INTER-OFFICE COMMUNICATION

by

HARRY W. HANLON

B.S. in E. E. University of Kansas 1923

Submitted to the Department of Electrical Engineering and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Electrical Engineer.

Approved by:

[Signature]
Instructor in Charge

[Signature]
Head of Department

May 14, 1931
Preface

In the field of communication, numerous articles on various phases of the subject have been submitted to the public from time to time. The lay public has become more or less informed on the general principles of communication in radio, telegraphy and telephony, and more information on these subjects is being made available as the respective fields are developed. But heretofore there has been very little information on the more or less restricted field of inter-office communication. No doubt this is largely due to lack of interest in this comparatively narrow field. However, it is felt that a discussion of the problem of designing and maintaining a satisfactory means of communication between operating centers, with particular emphasis upon the economy and business aspects of the work, will be of interest to the general public as well as to those who are directly connected with telephone work.

It is of interest to note how a circuit may be set up between two remote subscribers within such a short interval of time; how satisfactory transmission is available, regardless of the distance, or of the type of connection; and what progress is being made in providing an economical conductor for these inter-office messages. It is the purpose of this paper to give a general picture of the problem of providing inter-office communication with regards to traffic,
transmission, and plant, with some observations of the inter-office trunk plant of greater Kansas City.

This paper is written from the standpoint of the engineering of the outside plant involved in the providing of circuits between central offices. For this reason, only enough of the features of traffic, voice transmission, theoretical design, etc., are included to give a more complete background for the more definite picture of providing the proper inter-office facilities.

The problem of designing an efficient, flexible trunk plant that will make available any circuit desired between any two or more offices of the metropolitan area introduces many phases of efficiency, transmission, traffic and economics that may not be considered in the design of other classes of telephone plant.

Harry W. Hanlon,
Kansas City, Missouri,
May, 1931.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>5</td>
</tr>
<tr>
<td>Traffic Problem of Trunking</td>
<td>7</td>
</tr>
<tr>
<td>Direct and Tandem Trunking</td>
<td>10</td>
</tr>
<tr>
<td>Estimating Trunk Requirements</td>
<td>12</td>
</tr>
<tr>
<td>Satisfactory Transmission</td>
<td>14</td>
</tr>
<tr>
<td>Loop and Trunk Study</td>
<td>15</td>
</tr>
<tr>
<td>Trunk Loading</td>
<td>21</td>
</tr>
<tr>
<td>Providing Facilities</td>
<td>25</td>
</tr>
<tr>
<td>Combining of Trunk Routes</td>
<td>26</td>
</tr>
<tr>
<td>Main and Tributary Trunk Routes</td>
<td>28</td>
</tr>
<tr>
<td>Analysis of Trunk Requirements</td>
<td>29</td>
</tr>
<tr>
<td>Installation of Additional Facilities</td>
<td>31</td>
</tr>
<tr>
<td>Loading Coil Installation</td>
<td>33</td>
</tr>
<tr>
<td>Aerial vs. Underground Cables</td>
<td>36</td>
</tr>
<tr>
<td>Miscellaneous Use of Trunk Facilities</td>
<td>37</td>
</tr>
<tr>
<td>Maintaining Proper Transmission</td>
<td>38</td>
</tr>
<tr>
<td>Trunk Plan of Greater Kansas City</td>
<td>41</td>
</tr>
<tr>
<td>Summary of Transmission Tests</td>
<td>44</td>
</tr>
<tr>
<td>Summary of Trunking System of Kansas City</td>
<td>46</td>
</tr>
<tr>
<td>Conclusion</td>
<td>47</td>
</tr>
</tbody>
</table>
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Intra-Office Connection</td>
<td>7</td>
</tr>
<tr>
<td>2.</td>
<td>Inter-Office Connection</td>
<td>8</td>
</tr>
<tr>
<td>3.</td>
<td>Connection Through Tandem Board</td>
<td>8</td>
</tr>
<tr>
<td>4.</td>
<td>Direct and Tandem Trunks</td>
<td>10</td>
</tr>
<tr>
<td>5.</td>
<td>Inter-Office Subscriber Losses</td>
<td>16</td>
</tr>
<tr>
<td>6.</td>
<td>Combining of Trunk Routes</td>
<td>27</td>
</tr>
<tr>
<td>7.</td>
<td>Load Coil Spacing Diagram</td>
<td>34</td>
</tr>
<tr>
<td>8.</td>
<td>Trunk Route Guide Card</td>
<td>39</td>
</tr>
</tbody>
</table>

**Appendix**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>Trunk System of Greater Kansas City</td>
</tr>
<tr>
<td>10.</td>
<td>Annual Charges of Trunk Conductors</td>
</tr>
<tr>
<td>11.</td>
<td>Annual Charges of Tandem and Toll Trunks</td>
</tr>
<tr>
<td>13.</td>
<td>Variation of Trunks per Station and Cost per Station to Inter-Office Distance</td>
</tr>
</tbody>
</table>
Inter-Office Communication

INTRODUCTION

When telephony was first introduced as a system of communication, the problems of transmission were vastly different than they are today. At that time the conductors were short and of large gauge open wire. There were no long toll lines and the problem of switching was a simple matter. Hence, since there was a comparatively small loss of transmission in the conductors, it remained for the pioneer telephone engineer to develop a more efficient transmitter and a more sensitive receiver. As these were developed to a more practical standard, however, more and longer lines were demanded, necessitating developments in other phases of the system as well. A faster, more efficient method of switching the lines was necessary. The longer lines required some means of lessening the loss of transmission in the conductors, and at the same time, the demand for more lines necessitated a more compact arrangement of conductors which tended to increase rather than decrease the transmission loss of conductors. It was a mere question of time until the public demanded communication between operating centers, which further complicated the problem of providing satisfactory voice transmission. The various problems were solved from time to time by means of improved subscriber sets, and switchboards, replacing of open wire with cable conductors, the use of load coils, repeaters, carriers, etc., until now a composite plant
has been developed which is capable of carrying the human voice to any part of the world, provided that it is economically advisable to do so. Thus the question before the telephone engineer of today is not "Can it be done?" but rather "How can it be done economically as well as satisfactorily?" That is, telephony has passed through the pioneer stage and is now devoting its efforts towards a more economical system of universal communication.

