

TRANSMISSION DESIGN OF RURAL LINES

<u>CONTENTS</u>	<u>PAGE</u>
1. INTRODUCTORY . . . . .	1
2. TRANSMISSION STANDARDS . . . . .	1
3. GENERAL DESIGN FEATURES . . . . .	1
4. TYPES OF OUTSIDE PLANT FACILITIES . . . . .	1
4.1 Cable . . . . .	2
4.2 Open Wire . . . . .	2
4.3 Buried Wire . . . . .	3
5. DETAILED DESIGN FEATURES . . . . .	3

1. INTRODUCTORY

This Section discusses the general transmission features to be considered in the design of rural lines, i. e., subscriber lines serving stations located in territory surrounding the base rate area of an exchange. They are, in most cases, of the multi-party type.

Due to the relatively long length of these lines and the scattered development which they serve, the investment per line is frequently high and the cost of obtaining transmission improvement above average. In order to furnish this service economically it is, therefore, very important that both the outside plant and transmission phases of the design of this plant be carefully considered and coordinated. From the transmission standpoint, the purpose in the design work is, of course, to meet the transmission and signaling limits established for this type of line at the lowest possible cost.

2. TRANSMISSION STANDARDS

In the design of the normal loop plant there is established for each central office area a transmission limit known as a loop limit, which is intended to be the maximum loss for loops in that area. The nature of this loop limit and the items of loss included are discussed in Section AB22.075.

In general it appears desirable to furnish a grade of service on rural lines comparable with that given within the base rate area serving these rural lines. However, in some cases the cost of furnishing this grade of service may be so high that it may be desirable to employ a transmission limit for such cases somewhat greater than that used generally. Where this seems to be desirable, a limit for the rural

lines will be specified by the Chief Engineer's office.

Because of the relatively high costs involved per line for this type of service as mentioned above, the number of such lines in a given central office area, and to some extent the choice of the type of outside plant construction used for these lines, will influence the economical loop limit as determined from the loop and trunk study. In cases where unusual growth in rural lines is expected or where it appears desirable to make extensive use of types of outside plant construction having relatively high transmission losses such as buried wire, it will be important to insure that the derivation of the loop limit has adequately reflected these factors. For instance, where the loop limit has been established as a result of a study made prior to the introduction of buried wire and a relatively extensive application of buried wire appears desirable for outside plant reasons, where an unexpected extension of cable is encountered, or where the extensive use of long span open-wire construction is contemplated it will be desirable to review the limits in the light of the new conditions.

3. GENERAL DESIGN FEATURES

The general design features involved in the case of rural lines are the same as those for very long lines within the base rate area, as are the design procedures and the transmission and signaling instrumentalities to be considered. These matters are discussed in detail in Section AB22.075.

One factor encountered in the design of rural lines to a greater extent than in the case of other lines, is the reaction of the choice of the type of outside plant construction on the transmission performance. The several types of outside plant construction such as cable, open wire and buried wire have quite different transmission characteristics and in deciding upon the type of construction to be used it is very important that both the transmission and outside plant reactions be adequately reflected before making a final decision. The differences between these types of construction are discussed in more detail (in Section 4) below.

4. TYPES OF OUTSIDE PLANT FACILITIES

There are in general three types of construction employed in rural line design, namely, cable, open wire and buried wire.

The field of use of these types and a discussion of their transmission characteristics is given in the following:

4.1 Cable: Aerial or underground cable is usually employed near the central office. Depending on the size of the town and the nature of the development, the length of the cable may vary from a few hundred feet to several miles. The loop losses in cable circuits are covered in the various sections of the AB43 series - Effective Transmission Equivalent Data.

4.2 Open Wire: This type of construction is usually employed beyond the end of the cable and may be used for both main and branch leads in this part of the plant. Several types of open wire construction are available as follows:

(a) Steel Wire: Steel wire is available in several weights of galvanizing to meet variations in atmospheric conditions which affect physical life. Under ordinary conditions the light weight of galvanizing will provide a physical life of 15 to 20 years before rust effects become sufficiently serious to affect the transmission equivalent. Where atmospheric conditions are unusually severe on steel wire, as along the coasts, a heavier weight of galvanizing may be used to obtain a satisfactory physical life. The use of rolled joints avoids the relatively large series unbalances previously experienced with rusting joints and thus minimizes the possibility of line noise arising from such sources, which in some cases in the past resulted in severe transmission impairments. Steel wire may be had in several sizes and strengths and when used in long spans provides a relatively inexpensive form of construction for rural line leads.

