DISCUSSION ON "A STUDY OF MULTIOFFICE AUTOMATIC SWITCHBOARD TELEPHONE SYSTEMS." ATLANTIC CITY, N. J., JUNE 29, 1908.

A. B. Smith: For a number of years it has been my hope that the automatic would be able to solve the telephone problem for large cities; that it would bring the rental a little lower for the benefit of the many who need the telephone but cannot now afford it, and that it would afford relief from the party line. That this can only be done by subdivision into small offices with short subscriber lines is acknowledged, but the apparently insurmountable obstacles of trunk lines and office expenses have stood squarely in the way. However, it may now safely be said that the automatic has arrived at that point of development where its claims merit serious consideration.

With regard to the claimed flexibility of the system in being able to use subscribers' lines for trunks, I ask if it would not seriously interfere with the practice of making trunk cables of lower resistance and electrostatic capacity than subscribers' cables? It would necessitate making the whole installation of cables good enough for trunks, which would be very expensive.

In a continuously growing city the telephones increase in number in two ways—increase of density and increase of territory. If merely the telephone density increased, and the transmission equivalents had been properly cared for, any district might be converted into a branch office and old subscriber lines used for trunk lines with no loss. But all around the edge of the city the telephone exchange is expanding and the length of lines increasing, so that to continue indefinitely with the process would eventually make transmission very poor. In this respect the automatic offers no additional advantages except as it makes profitable a smaller branch office.

In a multioffice automatic exchange the trunk repeater is used to relay the calls and permit each subscriber to draw talking current from the nearest battery. This introduces added complications into the selecting mechanism, but as far as talking is concerned a little comparison will show the conditions. In the common battery manual trunk circuit there are two repeating coils between the two subscribers, one in the cord circuit at the *A* board, the other in the trunk circuit at the *B* board.

No repeating coils are used in the automatic, their place being taken by the condenser-retardation coil combination so common in independent cord circuits. From a test which I recently made, the repeating coil is considerably less efficient as a transformer of speech than the condenser-retardation coil combination. Hence the insertion of the trunk repeater into the line will still leave the automatic with an excellent transmission circuit.

Where there are a number of groups of trunks from one office

district to another, as from *E* to *A*, Fig. 21, it seems that there would be considerable advantage in making all the trunks more or less accessible to all the offices in that district. I ask Mr. Campbell if this can be done? If so, the number of trunks can be reduced and still have the same busy hour capacity as a whole.

For the benefit of many who may not now take kindly to the idea of an all automatic plant, I ask if the line switch or some other device can be used on manual boards to trunk small groups of subscribers to the office? My idea would be to place such a switch at the center of the subscriber group with as many trunks to central as necessary. When any subscriber in the group takes the receiver from the hook, he is automatically trunked to the manual board and answered by the operator just as if he were on an ordinary line. It would enable the giving of individual line service with as few wires as would be required for party lines. Has this been suggested or worked out, and is it considered practical?

John Wicks: This paper offers encouragement to those connected with the development of automatic telephone service. Few engineers have yet given the matter sufficient thought or study to enable them to see its possibilities. The fact that telephonic connections are made automatically has been viewed as a curiosity. That the public in large communities has made use of it for years, even in preference to the best manual service offered by competing companies, is still looked upon as incredulous. Many have wondered at its rapid general adoption, but few have stopped to investigate the reason of its growth. It is therefore interesting and gratifying to learn that it has developed along a line which makes it possible to decrease the great economic waste, which in the form of idle lines is to be found in the old-style telephone systems.

Automatic telephone service has been tried sufficiently to prove itself practical. We know that the telephone-using public likes it. We know also that there are no mechanical or electrical difficulties in the art which cannot be overcome. To compete with manually operated telephone systems, therefore, it has only to prove itself economically more efficient than its rival.

