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The Institution of Post Office Electrical Engineers.

Introduction and Application of Transmission Performance Ratings to Subscribers' Networks

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G. A. E. FUDGE, A.M.I.E.E.

. A Paper read before the Edinburgh Centre of the Institution
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1. INTRODUCTION

For engineering reasons, the telephone network is subdivided into two parts, a local network connected to the exchange and a system of trunks and junctions interconnecting the exchanges. The degree of efficiency by which information can be passed between subscribers depends on the performance of each and all of the links in the chain of connections.

Before 1946, the performance of this chain was assessed on a volume efficiency basis whereby the degree of goodness or badness of the circuit was assessed by its comparative loudness. In the local network the loudness of the received speech from a particular connection was related to that of a standard reference circuit, comprising a Tele. No. 162, Bell Set No. 25 connected via a 300 ohm non-inductive resistance to a 22 volt C.B. repeating coil transmission bridge.

In 1946 it was decided to adopt a more realistic basis of assessing the effectiveness of speech transmission and, to date, it has been practicable to apply the principles only to the local networks associated with C.B. Manual and Automatic exchange areas. This basis of assessment is referred to as " Transmission Performance " and takes into account the relevant factors affecting the transmission of information. The application of this technique to the trunk and junction network has not yet been finally introduced, therefore its consideration has been excluded from the paper.

Although it is recognised that volume is by no means the only factor required for good transmission, the volume efficiency basis of assessment remains the standard of transmission for international telephony in the absence of a suitably agreed alternative.

2. TRANSMISSION PERFORMANCE

2.1. Definition

The term " Transmission Performance " has a qualitative meaning and is defined as follows :—

> " The transmission performance of a circuit is the effectiveness of the circuit for transmitting or reproducing speech in the circumstances in which it is used."

The expression " in the circumstances in which it is used " means that the transmission performance of a particular circuit is dependent not only on its components but also on the conditions of use at each terminal.

2.2. Controlling Factors

The factors affecting the transmission performance of a circuit, may be classified under two broad headings, as follows :—

(*a*) *The attenuation/frequency response of the complete circuit, including the telephone instrument.* The relative importance of the frequency bandwidth is well known. Frequencies below 1000 c/s are important in volume or loudness considerations and the components of speech in the higher frequency range above 1000 c/s are important from a quality viewpoint, since intelligibility depends almost wholly on them.

Faithfulness of sound reproduction within the band is relevant from the point of view of transmitting information over a telephone connection but the human ear will tolerate considerable departure from perfect reproduction.

(*b*) *Sidetone and room noise.* Received speech can be greatly impaired by extraneous sounds which are largely controlled by sidetone and room noise.

Sidetone to the one who is talking on a telephone means the reproduction of his own voice in his own receiver. If this is loud it causes him, subconsciously, to speak more quietly and thus make it more difficult for the listener at the other end. Conversely, if the reproduction is quiet, he will tend to speak louder than normal. This is referred to as the subscriber's reaction to sidetone.

Sidetone to the listener means the reproduction in his receiver of extraneous noises picked up by his transmitter, thus tending to mask or mar the received speech.

The above named factors are controllable and are considered in assessing values on a transmission performance basis. Assessments made on the volume efficiency basis disregard the important effects of sidetone, room noise and the full frequency response of the circuit, particularly as regards the effects of the higher frequency components. Thus, the transmission performance basis leads to a truer measure of the effectiveness of a connection.

The subscriber's behaviour (other than his reaction to sidetone), talker's volume, listener's hearing sensitivity, strangeness or unexpectedness of subject matter discussed, etc., which play an important part in a telephone call, are uncontrollable factors of which only average conditions are considered.

3. METHODS OF ASSESSMENT

The effectiveness of speech transmission cannot be measured in absolute units. It is assessed, in the first instance, by subjective tests, that is, by speech testing. This method of testing is essentially comparative. Many articles have been published on this subject and many forms of comparative tests have been tried out in the past, of which the following two are the most important.

3.1. Articulation Tests

The subjective test generally employed is the articulation test, whereby a speaker transmits logatoms, meaningless syllables, consisting of three sounds, consonant-vowel-consonant over a circuit and a listener (or listeners) record the sounds heard. The result of the test is computed as the percentage number of sounds correctly received, known as the percentage articulation. The speaker talks at a fixed distance from the transmitter and at a constant level as indicated by a speech voltmeter displayed before him. A fixed generated noise, at a constant level is injected by loudspeakers into the cabinet used for the tests.

For a given test condition, the percentage articulation is noted for different circuit attenuations, the latter being controlled by a non-reactive attenuator in the circuit. Having made a change in the test circuit it is desired to assess, the test is repeated. The difference between the two sets of attenuations, for the same percentage sound articulation—usually taken at 80 per cent.—will indicate the improvement or impairment in dbs. due to the change made. For example, from Fig. 1, assume curve A represents the percentage articulation/attenuation with noise present and curve B without the noise, then the difference between the curves at 80 per cent. articulation represents the impairment in dbs. caused by the noise. Conversely, improvements may be assessed in a similar manner.