Thus, the various forces of the telephone system are centered toward the design of an over-all efficient system of plant, a system whose every part should be so designed as to be economically efficient. For the sake of satisfactory service and the public good will, the plant should be so designed that an approximately uniform grade of transmission is attained for all subscribers and for all types of circuits and connections. Also, it is obvious that the very nature of the telephone system requires an extremely flexible type of plant in order to promptly set up an accurate and satisfactory circuit between any two subscribers of the entire telephone network. It is equally important that the plant and the method of operation be designed as economically as possible. This general problem of producing an economical as well as a flexible, accurate, speedy and satisfactory grade of service, is a composite one, made up largely of minor problems of traffic, transmission, plant, etc. Since from 50 to 72 percent of all calls of a
metropolitan operating center are outside calls requiring a trunking circuit, and since the trunk circuits are more flexible than the distributing subscriber circuits, the method of trunking and the design of the trunk plant are major items of this general problem.

**TRAFFIC PROBLEM OF TRUNKING**

The switching necessary to provide a talking circuit from one subscriber to another is largely a traffic problem. In the case of a subscriber calling another subscriber in the same central office area, the operation is quite simple, only one connection being required between the calling subscriber A, and the called subscriber, B.

![Fig. 1: Intra-Office Connection](image)

If the subscribers who desire to converse are in different operating centers, the method of providing the circuit is somewhat more involved. If a direct talking circuit is available between the two central offices, the two subscribers are connected as in Figure 2. The operator
X, receives the call of the subscriber A and makes a connection to an idle trunk to the desired central office, and the operator Y, at that office, in turn connects this trunk to the called subscriber's line B, and the circuit is completed. If a direct circuit is not available between the two central offices, it will be necessary to route the call via another central office, as in Figure 3.
In this case, the operator, X, upon receiving the call, makes connection to an intermediate central office (usually designated as "tandem board") and the tandem operator Z sets up the circuit to the desired central office, and the operator, Y, of the called central office makes the final connection to the called party. In some cases, a second tandem operation may be required, if all central offices of the same metropolitan area are not connected to one tandem center.

It is obvious that any central office in order to have telephone communication with other central offices or communities must have trunk connections with at least one other central office, and the demand for inter-office communication facilities may demand trunk connections with a number of other central offices. Thus, as the traffic increases and more calls are made to other operating centers, the problem of properly routing these calls becomes one of appreciable magnitude, especially so when the central office is one unit of a multi-office metropolitan area. In any operating center of a multi-office community, all outgoing calls to other local operating centers maybe routed either via direct trunks or through the tandem board as in Figure 4.
From this it is seen that in the case of direct trunks there are twelve groups of direct trunks, whereas there are only eight groups required for tandem operation. On the other hand, the plan of tandem operation requires one more switching operation which means additional switching time and additional investment of switching equipment. Practically, a compromise between the two plans is usually advisable, direct trunk groups being provided where the volume of traffic warrants such, and the use of tandem operation where the volume of traffic between any two offices is too small to warrant the investment in direct trunk facilities.
The determining of the relative economic merits of direct and tandem trunking is a problem of no small proportions. However, it is obvious that the tandem operation would be impractical in the case of large adjacent operating centers, and it is equally obvious that facilities for direct trunk groups between small, remote suburban offices would be out of the question. As to the question of direct versus tandem trunking of those groups between these two extremes, it is largely a question of proper operating efficiency. Individual conditions largely govern the type of trunking adopted, e.g., comparison of available outside plant facilities for direct and tandem trunking, length of total trunk involved, switchboard facilities, etc. For example, there may be two small suburban offices whose traffic from one center to the other would normally be routed via the tandem board on account of the small amount of traffic. However, if direct trunk facilities are available, or can be provided at a small cost and the tandem board is becoming overloaded, the providing of direct trunks may be considered as a partial relief of the tandem board. On the other hand, if direct trunk facilities cannot be provided at a reasonable cost, it is possible that tandem board operation should be recommended.

While a comparison of theoretical costs of direct versus tandem trunking can be obtained by considering the annual charges of outside plant, switchboard,
operating, etc., of the two plans, actually the most economic plan cannot be determined except by a detailed study of the entire trunking system of the area. In a large metropolitan area the various trunk groups and their corresponding inter-office facilities are so inter-dependent that an accurate study of one particular group cannot be made without considering other groups that are, or may be, similarly routed. Since the tandem board is the center of the metropolitan trunking system, it is readily seen a study may become quite involved before the economic merits of the tandem system are determined.

After the general trunking plan has been adopted, it is important that the trunking facilities be used as efficiently as possible. Not only must the existing facilities be used efficiently, but also, in a fast developing area, it is just as important that the future requirements be anticipated with the greatest possible accuracy so that the best and most economical plans for the development of the trunk plant can be made to provide for an adequate, yet efficient plant for the future. A practical accurate estimate of the future trunk requirements between two central offices, A and B, may be obtained by the formula: \( C = \frac{a \times b}{K} \), where \( C \) = calls between offices A and B, \( a \) = originating calls in office A, \( b \) = originating calls in office B, \( T \) = total originating calls in the exchange area and \( K \) = community
of interest factor. The latter is somewhat of an arbitrary figure and is dependent upon various factors, such as class of service, distance between offices, etc. This factor, ordinarily does not vary greatly from time to time for two given central offices. The factors \(a, b, c,\) and \(t\) vary approximately as the respective number of stations. Thus, by comparing the present number of calls and number of trunks with the number of calls as computed for the estimated number of stations for the future date, a quite accurate figure for the future trunk requirements is obtained. The trunk requirements thus obtained may be more or less adjusted to fit the individual conditions. In the case of intra-office or short haul trunks, where the plant investment is small and the volume of traffic large and more or less changeable, it is reasonable that the estimate of trunk requirements be fairly liberal. On the other hand, if long tandem trunks to a small suburban central office are considered, a less liberal allowance would be advisable. At the same time, however, if the trunk requirements are being estimated for the purpose of providing additional plant facilities, the estimate should be ample for any growth or traffic changes that may occur for a somewhat longer time in the future, so as to forestall the need of additional facilities on a comparatively unimportant trunk route. For example, if it is proposed that a fifty pair
trunk cable be installed, and the total requirement is forty lines in five years, because of the small margin of ten lines, it may be well to consider first, if the estimated station growth is adequate; second, if a liberal calling rate has been allowed and third, if there is any possibility of traffic changes because of central office conversions and additional central offices. If these factors should materially increase the trunk requirements, it is probable that a one hundred pair cable should be provided since the additional facilities could be provided at a comparatively small additional cost.

SATISFACTORY TRANSMISSION

After determining the number of trunks required, the next problem to be solved is to determine what grade of facilities should be provided. Taken as a whole the entire telephone system should be so designed that any subscriber may obtain a circuit of a good serviceable grade of transmission to any other subscriber at the lowest cost consistent with good serviceable plant. To attain this standard requires the engineering of the entire plant on that basis in order that the allowable transmission loss may be properly allocated to the subscriber, trunk and toll lines.