In manually operated exchanges, party lines were long ago resorted to as a part solution of the problem involving the reduction of the percentage of idle lines. So important has this branch of the service been considered that a prominent telephone engineer stated only a few years ago that a grave objection to the automatic equipment was that it had no party lines. The manufacturers of automatic switchboards have since then successfully solved the party-line problem, but it is hoped that the introduction of multioffice automatic switchboards will eventually do away with a large part of party-line service without putting the rental above the reach of present party-line subscribers.

The principal reason for the moderate price of party-line service is the saving effected in line construction by using one line for several telephones. A similar reduction in line investment is obtained by the use of a large number of small offices interconnected by trunk lines. It has the advantage of offering individual lines to patrons who can now afford only party lines.

A plan has been proposed and is now about to be tested in an eastern city which, if successful, will enable a telephone company to offer a still cheaper direct line service. This new service might be termed "limited trunk" service, because the scheme is to limit the number of trunks to the main office from the district station to which the limited trunk subscribers are connected. For example, if 100 telephones, instead of being connected to the main central office by 30 or 40 party lines, should be connected individually to a 100-line switch unit in a district station, this district station may then be connected to the main central office by a number of trunks less than that necessary for furnishing each telephone a trunk line whenever demanded. For instance, the number of incoming and the number of outgoing trunks connected to the line switch unit might each be limited to five, thus making a total of 10 trunks instead of 30 or 40 party lines. It can readily be arranged so that any party attempting to call when all of the trunks outgoing from the district station are busy, will receive either the ordinary busy signal, or preferably a peculiar signal, which will inform him that all trunks are occupied for the moment and that he should call again in a few minutes. It often happens that one subscriber keeps a party line busy for an unnecessarily long period to the inconvenience of others on the line, but it would be impossible for any one or two inconsiderate subscribers to occupy all of the trunks from a district station. Another marked virtue of this limited trunk service is that communication would be absolutely private, thus eliminating one of the most objectionable features of party-line service.

There may be questions raised as to the advisability of having a small sub-station with its apparently complex line switches and connectors without an attendant, but experience has proved that even the operation of large switchboards contained in one room is done to a large extent through supervising signals. If a line becomes grounded or open, or if something goes wrong with the switching mechanism, attention is called to the matter by means of a signal, which may as readily be made to appear in another office miles away. Should the trouble be in the subscriber's line or instrument, no other part of the sub-station is affected, whereas a trouble in a party line will frequently throw all the instruments connected to that line out of service. Any part of the switching mechanism going wrong will affect only the trunk connected to that particular switch, and that can be made "busy" from the main exchange until it is convenient to repair it.

Apparently, rural or extremely isolated subscribers would still have to be furnished party-line service, but it would appear that multioffice and limited trunk multioffice service might be used both to the advantage of the telephone company and its patrons to dispense with the majority of the party lines.

The possibilities of limited trunk service will be still further enhanced, especially for residence districts, when the manufacturers of automatic equipment put apparatus upon the market that will make two-way trunks practical. It will then be unnecessary to have one group of trunks for handling outgoing calls and another group for incoming calls, but each trunk will be available for a call going in either direction. It is a well-known fact that the maximum flow of traffic from the residence districts to the business district of a city does not occur at the same time as the maximum flow in the opposite direction. Consequently, if the trunks could be used in either direction a less number would be needed. Two-way trunk equipment is possible, in fact has been tried experimentally a number of times during recent years. It is my belief that it will eventually be made a commercial success.

E. A. Mellinger: Practically the only argument which can at the present day be consistently advanced against the automatic system is the first cost of the apparatus, which, as indicated in Fig. 5, is considerably greater for a single automatic exchange than for a single manual exchange, except in cases of very large switchboards. In some instances this is a factor of more immediate importance in deciding what equipment shall be installed than is the comparative cost of operation and maintenance.

Mr. Campbell demonstrates the entire practicability of subdividing the automatic exchange to an extent not economically possible in manually operated switchboards. It is probable that, even with a comparatively limited subdivision, from 50% to 75% of the cable required for a single exchange can be eliminated. In comparison with the economy thus effected the additional first cost of the automatic switchboard is of small importance.

