ATTENUATION LOSSES AND TRANSMISSION CONSTANTS AT 1000 CYCLES OF OUTSIDE PLANT CABLE AND PAIRED CONDUCTOR FACILITIES

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1. GENERAL

1.1 Scope of Data

For the types of circuit facilities listed below, this Section provides the latest information as to the attenuation losses in db per unit length at 1000 cycles:

A. Non-quadded exchange area cable facilities.

B. Toll, entrance and intermediate facilities, including carrier loaded entrance and intermediate facilities, in paper-insulated quadded cables.

C. Quadded submarine cable and quadded emergency cable facilities.

D. Disc-insulated spiral-four (16-gauge) and low capacitance paper-insulated paired (10-gauge) entrance and intermediate cable facilities for type J carrier systems.

E. Miscellaneous cable and paired conductor facilities.

The miscellaneous cables referred to in (E) above include non-quadded submarine cables, service cables and inside wiring cables. The miscellaneous paired conductors include the various types of U wire and drop wire, bridle wire, AL wire and station wires.

In addition to the foregoing data, this Section also provides the latest information as to the following further transmission constants at 1000 cycles of the types of facilities listed in (A) and in (E) above:

1. Distributed primary constants (resistance, inductance, capacitance and leakage conductance) per unit length.

2. Secondary constants (propagation constant per unit length and characteristic impedance).

The non-quadded exchange area cable and the quadded toll cable facilities for which data are given herein include types at present standard, such older types as are still in rather common use, and several non-standard types which have been introduced into the plant in scattered cases as expedients in meeting special or temporary conditions. The data for the non-standard facilities are in most cases approximate values, but are deemed satisfactory for use in cases involving short lengths of these facilities or under other conditions where a high degree of accuracy is not essential. All such approximate values are indicated in the tables by x.

1.2 Added Data

The data in previous issues of this Section have been confined to attenuation losses at 1000 cycles, and have covered only -

A. Non-quadded exchange area cable facilities.

B. Toll, entrance and intermediate facilities in paper-insulated quadded cables.

C. 22-gauge quadded emergency cable and 17-gauge U wire.

Of the information listed in 1.1, all attenuation loss data for circuit facilities other than those above, and all of the data on primary and secondary transmission constants, have been added in this issue.

The attenuation losses of a number of types of exchange area cable facilities not covered in previous issues have also been added. These include values for circuits in 26BST and 24DSM cables, and also for several loaded 26AST and 24CSM facilities of types ordinarily encountered only where lengths of these finer gauges occur in a predominately coarser gauge trunk route. All of these added values are so indicated in Table 1.

1.3 Revised Attenuation Losses

The attenuation losses for a few types of loaded exchange area cable facilities, and also for U distribution wire, have been changed from the values shown in previous issues of this Section, and are so indicated in Tables 1 and 6.

1.4 Data Superseded

The data given herein are based upon the latest information and, for transmission purposes, supersede all similar data previously published. In particular, they supersede the following data in other AB Sections:

1. The primary transmission constants of exchange area cable facilities in Table 7 supersede those in Table I, Page 15, of Section AB42.026, Issue 1.

2. The secondary transmission constants of exchange area cable facilities in Table 8 supersede those in Table II, Page 16, of Section AB42.026, Issue 1. Current values which differ from those superseded are so indicated in Table 8.

3. The data for non-loaded and loaded U distribution wire in Tables 6 and 7 supersede the values for the primary and secondary transmission constants and for the 1000-cycle attenuation losses of this wire given on Page 6 of Section AB22.082, Issue 1.

1.5 Added and Revised Methods of Computing Corrections

A method of computing changes in resistance resulting from temperature changes has been added in this issue. This method is outlined in 6.1.

Also added in this issue is a method of approximating attenuation losses of facilities which differ in various respects from those covered by the data herein. This will permit ready determination of losses in such cases as, e.g., where average load spacings differ from standard or special loading arrangements are employed, or where temperature (and hence resistance) differs from that at which losses are given in the attached tables. This method is believed to be new, and is more accurate than approximate methods heretofore used. The more general applications of this method are discussed and illustrated in 5, and its application to determination of changes in losses resulting from temperature changes is discussed and illustrated in 6.2.

2. ATTENUATION LOSSES

The attenuation losses given herein for loaded facilities are based on the type of loading coils in most general use for each type of facility. Older or newer types of coils may result in values which differ slightly from those with the type most widely used, but these differences are insufficient to be of concern in transmission design.

2.1 Non-Quadded Exchange Area Cable Facilities

The attenuation losses of non-quadded exchange area cable facilities are given in Table 1. In accordance with current practices for exchange area transmission design these values are for a temperature of 68°F. Where values at other temperatures may be required these can be determined from the values given by the method in 6.2.

As an aid in identifying the various types of exchange area cables, values of their distributed resistance and capacitance per unit length are shown in the column headings of Table 1, immediately below the code designations.

2.2 Quadded Toll, Entrance and Intermediate Cable Facilities

The attenuation losses of quadded toll, entrance and intermediate cable facilities, except carrier loaded facilities, are given in Tables 2 and 3. In accordance with current transmission design practices these values are for a temperature of 55°F. Table 2 covers the types of facilities usually operated with pilot wire regulators; and, in addition to the attenuation losses at the mean temperature of 55°F, this table also shows the variations from these mean values under the extremes of temperature changes customarily assumed in engineering aerial and underground circuits. In Table 2A are given the losses of quadded submarine and emergency cables. Table 3 covers the types of facilities usually non-regulated, and also gives values for circuits in 22-gauge quadded emergency cable. Where the effects of temperature changes other than those included in Table 2 are required, these may be determined from the losses given by the method in 6.2.

The values for side and non-phantomed facilities in Tables 2 and 3 are based upon a distributed capacitance of .062 mf per mile, and may be applied to facilities in pairs of this capacitance in cables of other than quadded construction.

2.3 Carrier Loaded Facilities in Paper-Insulated Quadded Entrance and Intermediate Cables

Attenuation losses for carrier loaded facilities in paper-insulated quadded entrance and intermediate cables are given in Table 4. All standard types of carrier loading are included except Type J loading, which is restricted to disc-insulated pairs in shielded spiral-four quads in cables developed for Type J carrier systems. Attenuation losses for these J system facilities are given in Table 5 and discussed in subdivision 2.4.

In general, the attenuation data in Table 4 recognize two different average geographical coil spacings for each type of loading, viz., for "new" plant and for "old" plant installations, as discussed in Section AB45.030. It should be kept in mind in this connection that in general the actual spacing for carrier loading is closer than the theoretical spacing in .062 mf/mi cable, so as to permit precision capacitance building out adjustments in all of the individual loading sections. The larger the capacitance building out the larger is the ratio of coil resistance to cable resistance and the greater the average attenuation per mile. Because of the various conditions to which these data apply, the notes should be carefully consulted in selecting values from Table 4.

If desired, attenuation values for average spacings different from those assumed in Table 4 may be estimated by interpolation or extrapolation of the attenuation data in Table 4. In such instances, select the attenuation value for the reference spacing that is closer to the actual average spacing for the facility involved, and multiply this value by the ratio of the selected reference average spacing to the actual average spacing.

All losses given in Table 4 are for a temperature of 55°F. Values at other temperatures may be determined from those given by the method in 6.2.

2.4 Entrance and Intermediate Cable Facilities for Type J Carrier Systems

The attenuation data in Table 5 for 16-gauge disc-insulated quads with side circuit loading are for theoretical full loading sections with zero building-out. These theoretical side circuit loading section lengths are stated in Note (1) below the table. The total attenuation in the cable circuits, sides and phantoms, may be obtained by multiplying the theoretical unit values by the number of theoretical full loading sections. In many installations this numeric multiplier is not a whole number because of the use of fractional section loading terminations with F-type loading units at one or both ends of the cable. An alternative procedure is to derive the attenuation per mile in terms of the theoretical loading section lengths, and multiply this by the cable length in miles.

It is always necessary to build out the loaded side circuits in order to conform to design theory, and consequently the average coil spacing will be below the theoretical spacing. The building-out apparatus is adjusted to provide the required capacitance in the side circuits, but in the voice range it is deficient in resistance and inductance, and in consequence the actual attenuation per loading section is somewhat less than the theoretical value given in Table 5. The side circuit loading coils provide a very light weight loading for the phantom. In built out cables the phantom circuit attenuation per loading section is less than the theoretical value, primarily because of capacitance and resistance deficiencies in the phantom circuit effects of the side circuit building-out apparatus. Approximate magnitudes of the changes in attenuation per loading section, sides and phantoms, are stated in Note (2) under Table 5 as a function of the amount of side circuit building-out. These correction factors are sufficiently exact for practical needs since the disc-insulated cables usually have only a few loading sections, and very few loaded cables are as long as one mile.

The loss of the 10-gauge low capacitance pairs is for the shielded core group of four pairs in a cable layup having a total of 14 pairs. Because of their lower mutual capacitance the attenuation loss of the pairs in the outer layer group (located between the concentric shield and the sheath) is about 3 per cent. lower than the value shown in Table 5. The loss given is a preliminary value based on the very limited amount of this type of cable thus far manufactured.

