

# UNIFICATION OF THE MANUAL AND AUTOMATIC TELEPHONE SYSTEMS\*

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In telephone engineering and the resultant physical and economic accomplishment, June 1, 1918, figures prominently, for on that date the formal union of the Bell manual telephone system operated by the Pacific Telephone and Telegraph Company, and the Automatic Electric system operated by the Home Telephone and Telegraph Company in the City of Los Angeles, was effected under the management of the newly created Southern California Telephone Company, giving to every telephone user in that area a unified and unrestricted exchange telephone service and universal service over toll trunk lines to some eleven million telephones throughout the United States. Consolidations of this character have been made prior to this date but involving relatively small volumes of traffic and simple operating methods so that there were no records of actual performance or established engineering practices to serve as a precedent and guide for determining the effect of and the physical requirements necessitated by the sudden release of two large, distinct and separately bound volumes of traffic into a common channel.

Because of the novel operating and construction methods and the speculative possibilities involved in the important pioneering work of welding these fundamentally different telephone switching systems into a single eighteen million dollar plant serving 129,000 stations, a semi-technical summary of the events has been prepared for general information.

A brief reference to the conditions which brought about the consolidation will be made in order to better understand the problems that confronted the two competing telephone companies and their subscribers. Believing that competition instead of control was the automatic remedy to apply to public utilities, the City of Los Angeles invited telephone competition about sixteen years ago and then struggled along with her business firms and many of her residents paying two telephone bills for a divided and what proved to be an unsatisfactory telephone service. This condition was continued until the year 1916, when the public decided by popular vote to bring about an end to dual telephone service. Negotiations were begun and various proposals were considered by all concerned in an effort to avoid any waste or arbitrary measures. A plan was finally accepted for the organization of a local telephone company, which was to purchase the properties of the existing operating companies and unify the service, continuing with the equipments

then in plant and giving the right to the telephone users to determine for themselves whether they would retain their automatic stations or manual stations. War conditions imposed restrictions in the conservation of materials and men for such projects and called for a careful weighing of the expected benefits and expenditures of materials and labor.

With this clear understanding of the requirements, a joint committee of engineering representatives was appointed to determine the methods for the physical joining of the two systems. As a result of their efforts, a fundamental plan, together with preliminary estimates of cost, was submitted and formally approved by the City of Los Angeles, the Railroad Commission of the State of California and by the Attorney General for the Federal Government, and on May 1, 1917, formal authorization was given to proceed with the project.

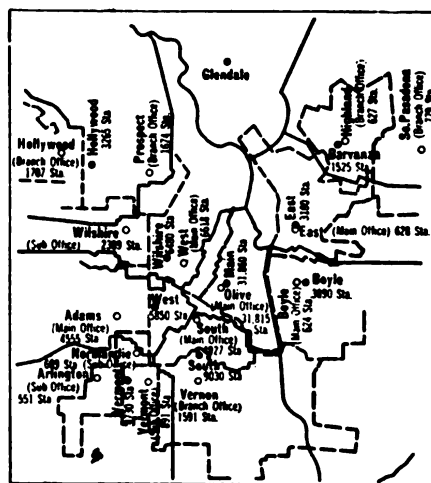


FIG. 1—AREA SERVED BY DUPLICATE PLANTS.

In order to picture the plants as they existed prior to the consolidation, I shall refer briefly to the physical properties and the operating methods of the two systems. Referring for a moment to Fig. 1, the area served by the duplicate plants was about 200 sq. mi. and lying within the corporate city limits. The open and solid circles show office and wire centers of the Home and Pacific Companies, respectively, while the dotted and solid lines mark the areas of the respective districts. The Pacific Company was established first and the opening and location of its offices followed the telephone development of the city. The first office was located in the business area and as the population increased and spread to outlying districts, new offices and districts were established. Each office was located as near as practicable to the center of the wire distributing system as determined by a study of the existing plant and expected growths for 15 or more

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years hence. As years go by and old offices are outgrown studies very often show an economy in subdividing the original district or changing the boundaries so that the natural process tends to correct any errors in estimates of growths and locations of such expected growths.