Loop loss data for loops composed of only 109 iron wire are given in the Sections of the AB43 series together with methods of approximating losses for other gauges of iron wire. Preliminary kite charts giving T+R losses for combinations of 109 iron wire, cable and buried wire are attached to this section. These are based on 109 iron wire, but may be applied with a good degree of approximation to the new high strength galvanized steel wire (AT-6701) until specific data for the latter are available.

(b) Copper Wire: Copper wire lines are considerably more expensive than steel wire lines because of the higher cost of the wire itself and the shorter pole spacings required with copper under similar storm loading conditions. The transmission losses and the d-c resistance of copper wire are considerably lower than those of steel

wire and copper wire may, therefore, have an economical field of use where transmission or signaling improvements are required.

Loop loss data for loops composed only of 104 copper open wire are included in the Sections of the AB43 series with a method of approximating the losses for other gauges of copper open wire.

Due to the relatively low loss of copper wire circuits the inclusion of this facility on the kite charts does not appear practicable. However, the effective T+R losses for loops composed of the copper open wire in combination with either cable or buried wire or both, may be approximated as follows: Add to the loop losses for the portion of the circuit in other than open-wire facilities, twice the effective attenuation of the copper wire and, in the case of common battery loops, battery supply corrections. The losses for the cable or buried wire portion of the circuit may of course, be obtained from the appropriate loop loss curves or kite charts. The values of the effective attenuation of the several types of wire and battery supply loss data are given in the AB43 series of Bell System Practices.

(c) Copper-Clad Steel Wire: Copper-clad steel open wire is not standard for use in the Bell System because, in general, considering both costs and electrical and mechanical characteristics, this type of wire appears to have no particular field of use as compared with steel and copper wires. However, copper-clad steel wire has been used to a limited extent in certain areas.

The transmission characteristics of copper-clad open wire, of course, depend upon the grade of wire as well as the usual factors, such as spacing, type of insulators, etc. The two common grades of copper-clad wire are rated as having 40 per cent. and 30 per cent. conductivity, this percentage applying to the conductivity of a copper wire of equal diameter. The limited information available regarding these wires indicates that for 12" spacing and DP insulators, the 1000-cycle attenuation of the copper-clad wires can be approximated by multiplying the 1000-cycle attenuation of a copper wire of equal diameter by 2.25 for the 40 per cent. grade and 2.75 for the 30 per cent. grade. As in the case of copper and iron open wires, the effective attenuation is somewhat higher than the 1000-cycle attenuation, the increases being of the order of 5 per cent. for the 40 per cent. grade and 10 per cent. for the 30 per cent. grade of copper-clad wire.

4.3 Buried Wire: As a result of development work carried on in the past few years a new type of construction for use primarily in the loop plant of rural areas has been made available on a field trial basis. This facility consists of a rubber covered paired wire known as "U" wire which is buried along the shoulder of the road or in fields by the use of an especially designed plow. The outside plant practices pertaining to this facility are described in detail in Sections of the AG series of the Bell System Practices. The field of use of the buried wire is primarily in rural areas which are sparsely settled. In general when installation in this manner is feasible, this type of construction will probably be used wherever it proves satisfactory from a transmission standpoint and economical as compared with open wire.

From an outside plant standpoint, the economy from the use of this wire will vary materially with local conditions. Where soil conditions, etc., are suitable for buried wire and tree or other conditions unfavorable for open wire, there may be considerable advantage in the use of buried wire. These factors should be carefully weighed in connection with the individual case and balanced against the transmission disadvantages usually present.

Detailed transmission data regarding buried wire will be made available as soon as the characteristics of this wire are finally standardized. Pending this, preliminary data are given on the attached table. Also the attached kite charts for combinations of cable, open wire and buried wire have been prepared using this tentative information regarding the buried wire.