Transmission Standard: The unit of transmission measurement is the DECIBEL, which is a term denoting the
the ratio of two powers. Two amounts of power differ by one decibel when they are in the ratio of $10^{\cdot1}$ and any two amounts of power differ by $N$ Decibels when they are in the ratio of $10^{N(\cdot1)}$. With this unit of measurement it is a simple matter to determine by experiment and calculation a definite standard of transmission that is commercially satisfactory. In general, a total loss of transmission from one subscriber to the other of approximately 22 decibels is considered as commercially satisfactory. The actual standard adopted may vary from this figure more or less, depending upon individual conditions, such as noise interference, class of service, etc. After a standard of transmission is adopted, the next problem is the proper and most economical allocation of these losses.

*The Loop and Trunk Study* is a study of the subscriber loops and trunk lines of a central office area for the purpose of determining the proper economic balance of costs between subscriber loops and trunk lines. In general practice it is found that a circuit of from 18 to 22 decibels transmission loss is satisfactory for local service, and from 20 to 25 decibels for toll service. An example of a local talking circuit involving an interoffice connection is shown in Figure 5, in which two subscribers are connected by means of their respective central office.
connections C and C₂, through a permanent inter-office circuit, LZ. Assuming the maximum required length of subscribers' loops, L₁ and L₂, the given route inter-office distance L, the central office losses, C and C₂,

Figure 5- Inter-Subscriber Losses

and a transmission standard of A decibels, the equation for the total inter-subscriber loss may be stated as follows:

\[ A = L₁B₁\text{TX} + C₁ + LZ + C₂ + L₂B₂\text{RY} \]

where \( \text{TX} \) = transmitting loss per unit length

\( Z \) = trunk loss per unit length

\( \text{RY} \) = receiving loss per unit length

B and B₂ = variable factors of subscriber loop transmission to provide for the non-proportional variation of subscriber loop transmission losses to length of loop on account of battery supply loss. From this equation, it is seen that with the given constant quantities of length, central office losses, and transmission standard, there are three
variable quantities of unit losses, whose relative values are dependent upon the relative costs of the conductors. A similar equation may be set up for tandem and toll trunks, the only difference being the introduction of one or more trunks, whose transmission must likewise be determined. The economic solution of this equation is the primary purpose of the loop and trunk study.

It is obvious that in many cases the maximum allowable transmission loss of subscribers' loops and the consequent allowable loss left for trunks may be determined from the standpoint of providing the proper facilities alone. For example, it would not be advisable to extend the allowable subscriber loop loss to such a point that large 16 gauge loaded conductors are required for the local inter-office trunks, and it would be likewise inexpedient to extend the allowable trunk loss to such an extent that an abnormal amount of large gauge conductors would be required for the subscribers' lines.

In the consideration of the transmission loss of inter-office calls, there are three classes of trunks, each of which has a distinctive transmission feature. The direct trunk is directly connected to the lines of the two subscribers desiring communication so that the entire allowable loss of transmission, less that of the central offices and the two subscribers' loops may be dissipated
in this trunk circuit. The tandem trunk requires a connection at the tandem board to a tandem completing trunk before the circuit between the two subscribers can be completed as in the case of direct trunks. Hence, the transmission loss should be only one-half of the amount allowed for a direct trunk. The toll switching trunk requires a superior grade of conductor on account of the small allowable loss between the toll switchboard and the subscriber. In Kansas City a maximum loss of seven decibels is allowed between the toll switchboard and the subscriber. It is the aim of the loop and trunk study to design the most economical subscriber and trunk plant that will meet the standards of transmission for these types of trunks. In many cases a detailed study may be required to actually determine the proper plan. Consideration must be given to the subscriber line distribution. By determining the average length of subscriber loop, and the cost of providing suitable subscriber and trunk conductors, the proper design is obtained. A hypothetical case may serve to picture the purpose of the study more clearly. Assume that in a given central office district it is to be determined whether the maximum total transmission loss of subscriber loops should be limited to eight or nine decibels, with the same standard of transmission in either case. From the discussion just given it is easily seen that if more loss is allowed in the subscriber's circuit there will be less allowable loss for the trunk circuits,
and vice versa. In the given case there are A subscribers whose average annual charge of conductor is "a₈" dollars, with 8 decibel allowable loss and "a₉" dollars, with 9 decibel loss, B subscribers with annual charges of "b₈" and "b₉", etc., until all of the lines are included. Likewise, these are M trunks with annual charges of "m₈" and "m₉", N trunks with annual charges of "n₈" and "n₉" etc., until all of the trunks terminating in the office are included. Therefore, assuming Z₈ and Z₉ to be the total annual charges of subscriber and trunk plant for the respective plans under consideration, $Z₈ = A₈ + B₈ + C₈ + \cdots + M₈ + N₈ + O₈ + \cdots \cdots$ and $Z₉ = A₉ + B₉ + C₉ + \cdots + M₉ + N₉ + O₉ + \cdots \cdots$. Thus, other factors being equal, the plan whose total cost, Z, would be less should be recommended.

It is to be noted that the loop and trunk study is a theoretical plan from which the practical design may digress quite materially, dependent largely upon previously designed plant. For example, in many cases there may be a surplus of 19 gauge, non-loaded conductors over which may be routed a number of trunks which, according to the loop and trunk study, should use 22 gauge loaded facilities. Obviously, it would not be advisable to provide load coils for these trunks when the transmission is satisfactory and there is no demand otherwise for the
19 gauge conductors. However, the proposed grade of conductor is held at all times as a standard so that when there is a demand for the larger gauge, they may be provided by installing the load coils on 22 gauge conductors for the trunks, thus providing the relief of the 19 gauge conductors without the cost of installing a new cable. Figure 10, in the appendix, is a chart showing the annual charges of the various gauges of conductors, with their standard types of loading. From this chart, it may be noted that the difference in annual charges between 19 gauge non-loaded and 22 gauge loaded conductors is quite appreciable, the difference being proportional to the length of the circuit. It is quite obvious from this chart that it is advisable to provide the smallest gauge of cable that will meet the requirements of transmission and supervision. It is therefore important in any case where additional trunk plant is being proposed that a careful analysis be made of the trunk requirements by gauges and loading to determine the needs according to the grade of facilities.

It is, of course, to be expected that the standards of transmission and economy cannot be followed without some variation. However, since the transmission of speech is the chief commodity to be sold by the telephone system, it is important that a sub-standard grade of transmission is not sold to the public because of laxity in adhering to the adopted standards. It is of interest to note the
difference in annual charges on trunks required for standards of 20 and 22 decibels respectively. This is shown in chart form in Figure 12 in the appendix. These curves are based on average trunk losses and compiled from Figure 10. By determining the number of trunks involved and their route distances a comparison of theoretical costs may be obtained. It is also interesting to note that up to a route distance of approximately 62,500 feet the cost of trunks for a standard of 20 decibels is very little higher than of those for the 22 decibel standard. Since the most of the direct trunk groups are of shorter length than this maximum length, it may be deemed advisable to prescribe the standard of lower loss of transmission.