May 1, 1917, the Pacific Company's exchange consisted of its standard outside plant and station equipment and nine manually-operated central offices serving about 69,000 stations. Bell equipment was used in units having a capacity of 9,600 multiple lines. Telephone connections were established generally by the calling subscriber removing the receiver from the switch hook, causing a light to appear before an answering *A* operator, who upon receiving a request for a particular number cut-in on an order wire to the particular switchboard unit in the district, indicated by the prefix of the number called for. An operator at the distant switchboard unit, assigned a trunk over this order wire to the calling *A* operator and completed the connection by plugging into the called-for subscriber's multiple. Fig. 2 shows a schematic transmission circuit of a typical connection. The operation of this circuit will be described later and in connection with the unified plant.

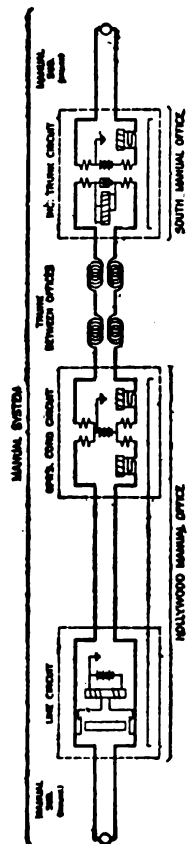


FIG. 2—EQUIPMENT INVOLVED IN A CONNECTION BETWEEN A HOLLYWOOD OFFICE MANUAL SUBSCRIBER AND A SOUTH OFFICE MANUAL SUBSCRIBER.

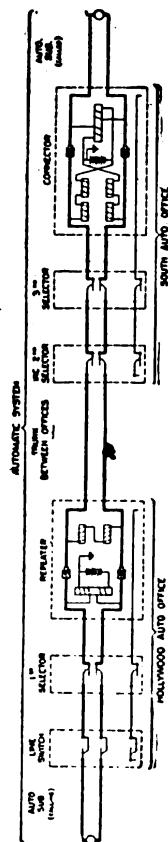


FIG. 3—EQUIPMENT INVOLVED IN A CONNECTION BETWEEN A HOLLYWOOD OFFICE AUTOMATIC SUBSCRIBER AND A SOUTH OFFICE AUTOMATIC SUBSCRIBER.

The former Home Company operated an automatic exchange including a parallel and similar constructed outside plant and fourteen offices serving a total of approximately 60,000 stations. About 35,000 stations were equipped with dials and approximately 25,000 manual stations operated from private branch exchanges and as public pay stations. The lines from the manual stations

terminated on a 45-position manual switchboard in the Olive office. Calls from automatic stations to automatic stations were made by dialing five or six digits, as required, to reach the particular district and individual subscriber. In capacity the former Home plant was one of the largest and probably the most successfully operated of any automatic system installed in the United States or abroad. Home Company private branch exchange subscribers were reached by dialing the private branch exchange operator, who completed the connection. Calls outgoing from private branch exchange subscribers were trunked to the manual transfer board above mentioned, the calls coming in on an automatic traffic distributor which placed each line lamp signal before a non-busy operator. The operator upon taking up these connections would complete the call direct if to another private branch exchange station through the subscriber's multiple or dial the number required, if automatic station was wanted. Fig. 3 shows a schematic transmission circuit of a typical full automatic connection. The operations and functions will also be described step by step later.

Los Angeles has had the distinction of having more telephones per capita than any other city in the world and is now very close to the top of the list. This general usage is reflected in the number of calls originating in each system, as shown by the records of traffic. The approximate numbers of daily average calls originating in the former Pacific plant and Home plant were in the vicinity of 430,000 and 420,000, respectively.

The engineering problems demanded, therefore, a reasonably close approximation of the volume of existing and added traffic which could be expected to flow between the groups of stations of the various districts of the two plants; a determination of the most direct and economical routing of such calls based on efficient operating methods and the use of existing facilities; and the design and development of an inter-unit trunking plant and switching circuits necessary to maintain the commercial standards for transmission and supervision between the two systems regardless of the mechanical, electrical and operating inequalities. Visual and audible signals peculiar to the separate systems required for supervisory purposes needed to be synchronized or harmonized and extended when necessary so as to afford common usage.

It is obvious that a great many plans and combinations of plans for unification were developed in sufficient detail to determine their relative capital and operating costs and advantages and disadvantages. The plan in principle that was adopted for handling the inter-office traffic between the systems was to operate all existing offices as units of the complete exchange and route the new automatic or manual trunks of each office into the adjacent office of the opposite system, where the connection could be completed by the most direct method and route.