It will be noted that the losses in buried wire are relatively high as compared with open wire construction. As discussed in Section 2 above, where an appreciable amount of this facility is expected to be used in a particular central office area there may be an important reaction on the economical loop limit and this question should be reviewed especially where the use of the facility with the existing loop limit would involve relatively high costs in other parts of the plant to offset the high losses of the buried wire.

Because of the relatively high losses of this facility, the use of appreciable amounts in rural lines may tend to restrict the possibility of future extensions because of the excessive costs involved to obtain a satisfactory grade of transmission. It is important, therefore, to consider the effect of such future limitations before deciding upon the use of this wire.

The noise and crosstalk considerations involved in the use of buried wire are discussed in Section 5 below.

## 5. DETAILED DESIGN FEATURES

The first consideration in the detailed design of rural lines is to obtain a tentative layout from the outside plant standpoint, that is, the extent of use of cable, open wire and buried wire. In general the extent of the cable will be determined by other than transmission requirements, e.g., greater number of circuits than practical for open-wire construction, etc. In the case of the choice between open wire and buried wire the decision will depend primarily upon the relative costs and in estimating these, as indicated above, it is essential to reflect the relatively large differences in the transmission characteristics of these two types of plant. Where open wire is to be employed the type of wire can be varied depending upon the transmission and signaling requirements. In determining the economy of the various possible types of construction, the measures which may be considered in order to meet the transmission limit include:

(1) Use of Loading: The application of loading in order to obtain transmission improvements is discussed in detail in Section AB22.075. Loading may be employed on either the cable or buried wire portions of the rural lines.

On rural line leads on which loaded cable pairs are used to provide satisfactory transmission on the longest lines, it is important to insure against stations being bridged to the loaded portion of these lines. In certain cases the application of loading to an existing lead may, therefore, require some rearrangement of the stations and lines. On loaded buried wire lines, because of the very light loading system employed, the effect of bridging stations between loading points is not as serious, but where practicable, such bridging should be avoided.

(2) Use of Special Station Apparatus: There is usually available a type of station apparatus more efficient than the best set in general use but which, because of its higher cost or limitations on its field of use, is intended for application only in special cases, as for example, the local battery talking, common battery signaling set for use on long common battery lines. During the transition from the older sidetone set to the anti-sidetone set employing the F1 transmitter units and HA1 receiver units, this combination of improved station apparatus may be used to reduce the losses of the rural lines. When the use of this improved apparatus is sufficiently general to form the basis of normal plant design, it will, of course, be necessary to further improve the transmission obtained by these rural stations.

The steps to be considered at that time will probably include the use of more efficient instruments expected to be available in the future, the use of local battery sets on the longer common battery lines, loop loading, etc.

(3) Type of Open Wire: Where open wire construction is involved several types of wire as discussed in Section 4 above may be employed. In areas where experience has indicated that appreciable increases in the transmission and d-c resistances of steel wire with age are realized, it is the usual practice to include allowances for these increases in the design of lines using this type of facility. The magnitude of these allowances, which depend, of course, on the local conditions, will influence the field of use of the heavier galvanized coatings and also the choice between steel and copper wire.

(4) Open Wire vs. Buried Wire: Where the use of buried wire is indicated in the tentative outside plant layout and transmission improvements are required it may be economical to employ open wire for part or all of the section for which the buried wire has been considered.

(5) Telephone Repeaters: Isolated cases may be encountered where it is impossible to meet transmission requirements by means of the measures discussed above. In such instances it may be desirable to employ a telephone repeater.

In common battery offices where the tentative layout involves a loop resistance in excess of the signaling limit for the central office, consideration must be given to measures which will reduce the loop resistance or extend the signaling limit. These measures include:

(1) Signaling Equipment: Where a limited number of lines are involved the use of long line equipment will often be found the most economical means of meeting the signaling requirements.

(2) Type of Open Wire: As the resistance of copper wire is considerably lower than that of steel wire the use of the former may be economical in some cases where signaling is controlling.

(3) Open Wire vs. Buried Wire: The resistance of buried wire is considerably higher than that of copper open wire but slightly lower than that of steel wire. In some cases, therefore, for a part of the circuit, at least, where signaling is controlling, it may be economical to employ copper open wire rather than buried wire.