Since the cost of maintenance and operation of an automatic exchange is almost inappreciably increased by subdividing it into branches of 1000 lines or more, and since, obviously, the service is unaffected by such subdivision, the only items to be considered are the slightly increased cost of apparatus and buildings. With reference to the cost of apparatus, there can be no doubt but that there will be some increase with subdivision, owing principally to the present necessity for separate battery-supplying units; but in many instances there would be an actual saving in the cost of building, on account of the comparatively low value of building locations required for the branch offices. The central exchange is usually located of necessity in the heart of the business district where land values are at the highest, and any reduction in space required here would much more than

compensate for a corresponding increase in branch office space. It is probable also that less expensive building construction could be employed in branch offices than in central exchanges.

For the small sub-station serving an outlying district it is customary to rent space in some office or store building, or to erect a small building for housing the apparatus; but in an exclusive residence district it is sometimes difficult to obtain space in a suitable location. In at least one instance this difficulty has been successfully met by placing the sub-station under ground in a moisture-proof cement vault, similar to those used for housing batteries in railway signal work. The most logical location for a sub-station is usually at the manhole where the cable distribution for the district begins, and since no serious objection has been encountered in the installation and operation of the underground sub-station, there appears to be no reason why the manhole itself cannot be constructed to accommodate the switching apparatus, thus eliminating the necessity for building space.

The vault, or monolith as it is called, to which reference is made, was constructed complete in one piece before being lowered into place. It is elliptical, its dimensions being 4 ft. 10 in. by 7 ft. 8 in. by 6 ft. high, and accommodates a 100-line unit together with protector and distributing rack, batteries, etc. The average manhole is almost as large.

Carefully kept thermometer and barometer records indicate a practically constant temperature of 70 degrees fahr. and an almost complete absence of moisture, except as the presence of the troubleman or others in the vault for half an hour or more changes the normal atmospheric conditions. After such visits the vault is quickly dried by lighting an incandescent lamp for a short time. A small ventilating fan would doubtless prevent any moisture precipitation while the vault is open.

Every city has one or more telephone districts so far removed from the telephonic center that the installation of the sub-station is an economic necessity, particularly since the telephones in these districts usually yield smaller rentals than those centrally located. Such districts are being satisfactorily served by trunking stations of from one to five hundred lines in a number of automatic exchanges in various cities, but the limit of practical distribution appears by no means to have been reached. It is more than probable that in the not very distant future every large office or apartment building will have its sub-station trunking to the nearest branch exchange, even though the distance be only a few blocks, and that these trunking stations will in most cases be a part of the underground system.

From the underground sub-station to the underground branch exchange is not a long step, and although the branch office is usually of such size as to require the constant presence of one or more attendants, the necessity for artificial light and ventilation is hardly to be counted as a serious objection. The economy

which could be effected in the business center of large cities by such an arrangement is apparent.

Morgan Brooks: Mr. Campbell's paper speaks of the economic waste represented by 90% of the wire plant being idle even in the busiest hours. Imagine, if you please, a much smaller waste, such as 50%, and it is evident that the busy signal would be received from half the calls. Good service demands a minimum of busy signals, and necessitates economic waste. The author has shown that the quickness of disconnection characteristic of the automatic system helps the service, especially with trunk lines, although it evidently increases the percentage of non-use. It is only in private branch exchanges that good service may be coupled with a reasonably large load-factor of subscribers' lines.

L. E. Hurtz: A word or two about these sub-stations. Mr. Campbell speaks from the manufacturer's point of view; I speak from the operator's point of view. A very large advantage in the use of these sub-stations over the ordinary type of equipment is the fact that the exchange can be divided into units as small as one hundred lines. When considering the cable distribution of a telephone plant, the reasons that make it necessary to subdivide very large districts into several smaller ones are well understood. The question then arises as to the proper time to stop sub-dividing. In manual practice, on account of the cost of buildings and equipment and in order that satisfactory and economical service can be given, these branch exchanges vary in size from 1,000 to 10,000 lines, according to the density of the telephone development in that vicinity. With the use of low-priced buildings and low labor costs it is practical with these automatic switching units to reduce the size of these branch exchanges to one or several hundred lines, which increases the savings due to sub-division to a corresponding extent.

