a second time, as in some cases the party called responds on the second call, and usually advises that the first call did not reach him. The writer has also experienced the following service: " don't answer " report on first call, " busy " report on second call, party answers on third call and advises that line was not busy and no previous call or signal had been received.

Incoming wrong number calls are also annoying to the party wrongly called. The writer's telephone number is 6,033 and he has always been annoyed with calls for 6,433; this arises in part from the difficulty of distinguishing 0 from 4, when pronounced O instead of naught. There are many other instances of confusion of vowel sounds. The remedy of course is adequately loud and clear transmission and clear enunciation of numbers. But there is also the element of operator's errors, including the misunderstanding and mis-giving of orders and misplugging in the multiple. The writer has noticed that bad service at individual telephones, particularly in the way of incoming wrong number calls, seems to vary greatly and is no doubt traceable to inefficient operators on the incoming trunk or B positions, at certain hours or on certain days.

Among the prominent causes of poor manual service are overloaded operators, especially in the " busy hour " or peak load period; inexperienced operators; over-loaded order-wires or calling circuits; poor transmission, especially on order wires, which results in misunderstanding of orders and assignments; and lack of adequate traffic supervision and analysis.

The problem of procuring, training and maintaining an efficient force of operators is one of the important and sometimes difficult problems in manual service. In large cities it is necessary to maintain a training school and in consequence there is an ever-present percentage of non-productive labor. The operating force is usually somewhat unstable and the average length of service is not high.

The auto-manual system tends to eliminate many of these difficulties, because the opportunities for error are greatly diminished. The work of the operator is concentrated upon fewer

functions. The limited experience with it thus far, shows that an experienced operator can handle more than double the number of calls per hour than in a full manual system.

The full automatic system eliminates the operators' errors altogether, and in this respect should give superior service. On the other hand, it places an increased burden on the subscribers, due to the manipulation of the calling device. This burden does not appear, however, to be serious, and seems warranted if it eliminates the operators' errors in the manual system.

Both the semi-automatic and the full automatic eliminate the cut-offs due to errors in manual operation, but they tend to increase the cut-offs caused by accidental manipulation of the switch-hook by the subscriber. In these systems one depression of the hook disconnects the line, and if there is no element of time lag in the apparatus, this is likely to be annoying. A slow-acting disconnect feature seems very desirable.

Speed. Speed in operation is directly a factor in operating labor costs of manual and semi-automatic systems. The sacrifice of accuracy for speed, which is sometimes the result in manual systems when high operator loads are over-emphasized, can hardly fail to create a public sentiment of both inaccuracy and unreliability in the service. The semi-automatic system has a large advantage over manual systems in this respect, and the full automatic probably has an advantage over both, all things considered.

Rapid disconnection, especially on trunk circuits, is one of the important advantages of both forms of automatic operation. Slow disconnects reduce the circuit loads in the busy hour and generally slow up the service. The circuit loads in the busy hour are directly of prime importance in determining the investment in the trunking plant, and in toll lines.

It sometimes occurs in manual operation, that the disconnect signals fail, and in consequence a subscribers' line as well as the trunk line is sometimes tied up for considerable periods. It is conceivable of course that this may happen, with automatic operation, but it seems much less likely, owing to the positive character of the disconnect function.

Other Considerations. Coin-in-the-slot telephones and pay stations require manual operation, and in a full automatic system there is no feasible way to handle this class of service, except by introducing manual operation. This objection does not exist in semi-automatic systems.

Toll service cannot, of course, be handled on a full automatic basis. The experiments which Mr. Campbell describes in substituting automatic selection at the "inward" end of toll circuits, in place of manual operation, are very interesting. The increased circuit load in the busy hour thereby made possible, will have a very important bearing on the toll line investment and should result finally in cheaper rates. It should be noted, however, that where double checking is dispensed with, an in-

creased amount of supervision is essential to detect and prevent fraud, either by operators or subscribers. The fact which should be made plain to the operating force is not that supervision is possible, but that it exists without cessation.

One of the objections often advanced by advocates of manual systems against automatic operation has been the seeming difficulty of joining automatic with manual operation in the same plant. This difficulty exists to some degree, but manual operation in toll service will always be necessary and in toll boards designed for operation with automatic local service exclusively the objection seems more imaginary than real. It has not at least proved an insuperable objection in some of the instances where it has been tried.

OPERATING EXPENSES AND CHARGES

Operation. The cost of operation, including operating labor, supervision, rent, light, heat, etc., would seem to decrease in the following order: manual, auto-manual, automatic. Labor is the largest item in this account and the saving in labor costs is of basic importance.