All losses given in Table 5 are for a temperature of 55°F. Values at other temperatures may be determined from those given by the method in 6.2.

2.5 Miscellaneous Cable and Paired Conductor Facilities

Attenuation losses for other types of cable and paired conductor facilities covered in this Section are given in Table 6. With the exception of non-quadded submarine cable, for which values are at 55°F, values for these facilities are at 68°F. Losses shown are per unit length of one mile or of one kilofoot, depending upon which is the more convenient unit for dealing with the most common lengths of the particular facility. The unit of length and the temperature for which the loss of each facility is given, and also, in cases where this is pertinent, whether the value is for dry or wet conditions, are specified in the first three columns of Table 6. Values at other temperatures may be approximated from the losses given by the method in 6.2.

3. DISTRIBUTED PRIMARY CONSTANTS

The distributed primary transmission constants - viz., the loop resistance, inductance, leakage conductance and capacitance per unit length - of all cable and paired conductor facilities for which the attenuation losses are given in Tables 1 and 6, are shown in Table 7. These values are, of course, for the line conductors alone, i.e., exclusive of the lumped constants of loading coils. The resistances, inductances and capacitances are d-c values, but differences between these and 1000-cycle values are, for practical purposes, negligible. Leakage conductances are specifically 1000-cycle values.

The unit of length for which the values for each type of facility are given is specified, and, in cases where this is pertinent, it is also stated whether the values are for dry or wet conditions. The resistances vary with the temperature, and the temperature at which each value is given is shown. This is, in every case, the same as the temperature at which the corresponding attenuation losses are given in Tables 1 and 6. Resistances at other temperatures can be determined from those in Table 7 by the method in 6.1.

4. SECONDARY TRANSMISSION CONSTANTS

Values at 1000 cycles of the propagation constant per unit length and of the characteristic impedance of the various miscellaneous cable and paired conductor facilities whose attenuation losses are covered in Table 6 are also given in that table. The first three columns specify the unit of length and the temperature for which these secondary transmission constants are given, and also, in cases where this is pertinent, whether the values are for dry or wet conditions.

In Table 8 are given the secondary transmission constants of most of the types of exchange area cable facilities for which attenuation losses are shown in Table 1. All of these are 1000-cycle values at 68°F.

5. IMPROVED METHOD OF APPROXIMATING ATTENUATION LOSSES

Due to the effects of temperature variations upon resistance, or because of loading arrangements which depart from standard either in weight of coils or in average load spacing, or for other reasons, it is frequently required to determine the attenuation losses of circuit facilities whose resistance, inductance or capacitance per unit length (either singly or severally) depart from those of the facilities covered in this Section. Attenuation losses at 1000 cycles for such non-loaded or loaded facilities may be approximated quite closely from the data herein by the method outlined below and illustrated in subdivision 5.2 by several examples.

1. Let R_x, L_x and C_x denote the total* resistance, inductance and capacitance per unit length of the facility whose attenuation loss A_x per unit length is to be determined.

* Total introduced by line conductors, loading and building-out.

2. From the facilities whose attenuation losses are given herein, select as a reference facility the one whose corresponding transmission constants R_r, L_r and C_r are closest to those of the facility whose attenuation loss is required. Let the attenuation loss given for this reference facility be denoted by A_r.

3. In accordance with the further explanation in (3B), compute the required loss A_x by the following formula after simplifying it as discussed in (3A):-

$$A_x = \frac{K_x}{K_r} \cdot \sqrt{\frac{L_x}{L_r}} \cdot \sqrt{\frac{C_x}{C_r}} \cdot A_r \quad \text{db/unit length,} \qquad (1)$$

where the quantities K_x and K_r are as explained in (3Bb), and all other quantities are as already designated in (1) and (2) above.

A. In applying formula (1) it is necessary to evaluate all three of the factors K_x/K_r, $\sqrt{L_x/L_r}$ and $\sqrt{C_x/C_r}$ only in cases where R_x, L_x and C_x all differ from R_r, L_r and C_r - see Example 3 in 5.2. Under all other conditions one or more of the foregoing three factors become unity, as indicated below, and may, therefore, be ignored.

a. If the reference facility is so selected that $C_x = C_r$, then the factor $\sqrt{C_x/C_r} = 1$ and need not be considered - see Example 4 in 5.2.

b. If the reference facility is so selected that $L_x = L_r$, then the factor $\sqrt{L_x/L_r} = 1$ and need not be considered - see Examples 1 and 2 in 5.2.

c. The factor K_x/K_r becomes unity if, and only if, both $R_x = R_r$ and $L_x = L_r$, i.e., in cases where the reference facility selected is such that it differs from the required facility only in that C_r differs from C_x - see Example 1 in 5.2.

d. In particular, if $L_x = L_r$ and $C_x = C_r$, but R_x differs from R_r, as will ordinarily be the case in computing the effect of temperature variations upon attenuation losses, formula (1) simplifies to

$$A_x = \frac{K_x}{K_r} \cdot A_r \quad \text{db/unit length} \qquad (2)$$

The use of formula (2) in computing the effects of temperature variations is discussed in subdivision 6.2.

B. The values of L, C and K in formulas (1) and (2) may be obtained as follows from the data given herein, or from other Bell System Practices:

a. Values of L and C: - Values of the distributed inductance and mutual capacitance per unit length of the line conductors of exchange area cable facilities, and of various miscellaneous cable and paired conductor facilities, may be obtained from the attached Table 7. Similar values for the line conductors of other types of circuit facilities are given elsewhere in the AB information. Loading coil inductances may be taken to be the nominal values. Building-out capacitance will either be known or may be determined from other AB Sections. In these 1000-cycle computations mutual capacitance introduced by loading coils may be neglected. The value of L_x should be for the same unit of length as the value of L_r, and the value of C_x should be for the same unit of length as the value of C_r; but values of L need not be for the same unit of length as values of C; e.g., values of C_x and C_r may be capacitance per mile, while L_x and L_r are inductance per load section.

b. Values of K: - It will be noted that, although attenuation losses obviously depend upon resistance, R_x and R_r do not appear as such in formulas (1) and (2). The effects of resistance are, however, taken into account by the quantities K_x and K_r. These quantities depend upon the ratio of the total resistance per unit length to the total inductive reactance per unit length, of the corresponding required and reference facilities; and the values of K for a wide range of the values of this ratio are tabulated in the attached Table 10. In order to read values of K_x and K_r from this table it is first necessary to compute the corresponding values of the foregoing ratio.

For this purpose values of the resistance per unit length of the line conductors of exchange area cable facilities, and of various miscellaneous cable and paired conductor facilities, may be obtained from Table 7. Similar values for the line conductors of other types of circuit facilities are given elsewhere in the AB information. Values of the resistance at 1000 cycles introduced by loading coils, etc., may be obtained from Sections of the AB45 series.

Values of the inductive reactance at 1000 cycles for all loaded facilities covered in Tables 1 to 6 are given in Table 9. These values include both the reactance of the lumped inductance of the loading, and that of the distributed inductance of the line conductors. The corresponding values of the inductive reactance due to the line conductors alone, i.e., for non-loaded facilities, are given in Note 2 under Table 9. Values of inductive reactance for other non-loaded and loaded facilities may be computed from the values of distributed inductance given in Table 7 or elsewhere in the AB information, and from the nominal inductance of loading coils.

Where values of the above ratio fall between those tabulated in Table 10 the corresponding values of K may be obtained by linear interpolation between the tabulated values. To facilitate this, columns of tabular differences have been included in Table 10.

5.1 Accuracy of Results Obtained by New Method

Several examples illustrating the application of formula (1) are worked out in subdivision 5.2. The purpose for which this formula as herein presented is intended is, of course, for use in approximating the attenuation loss at 1000 cycles of cable and paired conductor facilities which differ in various respects from those covered in this Section. In the first three of the examples just mentioned, however, the losses of 26AST-B88, 24CSM-B88 and 24CSM-H88 are determined, using 26BST-B88 as the reference facility. Inasmuch as the losses for all of the foregoing exchange area cable circuit facilities are given in Table 1, these examples not only serve to illustrate the use of the formula, but they also demonstrate the accuracy of the approximations. The fourth example, in which the loss of 26BST-B88 is determined by using 26BST-NL as the reference, illustrates the use and demonstrates the accuracy of the formula in computing the losses of loaded facilities from the losses of the corresponding non-loaded facilities.

The exactness with which the losses computed in these examples agree with their known values will likely raise a question as to why results obtained with formula (1) are referred to as approximate. They are so called because, from the theoretical standpoint, the formula itself is approximate: although it does yield quite accurate results in dealing with exchange area and quadded cable facilities, it may lead to less accurate results when applied to other types of facilities; and since a complete discussion of its limitations is beyond the scope of the present Section, losses computed with it should in all cases be regarded as approximate. Inasmuch, however, as the types of cable or paired conductor facilities for which losses computed by formula (1) may not be of high accuracy are types usually occurring only in relatively short lengths, the approximations obtained with this formula will generally be satisfactory for engineering purposes.