Trunk Loading is of interest in the engineering of inter-office trunks because of the high degree of transmission attainable at a slight increase in cost. Recent developments in the design of loading coils and their containing cases have resulted in a material reduction in the cost of loaded conductors. Briefly, the loading of a circuit consists of inserting inductance coils in series with the line at definite regular intervals. Two types of loading are in general use by the Bell system for inter-office trunks, viz: the M-88 loading and the H-135 loading. The following table compares the transmission losses of the standard guages of cable conductor, without loading, and with the types of loading mentioned.
Gauge of Conductor | Trans. Loss per Mile Non-Loaded | Loaded M-88 H-135
---|---|---
24 | 2.2 | 1.48
22 | 1.8 | .96 .68
19 | 1.5 | .51 .38
16 | .8 | .24 .20

It is upon these eleven types of conductors that the transmission of the inter-office trunk lines is based. The particular type of conductor to be recommended for a given trunk group depends upon the length of the trunk loop and the allowable trunk loss.

The increasing demand for longer inter-office lines has, no doubt, been a great factor in the art of loading telephone lines. Yesterday a pole line of a few open wire circuits was sufficient to handle the traffic, and the problem of transmission was minor, since the lines were short and of small loss of transmission. Today, one or more cables, each containing from 50 to 900 circuits may be required between those same points. And the packing together of the several circuits into a lead sheathed cable of small cross section has introduced the problem of satisfactory transmission as one that is not to be disregarded. This problem of an economical conductor of low transmission loss has been largely solved by the introduction of the loading coil. And these loading coils have been so developed that the cost of manufacture and installation is negligible as compared with the cost of larger gauge cable conductors.
For example, by inserting one 135 millihenry coil at intervals of 6000 feet into a pair of 22 gauge conductors, a better grade of transmission is obtained than would be possible on a pair of 16 gauge conductors, with approximately four times the amount of cross section. The comparison of the transmission loss and the annual charges of maintaining those two grades of conductor are as follows:

<table>
<thead>
<tr>
<th>Decibels loss per Mile</th>
<th>Annual Charge per Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 Gauge H 135 type</td>
<td>.68</td>
</tr>
<tr>
<td>16 Gauge, non-loaded</td>
<td>.80</td>
</tr>
</tbody>
</table>

Thus the practice of the loading of telephone conductors, especially cable conductors, is recognized as a vital factor in the economic design of inter-office lines of any great length. In fact the chart of annual charges of non-loaded and loaded trunk conductors proves in the loaded cable conductor in preference to the next larger gauge as soon as the circuit of conductor is long enough that benefit may be derived from the load coils.

In other words, it is much more economical to use a smaller gauge conductor, with load coils, than the large gauge without load coils, the requirements of transmission permitting, of course. This makes it economically feasible to concentrate the conductors into smaller space, thus lessening the cost per circuit of conduit and pole lines, as well as the conductors themselves.
It is of interest to note how the loading coils have been concentrated into smaller space, along with the development of cables having more conductors of smaller gauge. Until about 1923, the maximum number of coils that could be placed in one case was 98. It is now possible to place 900 coils in one case of approximately the same dimensions. This is due first, to the adoption of a lighter type of loading (68 millihenry coils) in addition to the older standard coils of 135 and 175 millihenries, and second, to the "permalloy coil". This coil has a core of compressed insulated powdered permalloy, a material of high permeability and relatively low energy loss. With this core material it was possible to design a coil which had the same electrical characteristics as its predecessor, but was only one fourth as large. This resulted in a saving in the cost of potting the coils as well as the material cost of the coils themselves. Thus progress is made in the development of a cheaper and yet more efficient conductor for the voice currents.

The type of loading to be prescribed for a given trunk group depends upon the length of the trunk circuits, and the allowable loss, and the type to be finally specified for installation is that which proves to be the most economical to meet the needs of transmission of the several trunk groups that may be benefitted by this proposed loading. In the Bell system, the minimum length of a loaded circuit is three loading sections, so that the minimum length of a
circuit of M 88 loading is 27000 feet, while that of a circuit of H 135 loading is 18000 feet. Thus for circuits of greater length than these minimum lengths of loaded circuits, considerable economy may be realized by the use of loaded conductors.

**PROVIDING FACILITIES**

After the quantitative requirements of the interoffice traffic have been determined, and the qualitative requirements of transmission have been adopted, the next problem is to design an efficient economical trunk plant to meet these requirements. In an area of only two or three operating centers, the problem may be comparatively simple. In general the trunk lines are short, and few alternative routes are available, so that the transmission is comparatively simple and the question of facilities is somewhat limited by the routes that are available. In a larger metropolitan area, however, with a large number of operating centers, the problem of providing proper facilities may become quite involved. The problem of determining the most satisfactory of several alternative routes of a trunk network may be quite complicated. Also, in the larger areas there are continual changes of central office locations and consequent trunk route changes that may further complicate the problem.
In general trunk routes are largely determined by (a) traffic requirements, (b) geographical limitations such as streets, parks, railroad yards, etc., (c) locations of central offices and (d) co-ordination with plant provided primarily for subscriber line distribution. It is obvious that the shortest possible route should be provided but of course it is often economically impracticable to do so, but as the various factors regulating the economy of trunk routes undergo gradual changes, the ultimate routes should approach the shortest possible length consistent with the geographical arrangement of streets and highways to be considered as possible trunk routes and such permanent obstacles of direct routing as large parks, railroad yards, etc.

Another factor to be considered in the permanent routing of trunk cables is the possibility of combining the trunk routes of two or more central offices into one route. By this means the annual cost per circuit of the underground conduit in the case of underground cables and of the pole lines in the case of aerial cables may be greatly reduced, and the annual cost per circuit of the conductors themselves may also be reduced to some extent if the combining of the trunk groups results in a more efficient use of the available facilities. This method also results in a simpler means of analysis of trunk requirements and facilities, a simpler
system of loading, and usually results in a more flexible trunk cable plant. A specific example may help to clarify this point. In Figure 6

![Figure 6 - Combining of Trunk Routes](image)

each of us have a typical arrangement of central offices. In the same building with office A are the tandem and toll boards. Trunks between offices A and C may be routed via ac or via ab and bc through office B, assuming that the two routes are equal in length and type of facilities. The route ac can be used only for trunks between A and C, while on the other touts, ab is available for A-B, A-C, A-D, and A-E trunks, and bc is available for A-C, B-C, C-D, and C-E trunks. Thus larger conduit, cable and loading coil installations may be made for the total requirement of the combined groups, resulting in an appreciable saving of cost per circuit. It
may be noted that the abandonment of trunk facilities, such as those of the route ac, would probably not be justifiable without some additional reason, such as the re-use of the abandoned conduit and cable facilities for subscribers or other trunk lines.