Having referred to the facts that were most vital in shaping the project, I should like to outline the

organization and schedule of work involved in the construction program estimated to cost \$1,250,000. Every reasonable effort was demanded to bring about a unification of the properties without waste of time, and accordingly a complete schedule for the ordering of materials, manufacturing, assembly and installation thereof was set up after a canvass of probable material deliveries and of the labor situation. It became evident that a period of twelve months would be the shortest time possible to complete the necessary work, keeping in mind that war demands might upset the schedule, and all effort was centered on finishing the project within the minimum time. Specifications and plans were completed for each individual project, numbering all together about 110, and each one was charted with due regard to the materials involved, quantity, desired time of delivery and installation and its relation to the project as a whole.

The largest single project consisted in the design and manufacture of the 66-position special tandem switchboard and associated equipment to be located in Olive office for the translation and distribution of calls from automatic stations to manual stations in the downtown area. This switchboard, together with the switching circuits was designed in detail by the engineers in the general office of the telephone company, and all of the manufacturing and assembly work was performed in San Francisco. Extensive rearrangements of the Olive office building were necessary to provide space for this equipment and for retiring quarters for the large number of operators required to give the necessary 24-hour continuous service.

In the manual offices it was necessary to equip the regular subscriber positions with a dial for sending out the electrical impulses, and to provide outgoing trunks connecting directly with the automatic equipment in the adjacent office. There were approximately 375 subscriber switchboard positions in the manual system in the Los Angeles exchange that required the installation of this special equipment and associated wiring and this proved to be one of the most difficult parts of the work, because such work had to be performed on positions of switchboard that were in continuous operating service. I will refer to Fig. 4 and describe the switching circuit associated with the dials at the operators' positions. Each operator on the subscribers' switchboard is provided with 10 outgoing trunks terminating in the nearest automatic office on first selectors. These outgoing trunks are provided with twin jacks, one above the other, and electrically connected so that the dialing device can be associated with each of the trunk circuits to the distant office. The plug connecting with the dial is inserted in the lower first jack while a call originated by the manual subscriber for an automatic station is connected to the upper first trunk jack by means of a regular *A* operator's double-ended cord circuit. The operator then proceeds to dial the number requested and as soon as this number has been dialed, the operator moves the dial circuit plug to the lower second jack, thereby pre-

selecting the trunk circuit for the next call for an automatic station. The operation of the second and third selectors and final connector is the same as described later under "Automatic to Automatic Connections." The circuit is so arranged that the manual *A* operator just referred to receives direct supervision for both the calling manual and the called for automatic station. At the end of the conversation, the lighting of a lamp associated with each end of the *A* cord circuit indicates to the

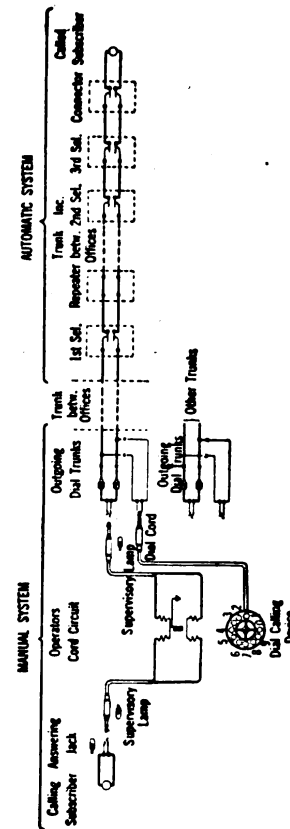


FIG. 4—METHOD OF ESTABLISHING A CONNECTION BY MEANS OF A DIAL CALLING DEVICE.

operator that the connection has been finished and all cords are to be cleared from the subscriber's line and trunk jacks. The outgoing dial trunks are used in rotation and the actual number of the trunks connected by such lines to the distant office varies with the traffic requirements.

Central office telephone installation work has generally been organized for individual projects usually confined to a particular office building. The plan of scheduling the material and utilizing this material to its greatest advantage made it necessary to depart from regular practices of the installing forces and to provide that all of the work should be treated as one project wherein the men trained for specific work were to be moved from one office to another as materials arrived and thereby facilitating the completion of the work regardless of irregularities in the arrival of materials for a particular office.