(4) Cable Pairs in Parallel: Where supervision and not transmission is

controlling, the use of two cable pairs in parallel may be justified in some cases. From a transmission standpoint, the losses resulting from the use of non-loaded pairs in parallel are generally somewhat higher than those obtained with a single pair of the same type of facilities. With loaded cable pairs the transmission is approximately the same as that with a loaded single pair. The practice of doubling pairs should, however, be regarded in the light of an expedient because of possible disadvantages from a crosstalk and maintenance standpoint.

The individual losses to be considered in the design of rural lines from a transmission standpoint are in general the same as those discussed in AB22.075 for the loop plant in the base rate area.

One loss item normally neglected in the design of base rate area lines, but which may be appreciable in certain cases of multi-party rural lines, is the loss due to bridged ringers. Where tube-type sets, or sets employing the high impedance (J-type) or new BLA ringers, are involved, the losses will usually be negligible. The losses for most grounded ringing conditions may be neglected. Where the low impedance or older types of high impedance ringers or ringing relays are used and are connected across the line, the loss per bridged ringer may be assumed to be  $0.1 \text{ db } \frac{(T+R)}{2}$ . In the case where the latter losses apply, the plant design should, of course, reflect the maximum number of stations contemplated.

One problem which in general is sufficiently serious to require consideration in the design problem only in the case of very long common battery multi-party lines, is that of transmission on reverting calls. Probably the most important factor contributing to the overall transmission on such calls is the relatively high battery supply loss of the station more distant from the office due to the bridging effect of the nearer station. This loss can be minimized to some extent by avoiding on the longer lines the connection of stations relatively close to the office. In some cases it is found necessary to employ local battery talking sets at the end stations. In general, it will be necessary to consider only the direction of the distant station transmitting, inasmuch as the battery supply at the nearer station will be materially better. It appears that with the effective data now available, the best method of approximating the overall transmission would be to assume that the two stations are on zero loops and are connected by a trunk. Of course, suitable battery supply corrections must be made and allowance included for junction losses, and the bridged tap loss due to the circuit from the central office to the nearest station.

Another loss frequently encountered on multi-party rural lines is that due to

"listening in." Normally this loss is not included in the loop design. However, the losses due to listening in are greater with common battery operation than with magneto service, and for both types, the losses are greater with some types of facilities such as iron wire than with others such as buried wire. Also, the loss in a particular case will depend upon the length of loop, relative location of the stations, types of sets and battery supply conditions. The order of magnitude of losses due to "listening in" for typical cases involving the various facilities is indicated in the table below.

Type of Loop	Bridging Loss
	Per Set $\frac{T+R}{2}$ (Exclusive of Battery Supply)
109 Iron Wire	5.0 db
104 Copper Wire	3.0
Non-Loaded Cable - 24 Gauge	3.0
Non-Loaded Cable - 19 Gauge	1.5
Loaded Cable (H-44)	4.0
Non-Loaded U Wire	1.0
Loaded U Wire (L-44)	2.5

Losses due to "listening in" by other subscribers may be minimized by the use of full or semi-selective rather than code ringing. Also, in specific cases of common battery lines on which "listening in" is prevalent, the battery supply losses can be reduced somewhat by avoiding relatively large separations between stations on the same line.

Bridged taps consisting of open wire are generally unimportant from a transmission standpoint unless they are very long. Taps consisting of cable or buried wire may cause quite large losses. The losses caused by bridged taps consisting of open wire or buried wire may be approximated by converting the length of bridged tap to an equivalent length of cable and using the data included in the AB43 series for cable taps. For this purpose the lengths of open wire and buried wire taps may be multiplied by .1 and 1.4 respectively to obtain equivalent-lengths of cable.

In considering the effects of room noise at stations served by rural lines, it may be found that these locations are relatively quiet as compared with the rest of the area. In such cases the use of room noise impairments lower than that established for the central office as a whole may be warranted. Where practical it will, of course, be desirable to establish these impairments as the result of room noise surveys. Where such surveys have not yet been made it may be desirable to assume that the room noise conditions for rural line stations are such as to justify a 2 db lower impairment (T+R) than established for

the base rate area. The treatment of room noise impairments will usually be specified in connection with the establishment of the loop limits for the office.

Line noise is quite important in rural lines because of the relatively great chance for exposure to power circuits. In the design of rural lines it is, of course, important to include the NTI's, where the assignment of such impairments is indicated after the economical remedial measures have been employed.