In our experience of a year and a half, during which time we have had two sub-stations in operation, we find we can give high grade service with but little additional labor. It is an easy matter to realize what vast savings can be made in the cable plant by use of this system. The saving in investment and maintenance cost and interest cost must be equated against the additional labor; if the additional labor item is low enough there is a big saving. This system is being tried in several places. Our experience with it leads me to believe that it is thoroughly practical and will work out as well as indicated by Mr. Campbell.

I am convinced that one of the greatest developments made in telephony in recent years is the production of this switch unit. It is possible now to put in sub-stations as small as one hundred lines, locating them at isolated points, and at the same time not increase the operative and maintenance expenses to any considerable extent.

Samuel G. McMeen (by letter): The economic waste of which Mr. Campbell treats has been recognized for many years, and efforts have been made to reduce it in manually operated sys-

tems. In most of the cases the effort has been successful. The method of waste-reduction by automatic apparatus, as treated by Mr. Campbell, is the most important recent attack, and is one from which a very large amount of new knowledge may be expected to be drawn.

The broad idea of dividing a telephone exchange wire-plant into two general parts, and then using one part at a high efficiency and the other at a low, is not new. It has been proposed again and again, and has been developed for various forms of apparatus and various arrangements of wire-plant. The planetary system of operating manual equipment was such an effort, proposed eight or ten years ago by Mr. Angus S. Hibbard. In that system all calls needed to be trunked from a small local office, in which they were first received, to a central switching office, even though they might need to be trunked right back again to the small first office to find the sought lines.

The telephone requirements of the business area of every city are served very largely by private-branch exchanges, privately operated. About two-thirds of the traffic originating in them requires to be trunked to a main exchange operated by the telephone company. If these private exchanges were to trunk *all* their originated business, even at the cost of receiving again all local calls, such a plan would be a *manual* counterpart of the waste-saving system Mr. Campbell describes. As it is, the plan is a real counterpart so far as concerns the traffic for which, mainly, a private branch exchange exists, and the object is the same—to save wire-plant at a cost for apparatus and attendance.

A proof of the widespread wish to make such a wire-plant saving is to be seen in the long effort to produce a selective and secret party-line equipment. It is possible to-day to have and use such a party-line system, but at best the privileges of the line are divided among the subscribers upon it. None has the same good condition as the subscriber on a single pair of wires, all his own. In either manual or automatic practice, the amount of central office equipment is controlled by the traffic, which party-lines do not reduce, unless by discouragement caused by poorer service. All that a party-line can do, at best, is to save something of the annual cost of its line, and unless this line be longer than a certain minimum, nothing at all is gained, and always something in quality of service is lost.

A condition not brought out by Mr. Campbell may well be considered as next in importance to the savings he treats of. I refer to the saving possible in the *character* of lines, as distinguished from their *extent*. The subdivision of the plant, so as to have many and short subscribers' lines, connecting over long and few trunk lines, enables the kind of circuits of both sets of lines to be reviewed with great gain. What I mean is this: the facts which govern the choice of circuit elements for subscribers' lines are much dependent upon distance. The conductivity of the sub-

scriber's loop governs the amount of current deliverable to his transmitter from a fixed-voltage central source. The capacity of the loop governs both transmitting and receiving. For a set standard of either, it is possible to distribute the lines of a subscriber's district, if that district be small, through cables of much smaller wires squeezed into a much smaller bundle and covered by a much smaller lead sheath, than if the district be a large one and the average lines be long. As the transmitter current problem is a direct-current distributing one, the analogy is that of large and small districts in direct-current power distribution, with the further advantages that the telephone problem involves great numbers of circuits, in each of which a small saving can be made.