This arrangement was one of the important factors in effecting the final completion of the central office work, April 30, 1918. The time intervening from the date until the beginning of the delivery of the directory and the formal announce-

ment of consolidation on June 1, 1918, was required in placing thousands of test calls over all combinations of connections to make sure of positive operation. In a typical connection between an automatic and manual station there are 41 relays, and 79 from manual to automatic, having movable parts controlling from one to ten electrical contacts, each of which must function in the proper sequence from the start to the completion of each telephone call. I do not wish to convey an impression that telephone circuits are inherently subject to failure, for they are not. The characteristics and operating requirements for each relay, for instance, is known mathematically and what it can be depended upon to do for a specific period of time. At regular intervals each type of relay is given its proper current adjustment, using measuring instruments designed for that purpose.

The installation of telephone cables and central office equipment of the manual or automatic type required the use of highly trained and skilled labor and the telephone company faced the difficulty of obtaining the large number of electricians and mechanics required to hold the schedule and training them for special work. As it was, considerable overtime became necessary to maintain a working balance between the arrivals of material and the available labor.

Among the larger items of expenditure, and one involving months of study and calculations in voice transmission were the additions and changes necessary in the cable trunking plant in order to maintain commercial standards on all local and long distance connections. These studies included the use of and application of loading coils to the former Home Company cable plant amounting to about 1000 coils and the addition and respacing of many of the coils in the portion of the Pacific Company cable plant. All together about 75,000,000 conductor-feet of various gages of underground telephone cables were ordered and installed to provide new routes and reinforce existing trunk groups required for consolidated service.

Prior to the consolidation, practically all of the subscribers having private branch exchanges maintained duplicate switchboards and station apparatus. The problem, therefore, of consolidating this type of equipment offered no particular difficulty, as such consolidations could be and were effected by grouping the trunks formerly serving the separate systems on the particular switchboard to be retained, adding thereto the amount of line and trunk facilities desired by the subscriber and eliminating the duplicate switchboard and stations not required. The net effect was to remove about 345 single-position private exchange switchboards from the system. In the case of several of the larger commercial companies, it was necessary to order complete multiple private branch exchange switchboards of the 640-line capacity and about 30 sections of such boards were placed in service as fast as the equipment could be engineered and manufactured. It will be interesting to note that the flow of traffic to and from private exchanges

was not greatly disturbed from the existing paths by this plan of consolidating, a principle which was kept well in mind and taken advantage of wherever practicable.

Where individual and party stations were duplicated, both stations were left connected until the new directories were delivered, at which time the subscriber was requested to use the telephone of the particular system that he had made application for and the other station was removed as soon as the construction forces could handle the work. Approximately 13,000 duplicate stations have been removed.

A considerable number of operators were required and for a while it looked very much as if the consolidation would have to be postponed because of the inability to obtain the needed force. Good service depends to a large extent on capable and efficient operators and you can appreciate the difficulty that confronted the operating department in the selection, employ and training of approximately 500 additional operators required for handling the special transfer switchboard installed in the Olive office building, and for the large number of added positions of switchboard in the various manual offices. A large operating school equipment was hurriedly manufactured and installed and training of operators was started about the first of the year 1918. The schedules also provided for the early installation of dials on the subscriber positions in the manual offices for advance training of the regular operating force. Special observation equipment was designed and furnished for practice work in placing test calls and later for supervision in determining and checking the accuracy of dialing the calls placed by the subscribers. By means of automatic recording devices the numbers called for by the subscribers or instructors were compared with the numbers actually dialed and in this way the operating force was gradually brought to an efficient basis by the time the construction work was completed.

Proceeding under the restrictions that each subscriber having duplicate service should determine for himself whether to retain automatic or manual substation equipment, the commercial department carried on a vigorous campaign to obtain these subscribers' choices and to arrange accordingly. I do not have the exact figures but I understand that of the 18,680 duplicate stations about 5,200 duplicates were retained and the balance were divided evenly between the two types. The expected result of this canvass has been forecasted and was an essential factor in engineering and in construction work.

As a function of the commercial canvass the Directory Department was confronted with the necessity of recasting the entire directory scheme to the particular needs of a unified service. A great amount of thought was given to the determination of the most efficient arrangement of listing and numbering subscribers, and while this seems trivial yet a careless directory arrangement reflects on the quality of the telephone service and robs the public

of valuable time. Many number of changes were involved and a complete relisting of every subscriber's name and number into one alphabetical list introduced great possibilities of errors. (It is a matter of passing interest that 165,000 copies of the directory were issued and distributed in Los Angeles and to other exchanges for long- and short-haul toll traffic and that over 441,000 pounds of paper were required in the printing of the consolidation issue.)