In lines served exclusively by cable, line noise is usually not an important consideration and the crosstalk performance is satisfactory unless non-staggered twist cable is involved together with loading or special sets. The limitations from this standpoint and possible treatment are covered in AB22.029.

In open wire the effect of exposures to nearby power circuits may be quite important and remedial measures which should be considered are discussed in detail in the AB63 series - Inductive Coordination Practices.

In the case of buried wire the fact that the direct capacitance to ground of this wire is about .04 mf. per mile per pair has made it necessary to control to a high degree of precision the dimensions of the conductors and of the rubber wall. In spite of this manufacturing control, certain noise considerations are involved, namely:

(1) For direct exposures between the buried wire and rural power circuits, the effects of longitudinal-circuit induction from ground-return currents may become important. The method of splicing discussed below in connection with crosstalk will to some extent overcome this difficulty. Where the section of buried wire is used as an alternative to one or two bracket pairs joint with a rural power distribution circuit the use of the buried wire should ordinarily cause a reduction in the direct-metallic noise induction which might otherwise be experienced.

(2) In the usual case, where the buried wire is installed on branches from main open-wire leads which are likely to be exposed to rural power distribution, the reaction on noise of the low impedance-to-ground of the buried wire may influence the overall noise, by:

(a) Reducing the effect of shunt unbalances in the open-wire portion where these are important due to voltages-to-ground induced by the power system voltages.

(b) Increasing the effect of series unbalances in the open-wire portion or of central office unbalances

in common-battery offices due to the lower impedance to the longitudinal-circuit induction from power system currents, afforded by the buried wire.

In the practical case, it would be expected that on the average the use of the buried wire would result in some slight noise improvements. However, in common-battery areas, the use of the buried wire, particularly with intervening exposed open-wire portions, may necessitate measures to reduce the effects of the central office unbalances on the more severely exposed circuits.

Where two or more pairs of the buried wires are installed together, suitable steps to prevent crosstalk will be required. As covered in other instructions, it is advisable at the time of installation to attempt as far as practicable to reduce the unbalances to ground of the buried wire by reversing the V-groove tracer at the splices between reel lengths. Not only will this aid from a noise standpoint but will also tend to reduce the crosstalk. It is, however, highly desirable to introduce twist in the wire. Ordinarily this may be done at the time of installation by paying out the wire over the end of the reel. With the splicing and twisting inserted, no adverse crosstalk reactions are to be ordinarily expected.

The standard recommendations regarding the use of protection at the junctions of open wire and cable circuits will apply in the use of buried-wire lines, the ground plate of the protector being connected to the shield wire where the latter is used. For the present at least, station protection should be used at all services fed by the buried wire whether the station is served directly by buried wire or by an aerial extension from the buried wire.

Attached:  
3 Charts.