For example, most subscribers' lines in multioffice manual practice require cable circuits of No. 22 B. & S. gauge wires, having a mutual capacity of not over 0.06 mf. per mile and a resistance per mile of loop of about 190 ohms. Assume that a system satisfies working conditions with such cables when the longer lines of a district have a length of somewhat under two miles and a loop resistance of, say, 350 ohms. If it were recast so as to be served by more centres, with maximum lines in each of a half-mile, a cable formed of No. 28 B. & S. gauge wires, pressed so tightly together as to have a mutual capacity of 0.22 m.f. per mile, should give similar results. Equally, wires of other metals than copper may be used, with a gain in certainty of jointing and terminating, and the reduced sheath diameter is accompanied by a reduction in its thickness.

The foregoing presumes that each small district contains its own source of current, so that the calling and the called subscriber each receives transmitter current over the minimum length of line. Experience with operating conditions shows this to be a preferred arrangement, for reasons other than transmitter supply; and the increased efficiency of transmission in private branch exchanges having localized current sources for trunked connections emphasizes the point.

Mr. Campbell's observation of the shorter holding of the line in an automatic system seems to be generally noted. It is a psychological matter more likely to be discovered than predicted. The same is true of quicker answering and less waiting for answer after actual ringing has been done. These differences in the actual performance of the two systems need to be considered in any study involving comparisons. The longer time of *initial* holding of interoffice trunks seems also to be overbalanced by the speed of disconnection in the automatic apparatus, and to this must be added a consideration of the slowing down of disconnecting efficiency on the part of the manual *B* operator during the rush period.

No casual study of large city work fails to show the beginner the influence of sub-division of districts on the amount of trunking. The percentage of calls trunked out of the New York

Cortlandt Street subscribers' board in 1896 was 75; in 1902 it was 90 or more, and to-day, under accepted manual practice for such surroundings, it is 100; that is, it is not worth while to complete any call directly in a manual multiple of lines when so few as a tenth of them can be so completed. Mr. Campbell's point of trunking all calls in an automatic system is of equal force in view of that tendency in manual practice, and of the present trend of thought in partly automatic manual systems.

A feature on which more might have been said is the possible danger of excessive changing of subscribers' numbers. It must be admitted that anything which endangers a subscriber's privilege to keep the same telephone number through a term of years is a bad thing. In a one-office exchange that danger is least, and under ideal conditions may be nothing, for the main distributing frame in that one office enables the central office equipment to follow up his line, into whatever quarter of town he may move. But in a multioffice system, it is a penalty upon the subscriber that he must change his number when he moves from district to district. The more districts there are, the worse it is for him. But it is further a hardship that in cases of relief of congested regions, as suggested toward the close of the paper, a subscriber may awake to find his number changed overnight, through no fault of his own. Certain care in districting regions, and certain stubbornness in following the resulting plan, will prevent a large part of the changes required by future splitting of original sub-office districts. It is strongly to be recommended that this forecasting be done, for the number-changing evil is one in which party-line and sub-office systems are alike.

W. Lee Campbell (by letter): Professor Smith asks if it is possible to make all of the trunks from *E* office to *A* office in Fig. 21 accessible to all of the subscribers. It is possible, in fact, equipment of the necessary type has already been installed for trial and is operating satisfactorily.

He also asks if line switch sub-stations could not be used with manual telephones in connection with a manually operated central office. I would reply that they could be, and probably will be.

Concerning the plan for relieving a congested district by converting the line cable into a trunk cable, I wish to say that this would often improve transmission from the original telephones, because it would bring the battery closer to the transmitters drawing current from it.

This feature might even permit the district to be enlarged; that is, new patrons farther away might be added and their transmission be equal to that afforded the original subscribers, before the new local office was installed.

I think that in economically designed plants the conductors of the trunk cables are not made heavier than the lines, unless the distances are so great that heavier wire is necessary to keep

the transmission up to standard. In other words, the subscribers in the district reached by such a cable would have to be served by heavier conductors if no branch office were installed in that district. I see no reason, therefore, why adding to the number of offices should increase the amount of large conductor cable used for trunks; it appears to me that it would tend to decrease the amount.