In the present unified plant, local calls are divided into four main groups and are obtained in the following ways:

*Calls from Automatic Stations to Automatic Stations* are obtained in the same manner as under the former Home management, that is, by the subscriber dialing the number wanted as indicated by the directory listing. Such subscriber sets are provided with the familiar dialing device arranged to transmit from one to ten electrical impulses for each "pull" of the dial. In the automatic system most of the stations are reached by dialing five digits although there are a few thousand six digit numbers. The operation of the first digit of the five digit numbers selects the office district required, the second digit selects the particular thousand, the third digit selects the particular hundred, while the fourth and fifth digits select the tens and units respectively of the number desired. Referring to Fig. 3, the calling automatic subscriber upon removing the receiver from the switchhook completes an electrical circuit through a Keith line switch, the chief function of which is to direct the simultaneous calls to a minimum number of trunks to first selectors. Each automatic line therefore terminates on a primary line switch having ten paths to as many first selectors, these trunks being multiplied to other line switches, depending on the calling rate or traffic load of the particular group of lines. The operation of the first digit of the number wanted causes the mechanism of the first selector to step the brush terminals upward to one of the ten levels, arbitrarily connecting to a particular 10,000-line unit. This selector is of the trunk-hunting type, that is, the subscriber, as noted above, having dialed, say, the digit 6, causes six electrical impulses to be transmitted through the selector mechanism through the stepping relay, raising the brushes to the sixth level. The selector then automatically begins a rotary movement and continues until an idle trunk is found. There are ten trunks over which this rotary trunk selection takes place and the traffic is so distributed over selector equipment that with very few exceptions an idle trunk will be found within this group of ten. The connection is then established through what is termed repeater equipment (consisting of coils and relays by the aid of which the calling impulses are repeated from the local to the distant office and talking battery is provided to the calling station) to a particular second selector in the distant office. The dialing of the second digit by the calling subscriber again operates the stepping mechanism to one of the ten levels corresponding to the thousands of the number wanted. Auto-

matic rotary movement takes place, selecting an idle trunk to the third selector where the dialing and selecting of the hundreds is the same as for the first and second selectors. The connection now is established through to the connectors which is similar in its operation to selectors with the exception that the ten digit steps the mechanism to the corresponding level while the units' digit controls the rotary movement to the particular unit required. The connector also supplies talking battery to the called subscriber and sends out the necessary ringing impulses to call either the individual or party subscriber desired or sends back the busy signal if the line called is in use. The restoring of the receivers to their switchhooks automatically returns all of the connecting equipment to normal position again for use on subsequent connections.

*Calls from Automatic Stations to Manual Stations* are obtained by operation of an arbitrarily assigned digit, the ninth digit or level being available in this case. Trunks from these first selector ninth levels lead the nearest manual office and terminate by the aid of the familiar line and cutoff relay on an answering jack with a lamp signal before an *A* operator. Referring to Figs. 5 and 6, the *A* opera-

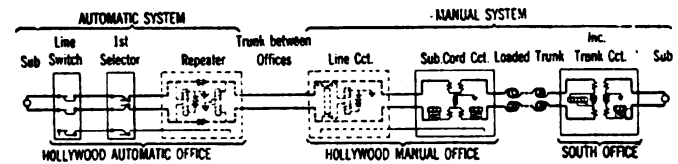


FIG. 5—EQUIPMENT INVOLVED IN A CONNECTION BETWEEN A HOLLYWOOD OFFICE AUTOMATIC SUBSCRIBER AND A SOUTH OFFICE MANUAL SUBSCRIBER

tor upon receiving a line lamp signal, plugs into the corresponding answering jack and requests the subscriber to give the number (and office prefix) wanted as shown by the directory listings. The call is then completed within the office received or is trunked over the manual trunking system to the distant *B* operator in the same manner as described under calls, manual to manual. In the downtown district where a considerable amount of traffic is

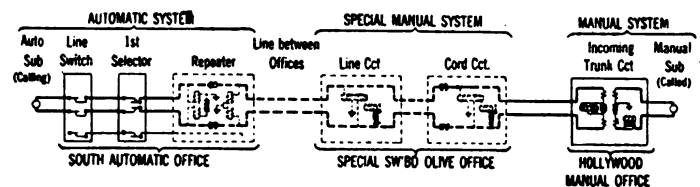


FIG. 6—EQUIPMENT INVOLVED IN A CONNECTION BETWEEN A SOUTH OFFICE AUTOMATIC SUBSCRIBER AND A SOUTH OFFICE MANUAL SUBSCRIBER

involved, it was found impossible to add to the large number of *A* positions to the various manual units and it was necessary to install a special manual switchboard, in available space in the Olive office building. This special board contains only the necessary multiplied terminating lines, outgoing trunks

and key and supervisory equipment necessary for establishing the connections between the automatic and manual system. Automatic calls therefore in this district are completed by the dialing of the digit 9 as before, bringing the line signal in on this special *A* switchboard where such connections are completed as in regular manual practice over trunk lines assigned over order wires.