This plan of combining trunk routes introduces the more or less arbitrary classification of main and tributary trunk routes, the former being defined as a trunk route via which trunks to two or more central offices are assigned, and the latter as a trunk route which serves only one central office. The two classes are to be treated in a somewhat different manner since the main trunk routes are made up of fairly large groups of several grades of conductors, and there is a substantial growth and fluctuation of demand for the various facilities, whereas the tributary trunk routes have smaller complements of possibly two or three different types of facilities and the trunk growth is slow, with very little changes due to central office cutovers, trunk rerouting, etc. The study of main routes requires close attention to the details of the various available facilities and required lines and of alternative routing of certain trunk groups, while the analysis of a tributary route may be obtained by a cursory study of the traffic and transmission requirements and comparison with available facilities. A trunk route serving two or three suburban offices may be classified as "tributary" if the
requirements for type of facilities are similar, the trunk growth is small, and the opportunity for alternative routing is nil.

It is evident that the greater part of the engineering of the inter-office trunk plant is centered on the main trunk routes, which are largely of underground cables with a comparatively large amount of loading coils. Figure 9 shows the general scheme of central offices and trunk cable routes of greater Kansas City. From this it is seen that, in the case of some of the longer trunk loop especially, there may be a number of alternative routes for a given trunk group, so that when the problem of engineering all of the inter-office trunk plant of a multi-office city is summed up, it may be quite complicated.

In order to facilitate the analysis of requirements and facilities it is usually advisable to divide the trunk routes into sections, a section including all of the trunk facilities extending between two central offices, or from a central office to a junction of two or more trunk routes, or between two junction points. In determining the facility requirements of a given route section, it is a comparatively simple matter to determine the requirements of those trunk groups which have no alternative routing. On the other trunks which may be routed via one or more other routes, it will be necessary to analyze the alternative routes with the purpose in mind of determining the
the effect of the ultimate routing of the given trunk group upon the facilities of those routes. For example, if the underground conduit facilities of a given trunk route are exhausted, it would probably be advisable to reroute as many trunk groups of optional routing as possible. Or possibly the grade of conductor in one route or the other is the deciding factor. After it has been determined what trunk groups are to be routed via the given route section, it is necessary to apportion the several groups according to gauge of conductor and type of loading, as required by the loop and trunk study. This final analysis may be compared with the available facilities, and the requirements thereby determined. An example of this summary follows:

<table>
<thead>
<tr>
<th>Trunks</th>
<th>Req. Ga. &amp; L</th>
<th>Req. Lines</th>
<th>Route Section &quot;a-b&quot;</th>
<th>22N L</th>
<th>22 M 88</th>
<th>19 N L</th>
<th>19 H 135</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - B</td>
<td>22</td>
<td>203</td>
<td>203</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A - D</td>
<td>22M88</td>
<td>60</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A - E</td>
<td>22M88</td>
<td>46</td>
<td>46</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A - C</td>
<td>22</td>
<td>30</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Toll - B 19 H 135</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Toll - E 19 H 135</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Misc.</td>
<td>-</td>
<td>10</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Total Lines Required</td>
<td>419</td>
<td>235</td>
<td>103</td>
<td>6</td>
<td>72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Facilities</td>
<td>876</td>
<td>505</td>
<td>101</td>
<td>200</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposed Facilities</td>
<td>878</td>
<td>404</td>
<td>202</td>
<td>150</td>
<td>120</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From this summary it is seen that there is a surplus of the total and of the non-loaded facilities, and additional loaded facilities are required, and additional loading may be proposed. There is the possibility that some of the trunks having a required gauge and loading
of 22 M 88 may meet the transmission requirements on 19 gauge, non-loaded conductors. If such is the case, the proposed M 88 loading of the 22 gauge conductors may be deferred until a later date.

A similar summary may be obtained of each route section involved in the study. In many cases the summarizing of the data may be quite complicated, a large number of trunk groups and types of facilities being involved, while other cases may be as simple as the example given. If additional conductors are required, a very detailed study is required to ascertain the actual need for the large amount of money to be expended, and the most suitable plan of construction for the purpose at hand.

Installation of Additional Facilities: After a summary of the required lines and available facilities has been obtained, and the amount of additional load coil and conductor facilities has been determined, a definite plan for providing the required facilities must be made. The engineer responsible for the preparation of these plans has as a foundation for his general plans, the standard conductors of 24, 22, 19, and 16 gauge (the latter being recommended for toll trunks only) and the standard types of loading, M 88 and H 135, previously mentioned. The maximum number of pairs obtainable in one cable sheath are 1212 pairs of 24 gauge, 909 pairs of 22 gauge, 455 pairs
of 19 gauge, and 152 pairs of 16 gauge. Composite cables made up of complements of two or more of these gauges are used to some extent and may be used to advantage for trunk cables, especially where 16 gauge conductors are to be provided for toll trunks. In most cases the 152 pairs of 16 gauge conductors is much more than required, so that a maximum sized cable may be made up of a complement of 16 gauge and another complement of smaller gauge. On these standard cables and standard size loading coil cases are based the general and detail plans of trunk cable construction.

In heavy underground leads where there is a rapid growth and possibility of exhaustion of conduit facilities in the near future, it is found to be good practice to install a maximum sized cable of the proper gauge of conductor. In sections of slower growth a smaller cable may be justified. However, due allowance should be made if the conduit facilities are well filled with maximum sized cables, in order to defer the heavy expense of conduit reinforcement as long as possible. In brief, the size of the proposed trunk cable should be determined by the most economic plan for the near future.

In designing the plans for proposed trunk facilities it is important that due consideration be given to the possibilities of the change of location of central offices, causing changes in trunk lengths, and possibly the re-routing...
of some groups. In the event of trunk lengths being made
greater there is the possibility of a higher grade of
facilities being required than may be available unless
consideration is given to this point when additional
facilities are provided for.

While it is desirable from the service standpoint
to forbid the use of a part of a trunk cable for subscriber
line distribution, such a practice is frequently not justi-
fied from the economic standpoint. In such a case where
a combined trunk and subscriber cable is to be installed,
definite separate complements should be definitely assigned
to their respective classes of service. For example, if
a 900 pair cable is installed for purpose of serving, say
650 subscriber lines and 60 trunk lines, in five years, the
first 100 pairs should be spliced in such a manner that they
will be available for trunk use only, and the balance to be
used for subscriber distribution only.