TABLE

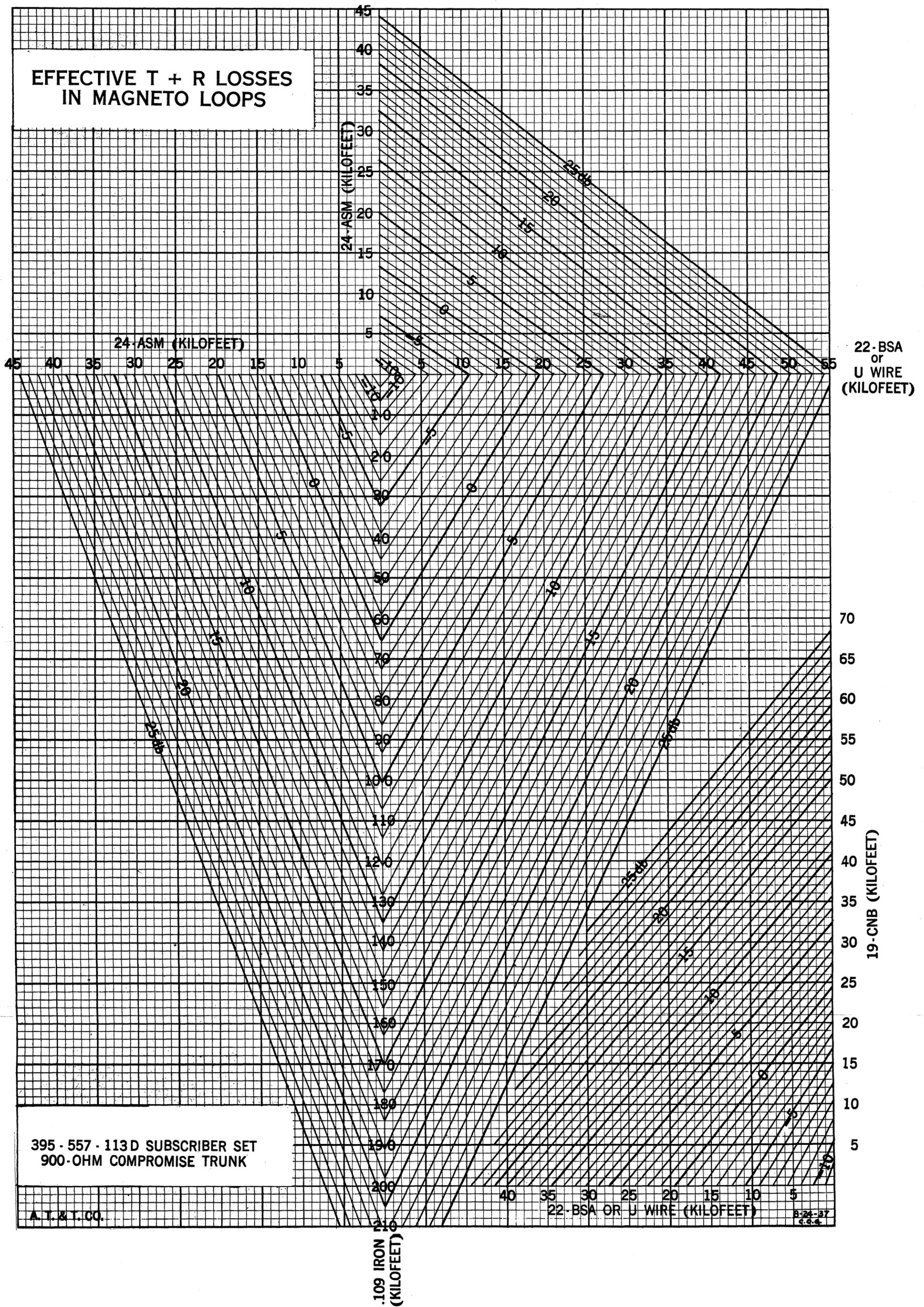
Preliminary Electrical Characteristics Of  
The Proposed Buried Wire

Size of Wire		17-gauge
Loop Resistance per mile		53.5
Capacitance per mile		0.117 mf.
Loading System		
Type of coil		44 milhenries
Resistance	4.8	ohms per load
Spacing		8000 ft. #
Characteristic Impedance	- Non-loaded	$275/\sqrt{40^0}$
	- Loaded	$525/\sqrt{80}$
1000-cycle Attenuation	- Non-loaded	1.1 db
	- Loaded	0.5 db
Effective Trunk Loss	- Non-loaded	1.3 db
	- Loaded	0.5 db
Effective Loop Losses		Equivalent to Non-loaded 22-gauge*
$\frac{T+R}{2}$ loop loss gain due to loading		0.9 db per coil

\*While the effective attenuation approximates that of 19-gauge non-loaded cable, because of the very low impedance of the buried wire the sidetone penalties are considerably greater than those for 19-gauge and the effective loop losses for buried wire closely approximate those of 22-gauge cable. Where common battery loops are involved corrections for battery supply differences must, of course, be made.

#Designated as "L" spacing. The L44 system was selected because it gives a satisfactory cut-off (above 3500 cycles), avoids the restriction on bridging subscriber sets between loading coils necessary with heavier systems such as H44 and is, of course, somewhat cheaper than the heavier systems.