Inasmuch as the form of formula (1) is that of a product of factors, values of losses satisfactory for most engineering uses can be rapidly computed by slide rule, or, where greater precision is desired, by means of logarithms. The latter means of simplifying the computations is employed in the examples in subdivision 5.2.

It will be noted that in none of the examples except Example 1 has the reference facility been selected in accordance with the stipulation in Step 2 of the method outlined in subdivision 5. The purpose of stipulating that the reference facility should be as similar to the required facility as it can be selected is primarily to save computing labor, as the examples will also illustrate. Whether or not it is complied with will usually have but little effect upon the accuracy of the results.

5.2 Examples Illustrating Attenuation Loss Computations

The nature of the following examples, the features of formula (1) which they illustrate, and the computational means employed, have already been discussed in 5 and 5.1.

Data Required in Examples

For convenience, the data required in the solutions of the following examples are tabulated in Table A. In this table are also collected all logarithms used in the solutions; and here, too, are determined the needed values of K.

Examples

Example 1

In this example the loss of 26AST-B88 will be determined, using 26BST-B88 as the reference facility. Referring to Table A, it will be seen that $R_x = R_r$ and $L_x = L_r$, and hence, also, $K_x = K_r$, so that, as pointed out in Step (3Ac) of outline of method in 5, formula (1) simplifies to -

$$A_x = \sqrt{\frac{C_x}{C_r}} \cdot A_r$$

The solution, using the logarithms collected in Table A, is -

$$\begin{array}{rcll}
\log C_x & = & 28.83885-30 & \} \text{ Subtract} \\
\log C_r & = & 8.89763-10 & \\
 & & 2)\overline{19.94122-20} & \\
\log \sqrt{C_x/C_r} & = & 9.97061-10 & \} \text{ Add} \\
\log A_r & = & .14301 & \\
\log A_x & = & .11362 & A_x = 1.30 \text{ db/mi}
\end{array}$$

This result agrees exactly with the loss for 26AST-B88 in Table 1.

Example 2

The loss of 24CSM-B88 will be determined, using 26BST-B88 as the reference facility. In this case, as may be seen by referring to Table A, $L_x = L_r$; but R_x and C_x differ from R_r and C_r. As pointed out in Step (3Ab) of outline of method in 5, formula (1) therefore simplifies to -

$$A_x = \frac{K_x}{K_r} \cdot \sqrt{\frac{C_x}{C_r}} \cdot A_r$$

TABLE A

		Circuit Facilities					
		26BST		26AST	24CSM		Data
		NL	B88	B88	B88	H88	From
A	(db per mi)	2.86	1.39	-	-	-	Table 1
Load Coil (Code No.		-	622	622	622	622	AB45 series
Load Coil (Nom. L	(hen)	-	.088	.088	.088	.088	AB45 series
Load Coil (R at 1000 cycles	(ohms)	-	9.6	9.6	9.6	9.6	AB45 series
Cond. R/mi	(ohms)	440	440	440	274	274	Table 7
Coil R/mi	"	-	16.9	16.9	16.9	8.4	Above
Total R/mi	"	440	456.9	456.9	290.9	282.4	Add
Cond. L/mi	(hen)	.001	.001	.001	.001	.001	Table 7
Coil L/mi	"	-	.1549	.1549	.1549	.07744	Above
Total L/mi	"	.001	.1559	.1559	.1559	.07844	Add
C/mi	(mf)	.079	.079	.069	.072	.072	Table 7
ωL/mi	(ohms)	6.3	979	-	979	493	Table 9
log(R/mi)		2.64345	12.65982-10	-	12.46374-10	12.45086-10	Above
log(ωL/mi)		.79934	2.99078	-	2.99078	2.69285	Above
log(R/ωL)		1.84411	9.66904-10	-	9.47296-10	9.75801-10	Subtract
R/ωL		69.84	.4667	-	.2971	.5728	Above
K		8.314	.3246	-	.2108	.3933	Table10
log K		.91981	9.51135-10	-	9.32387-10	9.59472-10	Above
log(L/mi)		7.00000-10	9.19285-10	-	-	8.89454-10	Above
log(C/mi)		-	8.89763-10	8.83885-10	8.85733-10	8.85733-10	Above
log(A/mi)		.45637	.14301	-	-	-	Above

The solution, carried out with logarithms given in Table A, is as follows -

$$\begin{array}{lrl} \log K_x & = & 19.32387-20 \\ \log K_r & = & 9.51135-10 \\ \log (K_x/K_r) & = & 9.81252-10 \\ \log \sqrt{C_x/C_r} & = & 9.97985-10 \\ \log A_r & = & .14301 \\ \log A_x & = & 9.93538-10 \end{array} \qquad \begin{array}{lrl} \log C_x & = & 28.85733-30 \\ \log C_r & = & 8.89763-10 \\ & 2) & 19.95970-20 \\ & & 9.97985-10 \\ & & \\ A_x & = & .862 \text{ db/mi} \end{array}$$

Rounded off to two significant figures, this result is .86, whereas the loss for 24CSM-B88 is given as .87 in Table 1. The latter value, however, is .867 rounded off.

Example 3

Again using 26BST-B88 as the reference facility, the loss of 24CSM-H88 will be determined. As may be seen by referring to Table A, R_x, L_x and C_x all differ from R_r, L_r and C_r, so that, as discussed in Step (3A) of outline of method in 5, no simplification of formula (1) occurs in this case. The required solution by logarithms is -

$$\begin{array}{lrl} & & \\ & & \\ \log K_x & = & 9.59472-10 \\ \log K_r & = & 9.51135-10 \\ \log (K_x/K_r) & = & .08337 \\ \log \sqrt{L_x/L_r} & = & 9.85085-10 \\ \log \sqrt{C_x/C_r} & = & 9.97985-10 \\ \log A_r & = & .14301 \\ \log A_x & = & .05708 \end{array} \qquad \begin{array}{lrl} \log L_x & = & 28.89454-30 \\ \log L_r & = & 9.19285-10 \\ & 2) & 19.70169-20 \\ & & 9.85085-10 \\ \log C_x & = & 28.85733-30 \\ \log C_r & = & 8.89763-10 \\ & 2) & 19.95970-20 \\ & & 9.97985-10 \\ A_x & = & 1.14 \text{ db/mi} \end{array}$$

This result agrees exactly with the loss for 24CSM-H88 in Table 1.

Example 4

In this example the loss of 26BST-B88 is determined, using the corresponding non-loaded facility, i.e., 26BST-NL, as the reference facility. Since $C_x = C_r$, then, as pointed out in Step (3Aa) of outline of method in 5, formula (1) simplifies to -

$$A_x = \frac{K_x}{K_r} \cdot \sqrt{\frac{L_r}{L_x}} \cdot A_r$$

The solution by logarithms is

$$\begin{array}{rll} \log K_x = & 9.51135-10 & \qquad \log L_x = 9.19285-10 \\ \log K_r = & .91981 & \qquad \log L_r = 7.00000-10 \\ \log (K_x/K_r) = & 8.59154-10 & \qquad 2)\overline{2.19285} \\ \log \sqrt{L_x/L_r} = & 1.09643 \longleftarrow & \qquad 1.09643 \\ \log A_r = & .45637 & \\ \log A_x = & .14434 & \qquad A_x = 1.39 \quad \text{db/mi} \end{array}$$

This result agrees exactly with the loss for 26BST-B88 given in Table 1.

6. VARIATIONS WITH TEMPERATURE

Resistances and attenuation losses at temperatures other than those for which values are given herein may be determined from the data in this Section by the methods explained below.

6.1 Resistance Changes

The resistance R_T at any Fahrenheit temperature T may be determined from the values given herein for the resistance R_{68} at 68°F or for the resistance R_{55} at 55°F by the following formulas:

$$R_T = \frac{395 + T}{463} \cdot R_{68} \quad \text{ohms} \qquad (3)$$

or

$$R_T = \frac{395 + T}{450} \cdot R_{55} \quad \text{ohms} \qquad (4)$$

6.2 Changes in Attenuation Losses

The 1000-cycle attenuation loss A_x at any Fahrenheit temperature T_x may be approximated from the values given herein by the following method:

1. In accordance with the discussion under item (3Bb) of the outline in subdivision 5, determine -

   A. The value of the total* resistance in ohms per mile for the given facility at the temperature T_r (68° or 55°) at which its attenuation loss A_r is given herein.

   B. The value of the total* inductive reactance of the given facility in ohms per mile.

   * Total introduced by line conductors, loading and building-out.

   C. The ratio of the total resistance obtained in (A) to the total inductive reactance found in (B).

2. Multiply the ratio obtained in (1C) above by the factor

$$\frac{395 + T_x}{395 + T_r}$$

thus obtaining the value of the corresponding ratio at the required temperature T_x

3. From Table 10 obtain the two following values of the quantity K:

   A. The value K_r corresponding to the ratio found in (1C) above.

   B. The value K_x corresponding to the ratio found in (2) above.

4. The required attenuation loss A_x at temperature T_x is then determined by substituting into formula (2) - see Step (3Ad) of outline of method in 5 - the known loss A_r at temperature T_r, and the values of K_r and K_x obtained in (3A) and (3B) above.