Maintenance. The cost of maintenance may vary considerably even in similar plants equally situated. The efficiency of maintenance is directly a factor in the quality of service, and comparisons are therefore difficult to draw. The character of equipment to be maintained in the respective systems is quite unlike. It has been urged against automatic systems that the cost of maintenance would prove excessive, but given well built and properly installed equipment it is not apparent why this should be so. In fact a comparison between automatic and manual systems does not appear to the writer to offer a very decided choice either way.

Fixed Charges. On the general question of fixed charges, the first consideration is the investment. This in a large measure fixes taxes, insurance and interest. Automatic office equipment costs more than manual, but the distribution system less. Approximately 75 per cent of the investment in a manual system is in the outside plant or distribution system. The saving which results from the use of substations, placed at about 75 per cent in residence territory, is almost certain to prove a substantial ultimate economy in favor of automatic operation. There will be further economies in the trunking plant, brought about through higher circuit loads, with automatic operation and secondary line switches.

The insurance risk on a well engineered telephone plant is low, and the rate should not differ materially in any of the systems. If it varies at all it should probably be slightly higher on manual equipment; the steel cords which are now in wide use have sometimes started fires. This, however, has led to the practice of introducing lateral and transverse fire bulkheads in manual boards to reduce the hazard.

The annual charges for a depreciation reserve fund are determined by the investment and the useful life of the plant. More properly it is the cost of reconstruction instead of the investment, labor and materials costing the same. Automatic and auto-manual plants have not been long enough in service to determine their useful life with reasonable accuracy. The oldest automatic plant in service is about 10 years old, but there are few manual plants that are much older, counting from the date of construction or last reconstruction. The effects of obsolescence and inadequacy have been prominent in the depreciation of telephone properties, because of the very rapid expansion of the business and the frequent advances in the art. For the same reasons depreciation will probably continue to be high, in the case of automatic plants at least. However, there is a growing recognition of the necessity of sound engineering, and plants to-day are more intelligently planned and better constructed than they were formerly. The results of this will inevitably diminish the rate of depreciation, as time goes on. The useful physical life of a well engineered plant ought to be very much in excess of 10 years, with the exception perhaps of some rural systems.

RATES

It seems pretty clear that, aside from any unforeseen contingencies, a modern automatic plant should be able to offer lower rates than a manual system, and should in consequence produce a greater development. The important advances in the automatic art are comparatively recent however, and rates do not seem to have been materially affected as yet.

The history of telephone rates shows that in the early days there was no scientific basis of rate making, but rates were fixed at what it was thought the traffic would bear. In many instances they were exorbitantly high, and consequently suppressed development and stimulated competition. The competitive movement placed rates in many instances too low again, because there was no scientific analysis of cost.

To-day, the generally accepted theory, or the theory toward which we are tending as a whole, is the cost-of-service-plus-a-fair-profit. The rates of public utility companies generally are undergoing revision, mainly downward. But this is only partly true of telephone rates; many companies after ten or fifteen years of operation have found it absolutely necessary to raise them in order to earn no more than the legal interest rate. The failure to provide at all for depreciation and the lack of intelligent planning of the original systems and their extensions have been responsible in part for this state of affairs.

It has frequently been stated that the cost of operating a telephone system increases per unit as the system enlarges. This statement has been advanced in support of high rates in some cities. It is of course true that the unit cost of construction is higher in cities than in towns and country districts, but the

greater density of development to some extent compensates for it. The aforementioned statement is somewhat misleading. The facts in the case are that the cost of a manual multiple switchboard increases in faster ratio than the number of lines, and the cost of distribution increases as the average mileage of wire per line increases. The investment in the distribution system exercises the largest single influence on the amount of the fixed charges. The average wire mileage per line increases with the area of the zone which comprises the exchange territory and within which the schedule of local rates applies exclusively to all traffic; it decreases with the density of development within this area. In large exchange areas more than one central office is a necessity, in manual systems, and where there are two or more offices there is necessarily an investment in a trunking plant. As a whole rates are higher in large exchange districts—higher in cities than in small towns. If the exchange district should be increased without limit, the cost of the trunking plant would make the rates prohibitive. Low exchange rates can be obtained by restricting the exchange area, and this principle has been recognized in at least one large city. Traffic between different exchange districts must bear a toll charge.

What effect the introduction of automatic operation will have upon this phase of the rate problem is not yet decided by any actual experience in very large cities, but in general it should result in lower rates, or, with present rates, in larger exchange areas. But as development will be increased by lower exchange rates, it appears to be desirable to reduce the rates rather than increase the size of the exchange district. The full automatic system as described in Mr. Campbell's paper is not worked out for more than 100,000 stations. This limit is already exceeded in the largest cities and further development of automatic equipment is necessary to fit such conditions. The competition between manual, semi-automatic and full automatic systems is certain to have a healthy result upon the telephone art and it is to be hoped that automatic equipment will soon be adapted for use in the largest cities, with ample margin for growth.