Loading Coil Installation: In order to obtain the
best results of transmission from the use of the load coils,
it is important that they be properly spaced. It is the
practice of the Bell system in exchange trunk loading to
allow a variation of the average spacing from the standard
of three percent, and a variation of individual sections
from the average of five percent. In other words, with
an average spacing of 6000 feet for H 135 loading, an
individual section should be between 5700 feet and 6300 feet
in length. This difference of 600 feet is greater than the length of mast sections of conduit between manholes so that the requirement may be met without any additional expense of building a special manhole for the load coil cases.

In laying out the load coil spacing, it is found to be good practice to begin from some given center of the trunking system, as for example, the toll or tandem center, by locating the first load point in each direction one-half section from the center, and then a full section for each successive point until the last load point is not less than 1/2 section, or more than 1-1/2 sections from the distant terminating central office. Figure 7 is a diagram of this plan of loading.

Figure 7- Load Coil Spacing Diagram
This plan provides for a very flexible scheme of cross-connecting from one loading system to another on the main distributing frame of the tandem center. Of course, there are many cases where loaded conductors are required for direct trunks which are quite remote from the tandem center, and such cases would necessarily be treated individually, although it would be well to consider the advisability of making use of load points previously located from the tandem center as a means of simplifying the loading system and minimizing the number of load coil cases required.

In underground construction, the load coil cases are installed in the manhole and may be either buried in the floor of the manhole, or if there is sufficient space below the space required for the cable racking, set on the floor. One or two load pots may be buried in the average sized manhole, but if the estimate of trunk growth indicates that more will be required within a reasonable length of time, a special auxiliary loading manhole would probably be advisable. The maximum sized load coil case contains three hundred 135 millihenry coils or nine hundred 88 millihenry coils and the advisability of using the maximum sized pots should be considered, where the demand for the given type of loading would warrant such. It is also to be noted, however, that if it is found necessary to remove a load pot because of inadequate loaded facilities
at this point, it may be salvaged and re-used as new material at some other point, whereas if a cable is removed it has no further value in the cable plant.

In aerial cable construction, the load coil cases may be either hung on the pole or buried at the foot of the pole. The former is slightly cheaper and is to be preferred if the pole is heavy enough to support it, and if the pole is not so large as to make an unsightly appearance. In most cases of aerial trunk cables, the trunk complement is so small that the small case required for the leading may be hung on the average pole quite satisfactorily.

**Aerial versus Underground Cables:** Aside from the standpoint of interruption of service, economy is the deciding factor in determining whether a proposed trunk cable should be placed in underground conduit or on poles. In most main trunk routes, the conduit facilities are available and the trunk growth demands a good sized cable. On the other hand, a tributary trunk route, as stated before, has a comparatively small number of facilities required, and would not warrant the cost of underground conduit. And so the general practice in the engineering of tributary trunk routes, has been to place the trunk complement in the same cable with subscriber lines, using underground conduit where the combined requirements of trunks and subscribers would warrant such, and using the aerial plan of construction where the requirements are less.
Miscellaneous Use of Trunk Facilities: A minor feature not to be disregarded is the miscellaneous use of trunk facilities for various kinds of inter-office circuits for use in traffic supervision and plant maintenance, and for inter-office subscribers' lines. The demand for such circuits is increasing as improved trunks facilities make possible longer loops for outside subscribers' stations and the like. Such subscribers as taxicab companies and police departments require a large number of long outside stations and because of the extremely long circuits, a very good grade of transmission is often required. Since a subscriber's line is more liable to immediate direct complaint than are the trunk lines in case of poor transmission, and since these lines are a direct source of revenue, particular care must be taken when such circuits are installed that satisfactory transmission will be attained.

There is a slight demand on inter-office facilities for what is known as "toll terminals", subscribers' stations working direct from the toll board. These are in some demand by some business firms having a large amount of toll calls but since the greater number of such firms are usually located in the same central office area as the toll board, inter-office facilities are not often required. However, if there are subscribers in another area who would desire such service, the inter-office facilities should be of such a nature that immediate service might be obtained. On account of the low
allowable loss for toll service, the inter-office facilities for toll terminals should be of as good a grade of transmission as for the toll switching trunks to that office. If satisfactory transmission is available, and there is a demand for such service, the subscriber will have obtained better switching service for his toll calls, and the revenue derived therefrom would aid in offsetting the expense of maintaining this necessarily high grade of conductors.

In making a study of trunk facilities, the engineer should make a proper allowance for a growth of subscribers' inter-office lines. Due consideration should be given to the question of proper transmission for such lines as may be required in the near future. Of course, individual cases cannot be anticipated very far in advance, but if there is the possibility of a demand for a high grade of conductor for such a purpose, due allowance should be made.

Maintaining Proper Transmission: After the various grades of trunk facilities have been installed, it is equally important that each trunk group is routed according to the plans on the proper grade of conductor. If additional trunk facilities of any kind are provided, there is necessarily some re-routing of trunks necessary and some definite means of instruction to the assignment bureau are necessary to assure the proper use of the available facilities. For such purposes, a guide card, similar to the example shown in Figure 8, may be of use.
After the plans for the routing of the trunks are definitely settled, and before the work of trunk rearrangement has started, such a card should be furnished to the assignment bureau for each trunk group, giving the proposed routing by cable numbers and the pair count where there is a difference of gauge and loading, an alternate route of similar transmission equivalent to be used in case of lack of facilities of the standard route, or in case of some emergency and an emergency route which may be of inferior grade of transmission, and is to be used only temporarily to restore service. Of course there are a number of trunk groups for which there are only one or possibly two groups of facilities available in which case only one or two types of facilities would be furnished.
Similarly this information may be assembled for new trunk groups that may be required from time to time. These cards may be held on permanent file by the assignment bureau until for some reason the routing plans may be changed, at which time the card may be revised or replaced by a new card with the revised information.