In several cases the temperature variation corrections shown in Table 2 differ slightly from values computed for those cases by the foregoing method. This is due to the fact that the figures in Table 2 are averages of the positive and negative variations determined by more exact methods.

Example

To illustrate the foregoing method of determining attenuation losses at temperatures other than those for which values are given herein, the loss of 26BST-B88 at 110°F will be computed from the value at 68°F given in Table 1. The required data are shown in Table A.

1. From Table A -

   A. The total resistance of 26BST-B88 at T_r = 68°F at which the loss A_r = 1.39 db per mile is given in Table A, is 456.9 ohms per mile.

   B. The total inductive reactance of 26BST-B88 is 979 ohms per mile.

   C. Carrying out this step by logarithms, as in Table A.

$$\left.\begin{array}{rl} \log R_r = & 12.65982-10 \\ \log \omega L_r = & 2.99078 \end{array}\right\} \text{Subtract}$$

$$\begin{array}{rl} \log (R_r/\omega L_r) = & 9.66904-10 \\ R_r/\omega L_r = & .4667 \end{array}$$

2. The reference temperature T_r = 68° and the required temperature T_x = 110°, so that

$$\frac{395 + T_x}{395 + T_r} = \frac{395 + 110}{395 + 68} = \frac{505}{463}$$

Completing this step by logarithms

$$\begin{array}{rcll} \log 505 & = & 2.70329 & \rbrace \text{ Subtract} \\ \log 463 & = & 2.66558 & \\ & & .03771 & \rbrace \text{ Add} \\ \log (R_r/\omega L_r) & = & 9.66904\text{-}10 & \\ \log (R_x/\omega L_x) & = & 9.70675\text{-}10 & \\ R_x/\omega L_x & = & .5090 & \end{array}$$

3. From Table 10, the needed values of K are -

   A. The value of K corresponding to the 68° ratio, $R_r/\omega L_r = .4667$, obtained in (1C) is $K_r = .3246$.

   B. The value of K corresponding to the 110° ratio, $R_x/\omega L_x = .5090$, found in (2) is $K_x = .3528$.

4. The known loss at temperature $T_r = 68^{\circ}F$ is $A_r = 1.39$ db per mile. The value of $K_r = .3246$, from (3A); and the value of $K_x = .3528$, from (3B) above. Carrying out the solution of formula (2) by logarithms -

$$\begin{array}{rcll} \log K_x & = & 9.54753\text{-}10 & \rbrace \text{ Subtract} \\ \log K_r & = & 9.51135\text{-}10 & \\ \log (K_x/K_r) & = & .03618 & \rbrace \text{ Add} \\ \log A_r & = & .14301 & \\ \log A_x & = & .17919 & \\ A_x & = & 1.51 \text{ db/mi} & \end{array}$$

INDEX OF ATTACHED TABLES

Attached:

Tables 1 to 10.

TABLE I

ATTENUATION LOSSES OF NON-QUADDED EXCHANGE AREA CABLE FACILITIES
AT 1000 CYCLES

GAUGE CABLE		26		24			22				19		16	13
TYPE OF CABLE		ST AST	BST*	M SM ASM CSM	DSM*	NM	SA ASA BSA CSA	NA ANA	TA	TS	BNB CNB	TB ANB DNB	TH NH	TJ
R, Ohms Per Mile At 68°F		440	440	274	274	274	171	171	171	171	85	85	42	21.4
C, mf Per Mile		.069	.079	.072	.084	.065	.082	.073	.062	.068	.084	.066	.066	.066
LOADING	LOAD SPACING (FEET)	DECIBELS PER MILE AT 68° F												
B-175	3,000	.94*	1.01*	.63	.68*	-	.44ø	-	-	-	.25	.22	.14	-
B-135	"	1.05*	1.12*	.69*	.75*	-	.48	-	-	-	.26	.24	.14	-
B- 88	"	1.30*	1.39*	.87ø	.94*	-	.60	-	-	-	.34	.30	.18	-
D-175	4,500	1.12*	1.20*	.74*	.80*	-	.51	.49	-	-	.28	.25	.15	-
D-135	"	1.25*	1.33*	.82*	.88*	-	.56	-	-	-	.30	.27	-	-
D- 88	"	1.52*	1.62*	1.01	1.09*	-	.70	-	-	-	.38	.34	-	-
H-250	6,000	-	-	-	-	-	-	-	-	-	-	.26	.17	.11
H-175	"	-	-	-	-	-	-	-	-	-	.31	.27	.15	.10
H-135	"	1.40*	1.50*	.92*	1.00*	-	.63	.60	-	-	.34	.30	.16	-
H- 88	"	1.69ø	1.80*	1.14ø	1.23*	-	.79	-	-	-	.42	.38	.21	-
H- 44	"	2.06	2.21*	1.46	1.58*	-	1.04	-	-	-	.56	.50	.27	-
M-175	9,000	-	-	-	-	-	-	.65	.60	.63	-	.33	.17	.11
M-135	"	1.63*	1.75*	1.09ø	1.18*	1.14	.75ø	.73	-	-	.41	.36	.20	-
M- 88	"	1.91*	2.04*	1.31	1.42*	1.25	.92	.87	-	-	.49	.44	.24	.14
R-133	11,600	-	-	-	-	-	-	-	.76	.80	-	.41	.21	.12
Non-Loaded	-	2.67	2.86*	2.14	2.31*	2.04	1.79	1.69	1.55	1.63	1.26	1.11	.75	.50

* Added values not included in previous issues. ø Value changed from previous issue.

TABLE 2

ATTENUATION LOSSES OF QUADDED TOLL CABLE CIRCUITS AT 1000 CYCLES
FACILITIES USUALLY REGULATED ø

GAUGE CABLE		19			16		
		DECIBELS PER MILE					
			VARIATIONS FROM 55° MEAN			VARIATIONS FROM 55° MEAN	
LOADING	SPACING FT.	LOSS AT 55° F.	AERIAL CABLE *	U.G. CABLE**	LOSS AT 55° F.	AERIAL CABLE *	U.G. CABLE**
B- 88- 50-S	3000	.28	± .031	± .011	.16	± .018	± .006
B- 88- 50-P	3000	.23	∓ .026	∓ .009	.14	∓ .015	∓ .005
B- 22-N	3000	.45	± .052	± .017	.24	± .028	± .009
H-174-106-S	6000	.28	± .032	± .011	.16	± .017	± .006
H-174-106-P	6000	.22	∓ .025	∓ .008	.13	∓ .013	∓ .004
H-172- 63-S	6000	.27	± .031	± .010	.16	± .018	± .006
H-172- 63-P	6000	.28	∓ .032	∓ .011	.16	∓ .018	∓ .006
H- 88- 50-S	6000	.35	± .041	± .014	.19	± .022	± .007
H- 88- 50-P	6000	.30	∓ .035	∓ .012	.16	∓ .019	∓ .006
H- 44- 25-S	6000	.47	± .055	± .018	.25	± .029	± .010
H- 44- 25-P	6000	.39	∓ .046	∓ .015	.21	∓ .024	∓ .008
H- 22-0-S	6000	.62 x	± .071 x	± .024 x	.32	± .037	± .012

* Temperature range, ± 54° F.; resistance variation, ± 12%.

** Temperature range, ± 18° F.; resistance variation, ± 4%.

x Approximate values.

ø See Table 3 for quadded toll and incidental cable circuit facilities usually non-regulated, and see Table 4 for carrier loaded entrance and intermediate quadded circuit facilities.

TABLE 2A#

ATTENUATION LOSSES OF QUADDED SUBMARINE AND EMERGENCY CABLES
AT 1000 CYCLES

TYPE OF FACILITY		VALUES SHOWN ARE			ATTENUATION LOSS
		Per Unit Length Of	At Temp Of F°	Dry or Wet	Decibels Per Unit Length
SUBMARINE CABLES - QUADDED		Same as for Quadded Toll Cables			
EMERGENCY CABLES - QUADDED					
22 Gauge *	Side	Kilofoot	55°	-	.29
	Phantom	"	"	-	.26
19 Gauge CL Type	Side	"	"	Dry	.28
				Wet	.32
	Phantom	"	"	Dry	.30
				Wet	.32

\# All data in this table, except losses of 22-gauge emergency cable, are added information not included in previous issues of this section.