**EFFECTIVE T + R LOSSES  
IN MAGNETO LOOPS**

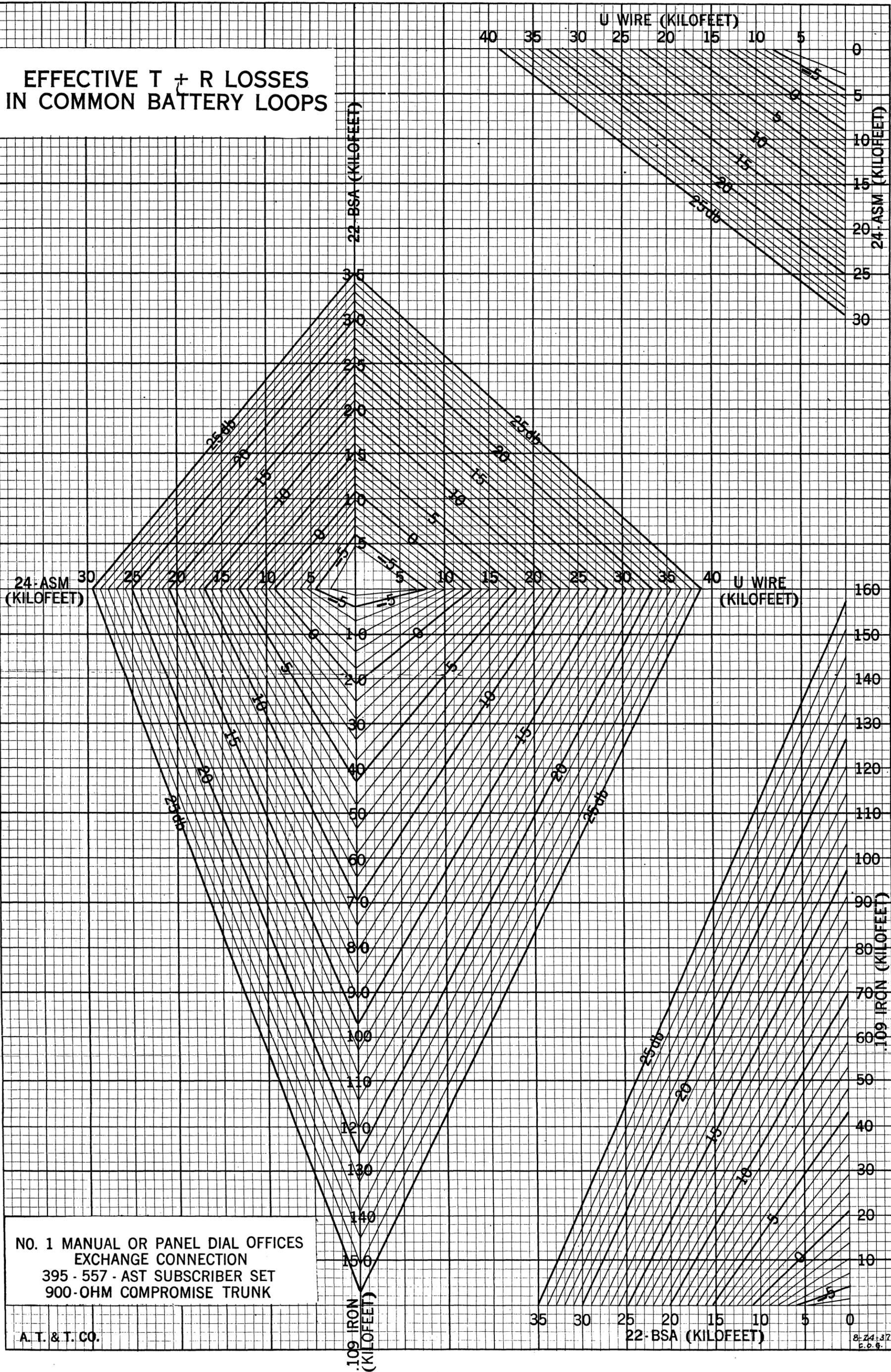


395-557-113D SUBSCRIBER SET  
900-OHM COMPROMISE TRUNK

A. T. & T. CO.

8-24-57  
4.9.4

# EFFECTIVE T + R LOSSES IN COMMON BATTERY LOOPS

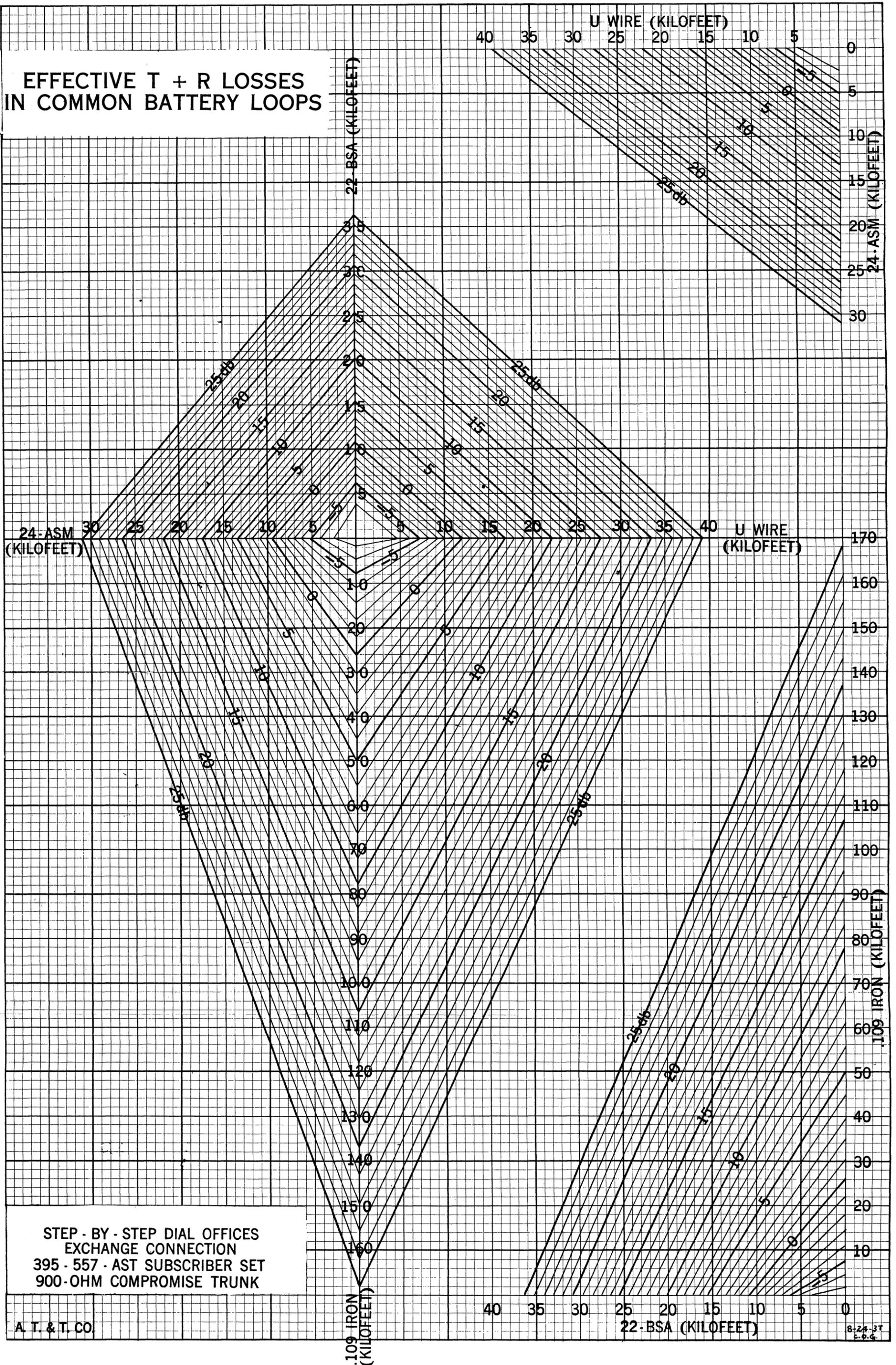


NO. 1 MANUAL OR PANEL DIAL OFFICES  
EXCHANGE CONNECTION  
395 - 557 - AST SUBSCRIBER SET  
900-OHM COMPROMISE TRUNK

A. T. & T. CO.

8-24:37  
E. P. 8

# EFFECTIVE T + R LOSSES IN COMMON BATTERY LOOPS



STEP-BY-STEP DIAL OFFICES  
EXCHANGE CONNECTION  
395-557-AST SUBSCRIBER SET  
900-OHM COMPROMISE TRUNK