*Calls from Manual Stations to Manual Stations* are obtained in the same manner as existed prior to the consolidation, that is, by the agency of the *A* and *B* operators and corresponding manual switchboards. Referring to Fig. 2, the calling manual subscriber upon lifting the receiver from the hook causes a lamp to light before an *A* operator in his district. This line terminates on the ordinary line and cutoff relays, the former operating as soon as the switchhook closes the circuit, causing the line lamp to burn. The *A* operator then plugs into the corresponding line jack with one end of a double-ended cord circuit, this operation causing the cutoff relay to energize and thereby opening the circuit through the line relay and lamp. The operator then throws the listening key and requests the called for number. She then proceeds to complete the connection by plugging either directly into the subscriber multiple or by plugging into a trunk line leading to the distant office required and as assigned by the distant *B* operator over an order wire circuit. The distant trunk operator then plugs into the required subscriber's multiple and automatic ringing proceeds until the subscriber answers. Supervisory lamps associated with both the trunk cord and the double-ended *A* cord furnish the necessary indication to the operators of the establishment of the connection and end of the conversation. When both lamps associated with the double-ended *A* operator's cord relight, the connection is taken down and this operation gives a disconnect signal also to the distant trunk operator.

*Calls from Manual Stations to Automatic Stations* are obtained by direct trunk circuits. An *A* operator receiving a manual subscriber's request for a particular automatic number, as indicated by the directory listing, proceeds to dial the number in the same manner as described above for an automatic subscriber. Each *A* operator is provided with a group of trunks, as shown by Fig. 4 and described in the first part of this paper, leading to the nearest automatic office and terminating directly on first selectors.

*Private Branch Exchange Calls* originating from such exchanges of the former Home Company were formerly operated and are still operated on a manual basis. Calls placed by extension stations from these private exchanges are trunked to a manual switchboard in the Olive office building, this switchboard having the familiar subscriber multiple of all the private exchange trunk lines. The incoming private exchange trunk lines, however, are carried through Keith line switches, the function of which is to select a non-busy operator and to place the line lamp signal before the operator. This arrangement is commonly known as the traffic distributor.

This pre-selected operator then receives the request for either an automatic or manual number and if for the former, she dials the number as described above for manual *A* operators. If the called for number is for another private exchange station, the operator completes the connection in the multiple similar to a manual-to-manual connection and if the request is for a station in a manual office, it may be obtained by the use of order wires and trunks direct to the office required or over trunk lines to the special Olive office manual *A* board. All connections to and from the former Pacific manual private branch exchange stations are completed in accordance with the above general methods of handling calls to and from manual stations.

So far as I know, no definite statement can be made as to the gains accruing to the subscriber at Los Angeles under the consolidated arrangement, because the most important factors are not capable of reduction to equated savings in dollars.

Some of the major factors resulting in direct benefit are:

1. Value to the subscribers resulting from telephone access to each and every subscriber in the Los Angeles exchange and to all long distance lines centering there.
2. Rental savings resulting from the elimination of a large number of duplicate stations and private exchange switchboards.
3. Elimination of the indirect economic loss due to confusion and community service inefficiency of separate telephone systems.

Some of the factors which tend to offset part of the savings are:

1. Added annual charges on the plant and equipment required to provide means for universal service. There was very little elimination of duplicate plant investment primarily because each plant was designed to care for a definite development and volume of traffic. Consolidation obviously does not reduce traffic volume, but because the telephone field is considerably increased to every subscriber, the total volume of traffic in the consolidated plant is substantially increased.
2. Added operating and maintenance costs.

From a careful weighing of these factors it is manifest that the consolidated plant offers substantial savings and benefits over the dual systems. The worth of a telephone system to any community lies, not only in its capacity for effecting good service but that such service shall be universal and available to the maximum possible number of local and distant subscribers.

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