* See Table 3 for losses of loaded 22-gauge emergency cable facilities

TABLE 3

ATTENUATION LOSSES OF QUADDED TOLL AND INCIDENTAL CABLE CIRCUITS AT 1000 CYCLES
FACILITIES USUALLY NON-REGULATED*

GAUGE OF CABLE		22Ø	19	16	14ØØ	13	10
LOADING	SPACING FT.	DECIBELS PER MILE AT 55° F.					
B- 88- 50-S	3000	.50	****	****			
B- 88- 50-P	3000	.42	****	****			
E- 28- 16-S	5575		.57	.29		.16	.081
E- 28- 16-P	5575		.48	.24		.14	.068
H- 28- 16-S	6000		.59	.30		.17	.086
H- 28- 16-P	6000		.49	.25		.14	.073
H- 31- 18-S	6000	1.08	.55	.28		.16	
H- 31- 18-P	6000	.90	.46	.24		.13	
H- 44- 25-S	6000	.92	****	****			
H- 44- 25-P	6000	.77	****	****			
H- 88- 50-S	6000	.66	****	****			
H- 88- 50-P	6000	.56	****	****			
H-172- 63 } H-174- 63 } -S	6000	.49	****	****			
H-172- 63 } H-174- 63 } -P	6000	.51	****	****			
H-174-106-S	6000	.50	****	****		.101	
H-174-106-P	6000	.40	****	****		.084	
H-245-N **	6000		.27x	.17	.12	.11	
H-245-155 } H-248-154 } -S	6000	.44	.26	.16		.104	.079
H-245-155 } H-248-154 } -P	6000	.35	.20	.12		.083	.062
K-200-N **	7400					.080x	
K-200-130-S	7400	.51				.083	.049
K-200-130-P	7400	.41				.067	.039
M- 44- 25-S	8770		.55	.28		.148	.079
M- 44- 25-P	8770		.47	.23		.126	.068
M-135-N **	8770	.64					
M-174-106-S	8770		.32	.17		.094	.059
M-174-106-P	8770		.25	.15		.078	.050
S- 44- 25-S	12000	1.26					
S- 44- 25-P	12000	1.06					
NON-LOADED S	-	1.54	1.07	.72	.51	.48	.30
NON-LOADED P	-	1.37	.95	.63		.41	.24

* See Table 2 for quadded toll circuit facilities usually regulated, and see Table 4 for carrier loaded entrance and intermediate quadded cable circuit facilities.

** Non-phantom or side circuits of groups having non-loaded phantoms.

**** Values for these facilities are given in Table 2.

Ø 22-gauge quadded emergency cable.

ØØ Non-quadded cable.

x Approximate value satisfactory for short length of facility.

TABLE 4

ATTENUATION LOSSES OF CARRIER LOADED FACILITIES IN PAPER-INSULATED QUADDED ENTRANCE AND INTERMEDIATE CABLES AT 1000 CYCLES

GAUGE CABLE					19	16	13
LOADING SYSTEM	CIRCUIT	FOR CONNECTION TO	COIL SPACING FT.	SEE NOTES	DECIBELS PER MILE AT 55° F.		
C-4.8-0	S* S*	12" - SPACED OPEN-WIRE CIRCUITS	800 685	(1-A) (1-B)	.66 .68	.39 .41	- .27 x
C-4.1-0	S* S*		800 685	(1-A) (1-B)	- .71 x	- .43 x	.27 .29
CF-4.8-7.1	{ S { P { S { P		800 2400 685 2055	(1-A) (1-B)	.68 .57 .71 .59	.41 .34 .43 .36	- - - -
CF-4.1-6.3	{ S { P { S { P		800 2400 685 2055	(1-A) (1-B)	- - - -	- - - -	.27 .23 .30 .25
CE-4.8-12.8	{ S { P { S { P		800 4800 685 4110	(1-A) (1-B)	.68 .60 .71 .62	.41 .36 .43 .38	- - .28 x .25 x
CE-4.1-12.8	{ S { P { S { P		800 4800 685 4110	(1-A) (1-B)	- - .72 x .62 x	- - .44 x .38 x	.27 .23 .30 .25
BH-15-15 } BH-15-16 }	{ S { P { S { P		3000 6000 2800 5600	(3) (1-A)	.63 .53 .64 .54	.36 .30 .37 .31	- - .24 x .20 x
A-3.0	N N	8" - SPACED OPEN-WIRE CIRCUITS	600 500	(1-A) (1-B)	.72 .76	.43 .47	- .32 x
A-2.7	N N		600 500	(1-A) (1-B)	- .77 x	.45 .48	.30 .33
C-4.8	N N		800 685	(1-A), (2-A) (1-B),	.67 .70	- .41 x	- .28 x
C-4.1	N N N N N N		800 685 800 685 685 685	(1-A) (1-B) (1-A), (2-A) (1-B), (1-B), (2-B) (2-C)	- .72 x - - - -	.41 .43 - - .49 -	- - .28 .30 - .34
X-2.7-0	{ S { P	OFFICE CABLE LOADING SYSTEMS ON SHORT ENTRANCE AND INTERMEDIATE CABLES	680 -	(3)	.84 x .82 x	.58 x .62 x	.44 x .50 x
Y-9-0	{ S { P		2130 -	(3)	.84 .82	.58 .62	.44 .50

NOTES:-

* VALUES FOR PHANTOMS OF THESE SYSTEMS MAY BE TAKEN TO BE THE SAME AS THOSE GIVEN IN TABLE 3 FOR PHANTOMS OF NON-LOADED GROUPS. THE ATTENUATION LOSSES AT 1000 CYCLES IN THE NON-LOADED PHANTOMS OF CARRIER LOADED SIDE CIRCUITS DO NOT DIFFER FROM THOSE IN THE PHANTOMS OF NON-LOADED SIDES OF LIKE GAUGE BY AMOUNTS WHICH, FOR THE LENGTHS OF CARRIER LOADED ENTRANCE AND INTERMEDIATE CABLE CIRCUITS ORDINARILY ENCOUNTERED, ARE SUFFICIENT TO JUSTIFY THE USE OF SEPARATE VALUES. SIDE CIRCUIT COILS INCREASE THE RESISTANCE AND THEIR LEAKAGE INDUCTANCE ADDS INDUCTANCE TO THE PHANTOM CIRCUIT. IN THE CASE OF THE 19 AND 16-GAUGE PHANTOMS THIS ADDED INDUCTANCE TENDS TO SOMEWHAT MORE THAN OFFSET THE INCREASED RESISTANCE, BUT IN THE CASE OF COARSER GAUGE PHANTOMS THE INCREASE IN RESISTANCE TENDS TO BE THE DOMINANT FACTOR.

x APPROXIMATE VALUES SATISFACTORY FOR THE SHORT LENGTHS OF THESE NON-STANDARD FACILITIES NORMALLY ENCOUNTERED ON A SINGLE CONNECTION.

(1) IN ORDER TO PERMIT OF CAPACITANCE ADJUSTMENTS, EITHER FOR THE PURPOSE OF CORRECTING FOR MANUFACTURING DEVIATIONS IN CABLE CAPACITANCE OR BECAUSE OF GEOGRAPHICAL IRREGULARITIES IN MANHOLE SPACINGS, LOADING COILS IN CARRIER LOADING INSTALLATIONS ARE USUALLY SPACED AT GEOGRAPHICAL INTERVALS SHORTER THAN THE THEORETICAL SPACINGS. THE ATTENUATION LOSSES GIVEN ABOVE FOR THESE SHORTER SPACINGS ARE:

(A) THESE VALUES ARE FOR THE APPROXIMATE AVERAGE SPACINGS ENCOUNTERED IN INSTALLATIONS WHERE CORRECTION FOR MANUFACTURING DEVIATIONS IN CABLE CAPACITANCE IS THE PRINCIPAL PROBLEM.

(B) THESE VALUES ARE FOR THE APPROXIMATE AVERAGE SPACING OBTAINING IN INSTALLATIONS IN OLD UNDERGROUND PLANT WHERE RELATIVELY LARGE GEOGRAPHICAL IRREGULARITIES IN MANHOLE SPACINGS MAY BE ENCOUNTERED.

(2) THESE ATTENUATION LOSSES APPLY TO ENTRANCE CABLES WITH THE "C-SPACED" LOADING ARRANGEMENTS, DESCRIBED IN SECTION AB45.030, FOR USE IN CONNECTION WITH 8-INCH SPACED, NON-PHANTOMED, OPEN-WIRE LINES PROVIDING 0-31 KC. TRANSMISSION.

(A) THESE VALUES INCLUDE THE EFFECT OF MODIFIED CAPACITANCE BUILDING-OUT.

(B) THIS VALUE INCLUDES THE EFFECT OF OPTIMUM RESISTANCE BUILDING-OUT.

(C) THIS VALUE INCLUDES THE EFFECTS OF MODIFIED CAPACITANCE BUILDING-OUT AND OPTIMUM RESISTANCE BUILDING-OUT.

(3) THESE LOSSES BASED ON THEORETICAL LOAD SPACINGS IN TERMS OF CABLE PAIRS HAVING .062 MF. PER MILE. ALL OTHER VALUES IN TABLE 4 ARE BASED ON SPACINGS SHORTER THAN THEORETICAL - SEE PARAGRAPH 1.04 OF TEXT.