After the trunk groups are routed via the specified facilities, some means of measuring the transmission loss is necessary, a means of diagnosing transmission complaints. A transmission measuring set is available for such a purpose. Each trunk should be measured annually, and oftener if the trunk circuit is changed in any way. The tested should be furnished full up to date information each trunk in regard to the type of loading, allowable loss, and the computed loss of the facilities in use. With this information, the tester can immediately tell from his tests whether there is any serious transmission trouble. If such trouble is found the trunk circuit may be segregated and re-tested until the source of the trouble is located. The annual routine tests are important in locating excess transmission loss that might otherwise be overlooked. Because of continual changes that are being made in the cable plant, some trunk groups may be thrown to improper conductors of poor transmission. Such factors introduced into a trunk circuit would not be detected without some means of actually testing the transmission loss.
TRUNK PLAN OF GREATER KANSAS CITY

After a discussion of the general problems of inter-office communication, it may be of interest to note some of the features of a specific example of an inter-office trunk cable system. Figure 9 of the appendix shows the general plan of the trunking plant of greater Kansas City, including central office locations and trunk cable routes. Greater Kansas City was until about 1921 served by two distinct telephone systems, known as the Home and Bell systems, each system having its own central offices and distribution and trunk plant. As a result, when the two systems were unified there was a vast amount of duplicate distribution plant, there were usually two central offices serving, or capable of serving the same area, and there were two separate trunking systems which must be co-ordinated into one universal system for all central offices of the area.

The effect of this condition upon the general scheme of the central offices of Kansas City was that in a number of cases, a given area capable of being served by one operating center actually had two or three central offices, resulting in a number of "short haul" trunk cables of from 1300 to 5000 feet in length and poor operating efficiency due to the smaller operating units. To obviate this condition, the duplicate central offices are gradually being replaced by dial units at one operating center for a given area. Figure 9 of the appendix shows in
code the location of the abandoned central offices, the present central offices, and the location of proposed or contemplated central offices. There have been eight manual central offices replaced by dial units in greater Kansas City, all but two of which have been replaced within the last five years. Construction work is well under way for the conversion of the Clifton and Benton manual offices, located in the northeast part of Kansas City, Mo., with dial units at one operating center in the fall of 1931, and construction work has started for a new dial unit to replace the Hiland and Jackson manual offices in 1932 and it is probable that the Drexel and Fairfax offices in Kansas City, Kansas and the Wabash and Linwood offices in the east central section of Kansas City, Missouri will be replaced with dial units in the near future. Thus the central offices and the trunking system are being gradually unified. When these replacements are completed there will be about 15 operating centers serving the same area that was once served by 25 different operating centers, resulting in more efficient operation and simplified trunk plant.

It will be noted from the trunk route map that the trunk routes deviate some distance from the most direct route in some cases. This is largely due to the locations of the old central offices. However, the most direct route is used if possible when additional trunk cables are proposed. In general, however, aside from this feature, the trunk
routes are as direct as geographical conditions will permit. It is to be noted that the tandem and toll center, located in the Telephone Building which also houses Grand, Harrison and Victor units of the business district, is some distance from the geographical center of greater Kansas City and its suburbs. As a result some of the tandem and toll trunks are much longer and require a better grade of conductor, than would be otherwise necessary. Figure 11 of the appendix shows the approximate variation of the costs of these trunks as to the route distance from the Toll-Tandem center, located at the Telephone Building. These curves were derived from the type of conductor prescribed by the loop and trunk study, and the actual route distance to all the operating centers of the area. Two exceptions of toll switching trunks which deviated quite radically from the curve on account of a smaller allowable subscriber loop loss, permitting a lower grade of facility for these toll trunks, were omitted. These curves may be of interest in estimating traffic requirements in trunks of this character. It is of interest to note that whereas the cost of tandem trunks increase by an approximate straight line curve, the increase of cost of toll trunks is much greater above a route distance of approximately two and three fourths miles which is due to the higher cost of 16 gauge conductors.

Previous mention has been made in the discussion of the traffic problem of trunking of the "Community of
Interest Factor". In general, this factor depends upon the inter-office distance and the class of service, i.e., residence or business. It is of interest to note what effect the community of interest has upon the trunks required per station. Figure 13 is a graphical representation of trunks per station required of typical residence central offices of the area, the air line distance between offices being designated as abscissae and the total trunks per 100 stations as ordinates. From this data and the cost of the trunks involved, the annual cost of trunks per 100 stations was obtained. While the cost of individual groups of trunks vary rather widely from an average curve due to deviation of the trunk route distance from the air line distance, the chart shows quite conclusively the increased cost per station of providing direct trunk facilities as the inter-office distance is increased, emphasizing the necessity for a study of the comparative costs of tandem and direct trunking where the inter-office distance is of any great length.

Because of the importance of the transmission of trunk circuits, it is interesting to note the standard of transmission achieved in Kansas City. The transmission standards adopted for Kansas City are from 16 to 22 decibels for direct and information trunks, 22 decibels for tandem connections and 7 decibels for toll switching trunks. It is upon these standards that the trunks of Kansas City have been engineered.
In some cases it has been economically impractical up to the present time to attain the desired standard, but as a whole it is found by the annual routine transmission tests that the condition is quite satisfactory. In the 1930 tests, there were 301 trunk groups, or a total of 5980 trunks tested. Of this number there were 31 groups or 380 trunk circuits that exceeded the standard. Of these defective trunks there were 80 trunks that exceeded the standard by more than one decibel. The maximum excess loss was 2.3 decibels on a group of six trunks. It was later found that this was due to incorrect cable splicing. On 18 out of the 31 defective trunk groups, plans have already been made for their remedy.

While these tests are indicative of some instances of sub-standard transmission, they are also indicative of the progress that has been made in the proper design of the trunking plant in Kansas City since the unification of the two systems. Until 1927 a number of the small suburban offices had no toll switching trunks and all calls, both local and toll, were switched through what was known as the "Hyde Park Suburban Board" which was a tandem position in the Hyde Park Central Office. At that time the subscribers' lines in these suburban offices were short and consequently of small loss, and the trunk lines to the Hyde Park suburban board were on open wire conductors, on which the transmission losses were likewise small. At the same time, the standards of trans-
mission demanded by the subscribers were not as high as they are today. In the course of time, however, the lengthening of the subscribers' loops, the traffic demand for additional trunk facilities, and the educating of the public to a higher type of transmission, has created a demand for improved facilities for inter-office trunks, especially to the smaller suburban offices. In response to this demand, the greater part of the open wire trunk facilities have been replaced with loaded cable conductors and direct facilities have been provided from the toll and the tandem boards to all central offices. This has made possible a much more satisfactory grade of transmission, especially to the remote suburban offices. When the facts are considered that the transmission standard of total allowable loss has been reduced by three decibels, and that the actual loss of some of the former trunk groups exceeded the former allowable loss by more than five decibels, the 1930 transmission tests are conclusive evidence of the progress that has been made for improved transmission. Incidentally, the providing of direct trunks from the toll and tandem boards to all offices has resulted in simpler methods of handling the traffic to the suburban offices.