TABLE 5#

ATTENUATION LOSSES AT 1000 CYCLES OF CABLE FACILITIES DEVELOPED FOR USE AS INCIDENTAL CABLES IN TYPE J OPEN-WIRE CARRIER SYSTEMS

TYPE CABLE	TYPE LOADING	TYPE CIRCUIT	ATTENUATION LOSS DB PER SECTION AT 55° F
16-GAUGE, SHIELDED SPIRAL FOUR, DISC INSULATED	NONE	SIDE	0.083 (1)
		PHANTOM	0.091 (1)
	J-0.72 ON SIDES	SIDE	0.041 (1),(2)
		PHANTOM	0.055 (1),(2)
	J-0.85 ON SIDES	SIDE	0.041 (1),(2)
		PHANTOM	0.056 (1),(2)
	J-0.94 ON SIDES	SIDE	0.041 (1),(2)
		PHANTOM	0.056 (1),(2)
10-GAUGE PAPER INSULATED	NONE	NON-QUADDED PAIRS	0.052 (1) *

NOTES: (1) THESE ATTENUATION LOSSES ARE FOR 1000-FT. LENGTHS OF NON-LOADED CABLE, AND FOR (SIDE CIRCUIT) FULL-LOADING SECTION LENGTHS WITH ZERO BUILDING-OUT IN THE CARRIER LOADED D.I. CABLE. THESE THEORETICAL LENGTHS ARE 633 FT. FOR J-0.72 LOADING AND 648 FT. FOR J-0.85 AND J-0.94 LOADING.

(2) EFFECTS OF BUILDING OUT: THE ATTENUATION PER BUILT-OUT SIDE CIRCUIT LOADING SECTION IS APPROXIMATELY 0.5P PER CENT. BELOW THE THEORETICAL ATTENUATION, WHERE P IS THE SIDE CIRCUIT BUILDING-OUT PERCENTAGE. IN THE PHANTOM CIRCUITS THE ATTENUATION PER LOADING SECTION IS APPROXIMATELY 0.8P BELOW THE THEORETICAL VALUE FOR ZERO BUILDING OUT.

* PRELIMINARY VALUE BASED ON THE VERY LIMITED LENGTH OF THIS TYPE OF CABLE THUS FAR MANUFACTURED.

ALL DATA IN THIS TABLE ARE ADDED INFORMATION NOT INCLUDED IN PREVIOUS ISSUES OF THIS SECTION.

TABLE 6#

ATTENUATION LOSSES AND SECONDARY CONSTANTS OF
MISCELLANEOUS CABLE AND PAIRED CONDUCTOR FACILITIES
AT 1000 CYCLES

TYPE OF FACILITY		VALUES SHOWN ARE: PER UNIT LENGTH OF	AT TEMP. OF F°	DRY OR WET	PROPAGATION CONSTANT PER UNIT LENGTH	CHARACTERISTIC IMPEDANCE	ATTENUATION LOSS DECIBELS PER UNIT LENGTH
SUBMARINE CABLES - NON-QUADDED							
Single Paper Insulation	24 Gauge	Mile	55°	-	.2326 + j .2372	801 \44.2°	2.02
	22 "	"	"	-	.1945 + j .2012	594 \43.8°	1.69
	19 "	"	"	-	.1376 + j .1478	412 \42.7°	1.20
Double Paper Insulation	24 Gauge	"	"	-	.2412 + j .2460	772 \44.2°	2.10
	22 "	"	"	-	.2009 + j .2078	575 \43.8°	1.75
	19 "	"	"	-	.1419 + j .1525	399 \42.7°	1.23
	16 "	"	"	-	.08564 + j .09939	316 \40.5°	.74
17 GAUGE U WIRE							
U Bridle Wire		Kilofoot	68°	Wet	.0257 + j .0314	260 \39°	.22
U / UA Distribution Wire (Buried)	Non-Loaded	Mile	"	"	.137 + j .153 (A)	265 \39° (A)	1.19** (A)
					.143 + j .161 (B)	255 \39° (B)	1.25 (B)
	Loaded ∅	"	"	"	.0667 + j .391 (A)	530 \7°* (A)	.58** (A)
					.0692 + j .412 (B)	510 \7°* (B)	.60 (B)
DROP WIRES							
18 Gauge	TP Type	Kilofoot	68°	Wet	.0809 + j .0831	440 \44°	.70
	TR "	"	"	"	.0749 + j .0770	475 \44°	.65
17 Gauge	BP Type	"	"	"	.0579 + j .0608	335 \44°	.50
	BR "	"	"	"	"	"	"
14 Gauge	HC Type	"	"	"	.0218 + j .0292	140 \36°	.19
MISCELLANEOUS WIRES AND CABLES							
Inside Wiring Cable	22 Gauge	Kilofoot	68°	-	.05299 + j .05484	485 \44.0°	.46
Service Cables - 22 Gauge	CR Type	"	"	-	.04708 + j .04938	543 \43.7°	.41
	JR "	"	"	-	"	"	"
	LR "	"	"	-	"	"	"
	TR "	"	"	-	"	"	"
AL Wire	14 Gauge	"	"	Wet	.0191 + j .0272	160 \35°	.17
Bridle Wire	20 "	"	"	"	.0467 + j .0508	305 \43°	.41
Duct Wire / DU Station Wire	22 " / 22 "	"	"	"	.0569 + j .0601	400 \43°	.49
GN Station Wire	22 "	"	"	"	.0686 + j .0725	330 \43°	.60

∅ L-44 Loading, 8000-foot spacing.

* Mid-section iterative impedance.

** Value changed from previous issue.

(A) Initial values after one day soaking in water.

(B) Estimated values after five to ten years in ground, depending upon moisture conditions in soil.

\# All data in this table, except attenuation losses of U distribution wire under condition (A), are added information not included in previous issues of this Section.

TABLE 7#

PRIMARY DISTRIBUTED CONSTANTS OF CABLE AND MISCELLANEOUS PAIRED CONDUCTOR FACILITIES

Type of Facility	Values Shown Are: Per Unit Length Of	At Temp Of F°	Dry Or Wet	R (Loop) Ohms (DC)	L Henrys	G Mhos (1000 Cycles) (x10^-6)	C Farads (x10^-6)	G/C
NON-QUADDED EXCHANGE AREA CABLES								
26 Gauge — ST, AST	Mile	68°	-	440	.001	1.8	.069	26
26 Gauge — BST	"	"	-	"	"	2.1	.079	"
24 Gauge — M, SM, ASM, CSM	"	"	-	274	"	1.9	.072	"
24 Gauge — DSM	"	"	-	"	"	2.2	.084	"
24 Gauge — NM	"	"	-	"	"	1.7	.065	"
22 Gauge — SA, ASA, BSA, CSA	"	"	-	171	"	2.1	.082	"
22 Gauge — NA, ANA	"	"	-	"	"	1.9	.073	"
22 Gauge — TA	"	"	-	"	"	1.6	.062	"
22 Gauge — TS	"	"	-	"	"	1.7	.068	"
19 Gauge — BNB, CNB	"	"	-	85	"	2.2	.084	"
19 Gauge — TB, ANB, DNB	"	"	-	"	"	1.7	.066	"
16 Gauge — TH, NH	"	"	-	42	"	"	"	"
13 Gauge — TJ	"	"	-	21.4	"	"	"	"
SUBMARINE CABLES - NON QUADDED								
Single Paper Insulation — 24 Gauge	Mile	55°	-	266	.001	1.7	.066	26
Single Paper Insulation — 22 "	"	"	-	166	"	1.9	.075	"
Single Paper Insulation — 19 "	"	"	-	83	"	2.0	.078	"
Double Paper Insulation — 24 Gauge	"	"	-	266	"	1.8	.071	"
Double Paper Insulation — 22 "	"	"	-	166	"	2.1	.080	"
Double Paper Insulation — 19 "	"	"	-	83	"	2.2	.083	"
Double Paper Insulation — 16 "	"	"	-	41	"	1.7	.066	"
17 GAUGE U WIRE								
U Bridle Wire	Kilofoot	68°	Wet	10.3	.00033	*	.025	-
U, UA Distribution Wire (Buried)	Kilofoot	"	"	"	.00027	7.6	.023(A) .026(B)	328(A) 296(B)
U, UA Distribution Wire (Buried)	Mile	"	"	54	.0014	40.0	.122(A) .135(B)	328(A) 296(B)
DROP WIRES								
18 Gauge — TP Type	Kilofoot	68°	Wet	51	.00021	*	.042	-
18 Gauge — TR "	"	"	"	"	.00023	*	.036	-
17 Gauge — BP Type	"	"	"	28	.00022	*	.040	-
17 Gauge — BR "	"	"	"	"	"	*	"	-
14 Gauge — HC Type	"	"	"	5	.00025	*	.041	-
MISCELLANEOUS WIRES AND CABLES								
Inside Wiring Cable - 22 Gauge	Kilofoot	68°	-	37	.00020	*	.025	-
Service Cables - 22 Gauge — CR Type, JR ", LR ", TR "	"	"	-	37 **	.00027**	*	.020**	-
AL Wire — 14 Gauge	"	"	Wet	5	.00029	*	.033	-
Bridle Wire — 20 Gauge	"	"	"	21	.00028	*	.036	-
Duct Wire — 22 Gauge; DU Station Wire — 22 Gauge	"	"	"	33	.00030ø	*	.033 ø	-
GN Station Wire — 22 Gauge	"	"	"	"	"	*	.048 ø	-

* Leakage conductance at 1000 cycles is negligible as compared with capacitive susceptance.

ø These values are satisfactory for pairs, triples or quads.

** These values may be applied to both one and two pair cables.

(A) Initial values after one day soaking in water.

(B) Estimated values after five to ten years in ground, depending upon moisture conditions in soil.

\# All data in this table are added information not included in previous issues of this Section.

TABLE 8#

SECONDARY CONSTANTS OF EXCHANGE AREA CABLE FACILITIES AT 1000 CYCLES

CABLE		LOADING	PROPAGATION CONSTANT AT 68°F		CHARACTERISTIC IMPEDANCE ∮ AT 68°F
GAUGE	CODE		PER MILE	PER KILOFOOT	
26	ST AST	NL	.3072 + j .3105	.05818 + j .05881	718 - j 706 = 1007 ∠44.5° *
		B-175	.1084 + j .9354	.02053 + j .1772	2204 - j 251 = 2218 ∠6.5°
		B-135	.1207 + j .8223	.02286 + j .1557	1929 - j 281 = 1949 ∠8.3°
		B-88	.1492 + j .6713	.02826 + j .1271	1567 - j 344 = 1604 ∠12.4°
		D-175	.1286 + j .7739	.02436 + j .1466	1848 - j 299 = 1872 ∠9.2°
		D-135	.1434 + j .6824	.02716 + j .1292	1618 - j 332 = 1652 ∠11.6°
		D-88	.1747 + j .5644	.03309 + j .1069	1325 - j 403 = 1385 ∠16.9°
		H-135	.1615 + j .6030	.03059 + j .1142	1440 - j 383 = 1490 ∠14.9°
		H-88	.1940 + j .5049	.03674 + j .09563	1192 - j 453 = 1275 ∠20.8°
		H-44	.2375 + j .4062	.04498 + j .07693	949 - j 552 = 1098 ∠30.2°
		M-135	.1880 + j .5153	.03561 + j .09759	1257 - j 460 = 1338 ∠20.1°
		M-88	.2196 + j .4424	.04159 + j .08379	1057 - j 525 = 1180 ∠26.4°
26	BST	NL	.3287 + j .3322	.06225 + j .06292	672 - j 660 = 942 ∠44.5°
		B-175	.1160 + j 1.0009	.02197 + j .1896	2060 - j 235 = 2073 ∠6.5°
		B-135	.1292 + j .8799	.02447 + j .1666	1802 - j 263 = 1821 ∠8.3°
		B-88	.1596 + j .7183	.03023 + j .1360	1464 - j 322 = 1499 ∠12.4°
		D-175	.1376 + j .8281	.02606 + j .1568	1727 - j 280 = 1750 ∠9.2°
		D-135	.1534 + j .7302	.02905 + j .1383	1512 - j 310 = 1544 ∠11.6°
		D-88	.1869 + j .6039	.03540 + j .1144	1238 - j 376 = 1294 ∠16.9°
		H-135	.1728 + j .6452	.03273 + j .1222	1346 - j 358 = 1393 ∠14.9°
		H-88	.2076 + j .5403	.03932 + j .1023	1114 - j 423 = 1192 ∠20.8°
		H-44	.2541 + j .4346	.04813 + j .08231	887 - j 516 = 1026 ∠30.2°
		M-135	.2012 + j .5514	.03811 + j .1044	1174 - j 430 = 1250 ∠20.1°
		M-88	.2350 + j .4734	.04451 + j .08966	988 - j 490 = 1103 ∠26.4°
24	M SM ASM CSM	NL	.2467 + j .2513	.04672 + j .04759	558 - j 542 = 778 ∠44.2° *
		B-175	.0722 + j .9504	.01367 + j .1800	2155 - j 155 = 2161 ∠4.1°
		B-135	.0794 + j .8344	.01504 + j .1580	1880 - j 171 = 1888 ∠5.2°
		B-88	.0998 + j .6757 *	.01890 + j .1280	1515 - j 216 = 1530 ∠8. ° *
		D-175	.0849 + j .7844	.01608 + j .1486	1800 - j 186 = 1810 ∠5.9°
		D-135	.0941 + j .6887	.01782 + j .1304	1566 - j 209 = 1580 ∠7.6°
		D-88	.1165 + j .5613 *	.02206 + j .1063	1264 - j 257 = 1290 ∠11.5°
		H-135	.1063 + j .6035	.02013 + j .1143	1386 - j 239 = 1407 ∠9.8°
		H-88	.1309 + j .4945 *	.02479 + j .09366	1123 - j 292 = 1160 ∠14.6°
		H-44	.1682 + j .3763	.03185 + j .07127	844 - j 372 = 922 ∠23.8°
		M-135	.1254 + j .5066	.02375 + j .09595	1187 - j 294 = 1223 ∠13.9°
		M-88	.1513 + j .4212	.02866 + j .07977	968 - j 345 = 1028 ∠19.6° *
24	DSM	NL	.2664 + j .2715	.05045 + j .05142	517 - j 503 = 721 ∠44.2°
		B-175	.0780 + j 1.0266	.01477 + j .1944	1996 - j 143 = 2001 ∠4.1°
		B-135	.0858 + j .9013	.01625 + j .1707	1741 - j 158 = 1748 ∠5.2°
		B-88	.1078 + j .7298	.02042 + j .1382	1402 - j 200 = 1416 ∠8.1°
		D-175	.0917 + j .8473	.01737 + j .1605	1667 - j 172 = 1676 ∠5.9°
		D-135	.1016 + j .7439	.01924 + j .1409	1450 - j 193 = 1463 ∠7.6°
		D-88	.1258 + j .6063	.02383 + j .1148	1170 - j 238 = 1194 ∠11.5°
		H-135	.1148 + j .6519	.02174 + j .1235	1284 - j 222 = 1303 ∠9.8°
		H-88	.1414 + j .5341	.02678 + j .1012	1039 - j 271 = 1074 ∠14.6°
		H-44	.1817 + j .4065	.03441 + j .07699	781 - j 345 = 854 ∠23.8°
		M-135	.1354 + j .5472	.02564 + j .1036	1099 - j 272 = 1132 ∠13.9°
		M-88	.1634 + j .4550	.03095 + j .08617	897 - j 319 = 952 ∠19.6°
24	NM	NL	.2342 + j .2388	.04436 + j .04522	588 - j 572 = 820 ∠44.2° *

THIS TABLE CONTINUED ON NEXT SHEET.

* Value changed from that in AB42.026, Issue 1.

∮ Mid-section iterative impedance in cases of loaded facilities.

\# All data in this table are added information not included in previous issues of this Section.

TABLE 8# (CONTINUED)