Summary of Trunking System of Kansas City - There are approximately 153000 subscribers' stations in an area of about 350 square miles connected to the 19 central offices of greater Kansas City. Between the several offices there is a total of 32300 circuit miles of trunk conductors
available for use, of which approximately 14800 circuit miles are provided with load coils. There are 123 load coil cases containing 10640 load coils in the trunk plant. Of the 19 central offices, 15 are of manual operation and four of the dial. Two of the latter are non-attended rural offices, and the other two are large down-town central offices, each made up of three operating units in the same building. The longest direct trunk loop is between the Independence and Hiland central offices, a route distance of 15.5 miles, and the longest tandem trunk group is 19.4 miles long. The longest possible talking circuit between two subscribers of the Kansas City area is approximately 45 miles. It is of interest to note that if direct trunks were available between these two central offices via the most direct route, the length of the circuit in this case would be only about 22 miles. The traffic between these offices, however, is so small that the high cost of providing the direct trunk facilities is not advisable.

CONCLUSION

From the general picture of inter-office communication and the more specific picture of the inter-office trunking system of Kansas City, it is obvious that the general problem of providing an economic and satisfactory system of communication demands a strict co-ordination of the traffic, general engineering and plant forces. It is advisable to provide the most economical facility possible, all factors
being considered. The question of economy in a given example may involve all of the factors of first costs, traffic operation, proper transmission, fundamental plans, etc.

The interoffice trunking system may be compared to the network of a railroad system. The railroad has its trunk lines between the points of heaviest traffic. From these trunk lines a number of tributary lines or spurs are brought out which carry a portion of the traffic to isolated points away from the trunk lines. Through traffic may be provided between two given points, or some means of transfer at one or more division points may be advisable, depending upon factors of comparative costs, the required time of completing the service, public good will, etc. The advisability of providing a direct line between two given points depends largely upon whether the traffic that may be routed via the proposed line will warrant the expense involved. The traffic on longer lines often require better service, involving heavier road beds, faster trains, and better facilities for the comfort of the passengers, whereas the shorter lines may furnish satisfactory service with less elaborate type of facilities. In brief, the railroad will furnish the most economic means of transportation possible, consistent with the demands of the public for safety, dependability, speed and comfort. In like manner, a telephone system endeavors to furnish the most economic means of communication possible, consistent with the demands of
the public for dependability, speed and satisfactory transmission. In both the transportation and the communication systems, intelligent engineering supervision is constantly required to meet the demands of traffic and service in order that the best facilities consistent with economy are made available. Laxity in proper engineering results in either sub-standard service or poor economy.
BIBLIOGRAPHY


Bell System Practices:
Feb. 1930, Outside Plant Engineering of Trunk Cable.
Nov. 1928, Transmission Equivalent Data, Sec. I-A, Definition and Explanation of Terms.
April 1927, Transmission Equivalent Data, Sec. IV-A, Attenuation Losses in Trunk, Toll and Incidental Cables.
# ALPHABETICAL INDEX

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative Trunk Routes</td>
<td>29</td>
</tr>
<tr>
<td>Analysis of Trunk Requirements</td>
<td>30</td>
</tr>
<tr>
<td>Cables, Aerial and Underground</td>
<td>36</td>
</tr>
<tr>
<td>Decibel</td>
<td>14</td>
</tr>
<tr>
<td>Direct Trunks</td>
<td>17</td>
</tr>
<tr>
<td>Facilities, Installation of</td>
<td>31</td>
</tr>
<tr>
<td>Facilities, Providing</td>
<td>25</td>
</tr>
<tr>
<td>Kansas City, Trunk Plan of</td>
<td>41</td>
</tr>
<tr>
<td>Load Coils, Development of</td>
<td>24</td>
</tr>
<tr>
<td>Load Coil Installation</td>
<td>33</td>
</tr>
<tr>
<td>Loop and Trunk Study</td>
<td>15</td>
</tr>
<tr>
<td>Losses, Inter-Subscriber</td>
<td>16</td>
</tr>
<tr>
<td>Maintaining Transmission</td>
<td>38</td>
</tr>
<tr>
<td>Miscellaneous Use of Trunk Facilities</td>
<td>37</td>
</tr>
<tr>
<td>Tandem Trunks</td>
<td>18</td>
</tr>
<tr>
<td>Tandem vs. Direct Trunking</td>
<td>10</td>
</tr>
<tr>
<td>Toll Switching Trunks</td>
<td>18</td>
</tr>
<tr>
<td>Toll Terminals</td>
<td>37</td>
</tr>
<tr>
<td>Traffic Problem</td>
<td>7</td>
</tr>
<tr>
<td>Traffic Requirements, Estimate of Transmission Standard</td>
<td>12</td>
</tr>
<tr>
<td>Trunk Loading</td>
<td>14</td>
</tr>
<tr>
<td>Trunk Route, Combining</td>
<td>21</td>
</tr>
<tr>
<td>Trunk Route Guide Card</td>
<td>26</td>
</tr>
<tr>
<td>Trunk Routes, Main and Tributary</td>
<td>39</td>
</tr>
<tr>
<td>Trunk Route Sections</td>
<td>28</td>
</tr>
</tbody>
</table>

Page 51.
APPENDIX.
Figure 9
INTER-OFFICE TRUNK ROUTES OF
GREATER KANSAS CITY

CODE:
• Permanent Central Offices
○ Central Offices to be Replaced
★ Definite Location of New Central Offices
□ Tentative Location of New Central Offices
■ Tandem and Toll Center
× Former Central Office Locations
— Trunk-Cable Routes
---- Open Wire Trunk Routes

Greater Kansas City
AND SUBURBS
Commissioned and Published by
GALLUP MAP & SUPPLY CO.
KANSAS CITY, MO
"Everything in Maps"
BLUE PRINTING
DRAWING MATERIALS AND SUPPLIES
PHOTO PRINTS
GALLUP MAP & SUPPLY CO.
KANSAS CITY, MO
Copyrighted by Gallup Map & Supply Co., Kansas City, Mo.
Figure 12
COMPARISON OF ANNUAL CHARGES
OF DIRECT TRUNKS BETWEEN
3 DECIBEL OFFICES
with Standards of 20 and 22
Decibels.

--- 20 DB Standard
----- 22 DB Standard

Inter-Office Distance - Kilofeet

Annual Charges
Figure 13:
INTER-OFFICE TRUNK STUDY
Variation of Trunks per Station
To Inter-Office Distance
Typical Residence Central Offices
and Trunk Groups of
Kansas City as of Jan. 1, 1931

- Trunks per 100 Stations
- Ann. Charge of Trks. per 100 Stations

Inter-Office Distance, Miles

Trunks per 100 Stations

Alt. Charges per Station

1. LI-WA
2. OR-FA
3. BE-LI
4. BE-WA
5. WE-JA
6. BE-HI
7. BE-JA
8. JA-LI