SECONDARY CONSTANTS OF EXCHANGE AREA CABLE FACILITIES
AT 1000 CYCLES

CABLE GAUGE	CABLE CODE	LOADING	PROPAGATION CONSTANT AT 68°F PER MILE	PROPAGATION CONSTANT AT 68°F PER KILOFOOT	CHARACTERISTIC IMPEDANCE ø AT 68°F
22	SA ASA BSA CSA	NL	.2065 + j .2134	.03911 + j .04042	416 - j 399 = 576 \43.8°
		B-175	.0503 + j 1.0155	.00953 + j .1923	2025 - j 92 = 2027 \2.6°
		B-135	.0549 + j .8900 *	.01040 + j .1686	1762 - j 102 = 1765 \3.3° *
		B-88	.0689 + j .7177	.01305 + j .1359 *	1414 - j 130 = 1420 \5.3°
		D-175	.0583 + j .8365	.01104 + j .1584 *	1694 - j 113 = 1698 \3.8° *
		D-135	.0647 + j .7325 *	.01225 + j .1387 *	1465 - j 125 = 1470 \4.9° *
		D-88	.0808 + j .5922	.01530 + j .1122	1170 - j 156 = 1180 \7.6°
		H-135	.0729 + j .6402	.01381 + j .1213	1298 - j 144 = 1306 \6.3°
		H-88	.0907 + j .5185 *	.01718 + j .09820 *	1036 - j 177 = 1051 \9.7°
		H-44	.1199 + j .3796	.02271 + j .07189 *	748 - j 233 = 783 \17.3° *
		M-135	.0863 + j .5333	.01634 + j .1010	1109 - j 178 = 1123 \9.1°
		M-88	.1060 + j .4341	.02008 + j .08222	879 - j 214 = 905 \13.7°
22	NA ANA	NL	.1946 + j .2012	.03686 + j .03811	442 - j 424 = 612 \43.8° *
22	TA	NL	.1792 + j .1853	.03394 + j .03509	479 - j 460 = 664 \43.8°
22	TS	NL	.1882 + j .1945	.03564 + j .03684	457 - j 438 = 633 \43.8° *
19	BNB CNB	NL	.1446 + j .1551	.02739 + j .02938	295 - j 273 = 402 \42.8°
		B-135	.0304 + j .900	.00576 + j .1705 *	1741 - j 52 = 1742 \1.7° *
		B-88	.0386 + j .725	.00731 + j .1373	1393 - j 69 = 1395 \2.8°
		D-175	.0321 + j .8457	.00608 + j .1602	1676 - j 58 = 1677 \2.0°
		D-135	.0349 + j .740	.00661 + j .1402 *	1448 - j 63 = 1449 \2.5° *
		D-88	.0439 + j .5957	.00831 + j .1128	1155 - j 81 = 1158 \4.0° *
		H-135	.0388 + j .6455	.00735 + j .1223	1281 - j 74 = 1283 \3.3° *
		H-88	.0487 + j .5194	.00922 + j .09837	1013 - j 92 = 1017 \5.2°
		H-44	.0645 + j .3701	.01222 + j .07009 *	713 - j 122 = 723 \9.7°
		M-88	.0568 + j .4302	.01076 + j .08148 *	854 - j 111 = 861 \7.4° *
19	TB ANB DNB	NL	.1282 + j .1375	.02428 + j .02604	333 - j 308 = 453 \42.8°
		B-175	.0254 + j .908	.00481 + j .1720	2237 - j 54 = 2238 \1.4° *
		B-135	.0270 + j .795	.00511 + j .1506	1951 - j 61 = 1952 \1.8° *
		B-88	.0342 + j .641	.00648 + j .1214	1563 - j 76 = 1565 \2.8° *
		D-175	.0282 + j .7461	.00534 + j .1413	1862 - j 65 = 1863 \2.0°
		D-135	.0310 + j .653	.00587 + j .1237	1618 - j 71 = 1620 \2.5° *
		D-88	.0390 + j .5269	.00739 + j .09979	1292 - j 91 = 1295 \4.0°
		H-175	.0315 + j .6507	.00597 + j .1232 *	1643 - j 75 = 1645 \2.6° *
		H-135	.0345 + j .5694	.00653 + j .1078	1423 - j 82 = 1425 \3.3° *
		H-88	.0432 + j .4590	.00818 + j .08693	1132 - j 103 = 1137 \5.2°
		H-44	.0571 + j .3282	.01081 + j .06216 *	799 - j 138 = 811 \9.8° *
		M-88	.0505 + j .3796	.00956 + j .07189 *	948 - j 123 = 956 \7.4° *
16	TH NN	NL	.0868 + j .1004	.01644 + j .01902 *	243 - j 208 = 320 \40.6°
		B-175	.0156 + j .908	.00295 + j .1720	2238 - j 30 = 2238 \0.8°
		B-135	.0158 + j .795	.00299 + j .1506	1951 - j 31 = 1951 \0.9°
		B-88	.0203 + j .641	.00384 + j .1214	1564 - j 44 = 1565 \1.6°
		D-175	.0168 + j .765	.00318 + j .1449	1824 - j 64 = 1825 \2.0°
		H-175	.0178 + j .6503	.00337 + j .1232	1648 - j 41 = 1649 \1.4°
		H-135	.0188 + j .5687	.00356 + j .1077 *	1419 - j 42 = 1420 \1.7° *
		H-88	.0238 + j .4577	.00451 + j .08669	1129 - j 55 = 1130 \2.8°
		H-44	.0307 + j .3249	.00581 + j .06153 *	791 - j 72 = 794 \5.2°
		M-88	.0271 + j .3773	.00513 + j .07146	934 - j 75 = 937 \4.6° *

* VALUE CHANGED FROM THAT IN AB42.026, ISSUE 1.

ø MID-SECTION ITERATIVE IMPEDANCE IN CASE OF LOADED FACILITIES.

\# ALL DATA IN THIS TABLE ARE ADDED INFORMATION NOT INCLUDED IN PREVIOUS ISSUES OF THIS SECTION.

TABLE 9#

INDUCTIVE REACTANCE OF LOADED FACILITIES
OHMS PER MILE AT 1000 CYCLES

TYPE LOADING	TYPE CKT. (1)	LOAD SPACING FEET	ωL OHMS PER MILE AT 1000 CYCLES (2)
A- 3	S	500*	205
		600*	172
A- 2.7	S	500*	185
		600*	156
B-175	S	3,000	1,942
B-135	S	"	1,499
B- 88	S	"	979
B- 50	P	"	557
B- 22	S	"	250
B- 15	S	2,800*	184
		3,000	172
	P	2,800*	182
		3,000	170
C- 4.8	S	685*	239
		800*	205
C- 4.1	S	685*	205
		800*	176
D-175	S	4,500	1,296
D-135	S	"	1,002
D- 88	S	"	655
E- 28	S	5,575	173
E- 16	P	"	99.6
E- 12.8	P	4,110*	108
		4,800*	92.9
F- 12.8	P	2,055*	211
		2,400*	181
F- 7.1	P	2,055*	119
		2,400*	103
F- 6.3	P	2,055*	106
		2,400*	91.5
H-250	S	6,000	1,389
H-248	S	"	1,378
H-245	S	"	1,361
H-175	S	"	974
H-174	S	"	968
H-172	S	"	957

TYPE LOADING	TYPE CKT. (1)	LOAD SPACING FEET	ωL OHMS PER MILE AT 1000 CYCLES (2)
H-155	P	6,000	861
H-154	P	"	856
H-135	S	"	753
H-106	P	"	590
H- 88	S	"	493
H- 63	P	"	353
H- 50	P	"	281
H- 44	S	"	250
H- 31	S	"	178
H- 28	S	"	161
H- 25	P	"	143
H- 22	S	"	128
H- 18	P	"	104
H- 16	P	5,600*	99.2
		6,000	92.9
H- 15	S	5,600*	95.2
		6,000	89.2
	P	5,600*	93.3
		6,000	87.3
J- 0.94	S	648**	60.3(2C)
J- 0.85	S	"	55.7(2C)
J- 0.72	S	630**	49.9(2C)
K-200	S	7,400	903
K-130	P	"	587
L- 44	S	8,000	191 (2D)
M-175	S	9,000	651
M-174	S	"	648
M-135	S	"	504
M-106	P	"	395
M- 88	S	"	331
M- 44	S	"	169
M- 25	P	"	96.6
R-133	S	11,600	387
S- 44	S	12,000	128
S- 25	P	"	73.5
X- 2.7	S	680	138
Y- 9	S	2,130	146

* These are modified spacings on carrier loaded entrance and intermediate quadded cable circuits - see Table 4 and Notes (1) and (2) thereunder.

** These are theoretical spacings on carrier loaded entrance and intermediate 16-gauge disc-insulated spiral-four cable circuits - see Table 5 and Note (1) thereunder.

(1) The letter S is used to designate both physical circuits and side circuits. The Letter P designates phantom circuits.

(2) These values include the following reactances introduced by the distributed inductance of the conductors:

(A) For all circuits designated S - except J-0.94, J-0.85 and J-0.72 which are covered by (C) below, and L-44 which is covered by (D) below -, an inductive reactance of 6.3 ohms per mile.

(B) For all circuits designated P, an inductive reactance of 4.4 ohms per mile.

(C) The values for J-0.94, J-0.85 and J-0.72. These values are for 16-gauge disc-insulated spiral-four cable and include an inductive reactance of 12.2 ohms per mile.

(D) The value for L-44. This value is for loaded U wire and includes an inductive reactance of 8.8 ohms per mile.

\# All data in this table are added information not included in previous issues of this Section.

TABLE 10#

ATTENUATION CORRECTION FACTORS

R/ωL	K	ΔK*	R/ωL	K	ΔK*	R/ωL	K	ΔK*	R/ωL	K	ΔK*	R/ωL	K	ΔK*
.001	.002154		.01	.00956		.1	.0735		1	.647		10	3.015	
		.001052			.00725			.0701			.468			1.356
.002	.003206		.02	.01681		.2	.1436		2	1.115		20	4.371	
		.000906			.00715			.0692			.360			1.027
.003	.004112		.03	.02396		.3	.2128		3	1.475		30	5.398	
		.000843			.00711			.0677			.297			.861
.004	.004955		.04	.03107		.4	.2805		4	1.772		40	6.259	
		.000806			.00709			.0661			.258			.756
.005	.005761		.05	.03816		.5	.3466		5	2.030		50	7.015	
		.000783			.00708			.0641			.230			.683
.006	.006544		.06	.04524		.6	.4107		6	2.260		60	7.698	
		.000768			.00707			.0621			.210			.626
.007	.007312		.07	.05231		.7	.4728		7	2.470		70	8.324	
		.000756			.00707			.0601			.194			.583
.008	.008068		.08	.05938		.8	.5329		8	2.664		80	8.907	
		.000749			.00706			.0579			.182			.547
.009	.008817		.09	.06644		.9	.5908		9	2.846		90	9.454	
		.000742			.00705			.0560			.169			.517
.010	.009559		.10	.07349		1.0	.6468		10	3.015		100	9.971	

* THE VALUES OF ΔK ARE TABULAR DIFFERENCES, AND HAVE BEEN PROVIDED TO FACILITATE INTERPOLATION BETWEEN THE TABULATED VALUES OF THE CORRECTION FACTOR K.

THIS TABLE PROVIDES ADDED DATA NOT INCLUDED IN PREVIOUS ISSUES OF THIS SECTION.