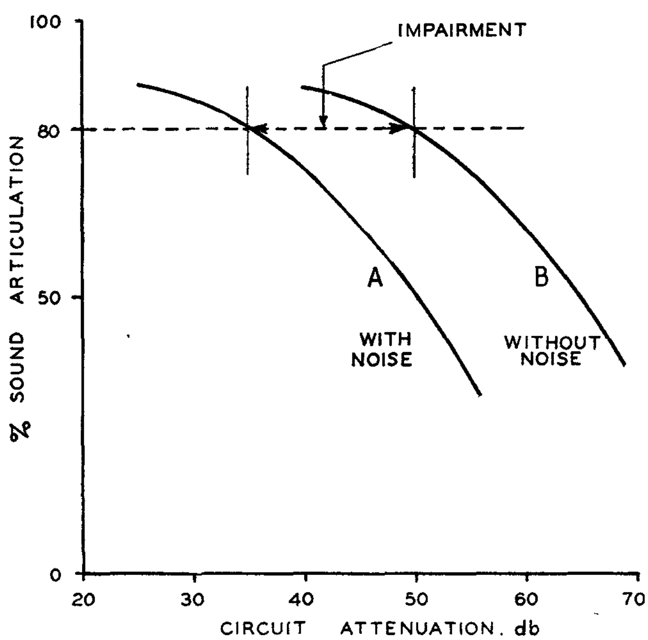


FIG. 1.—ARTICULATION TEST.

The comparative method of testing the controllable factors entails the use of a working reference circuit against which assessments are made. This circuit is known as the Standard Reference Circuit.

Some factors may, however, be calculated or measured from empirical data derived from subjective testing methods. For instance, the results obtained for impairment due to unloaded cables (other than feeding-current and sidetone effects) by articulation and repetition rate testing methods compare most favourably with those obtained by calculation and measurement of line attenuation at 1600 c/s. This latter and more simple method has been adopted for determining assessments of subscribers' lines with allowances made for sidetone and transmitter feeding-current effects.

3.2. Repetition Rate Tests

This test is based on the number of repetitions requested by subscribers in a telephone conversation, which are recorded by an official observer monitoring across the connection. By relating the repetitions observed in unit time, under differing conditions, comparisons of the two circuit conditions may be made.

Repetition rate testing is a method of testing quality of transmission actually provided for the subscriber under field conditions. The number of repetitions in a telephone conversation may be accepted as an indication of the inefficiency of the system. The practical application of the method, primarily statistical in nature, is however, most complex. Any one repetition may be caused by the inadequate nature of the equipment or by some limitation peculiar to one or both of the subscribers, such as deafness, lack of mental alertness, unexpected or complicated subject of discussion, etc., and thus a considerable number of observations must be made to reduce the effects of these characteristics, or uncontrollable factors, to a minimum. Requirements of secrecy necessitate that tests can only be carried out on official P.B.X.'s, thereby limiting the sphere of application.

Further, it is not possible to control the circuit condition. If the tests are carried out between official P.B.X.'s and the make up of the circuit is known, the important factors, room noise, talking volume are still unknown and only average values can be assessed. The main difference between articulation and repetition rate tests is that whereas each articulation test represents a single set of listening conditions, the repetition rate test is always the combined result of a large number of different conditions. The effect of each part of a circuit cannot be assessed by repetition rate tests and thus it does not facilitate the design and development of new equipment. Some more easily controllable laboratory test is essential for the purpose.

These are some of the reasons why this method of testing is not wholly employed by the B.P.O. in the assessment of Transmission Performance Ratings.

4. STANDARD REFERENCE CIRCUIT

The assessments made by articulation tests are relative to the transmission performance of the standard reference circuit. This circuit has been arbitrarily agreed to represent the condition for the worst permissible grade of transmission. A subscriber's line which compares unfavourably with this circuit is considered to have a transmission performance below standard

The criteria of a reference circuit suitable for assessments on a transmission performance basis, are :—

(i) It must be practical, that is, it must contain all items of plant which contribute to the effects requiring investigation, such as, sidetone paths, subscriber's line, transmission bridges, transmitters and receivers.

(The fact that the volume reference circuit contains a non-inductive 300 ohm line immediately rules it out as being unsuitable for side tone and frequency response comparisons.)

(ii) It must link up with the past, that is, bear a relationship with the international standard reference circuit which is, at present, assessed on a volume basis.

A practical level of room noise and speaker's volume is specified for use with the reference circuit. The reference circuit consists of Tele. No. 162, Bell Set No. 25 with a line having a resistance of 450 ohms (2.557 miles) of 10 lb. cable on a 50 volt, 200+200 ohm non-ballast automatic exchange transmission bridge. It will be appreciated that this circuit is used as a reference standard only and thus it is unnecessary to change the components whenever such components become non-standard provision.

5. COMPONENTS OR CHARACTERISTICS OF SUBSCRIBERS' LINES

The components or characteristics of a subscriber's circuit affecting the controllable factors may be subdivided under five headings, the salient points which arise are :—

(i) *Telephone Instrument.* The transmitter, receiver, induction coil and capacitor are the components concerned with transmission. The frequency characteristics of the transmitter and receiver have a considerable bearing on the overall quality performance of the circuit. The induction coil matches the transmitter to the line and the line to the receiver to obtain optimum transference of energy, and its performance will have a large effect on the sending and receiving efficiency as well as the sidetone behaviour of the instrument.

The non-linear current output of present transmitters causes harmonics of the lower speech frequencies to mask the higher frequencies present and so give rise to distortion. Receivers are practically free from non-linear distortion.

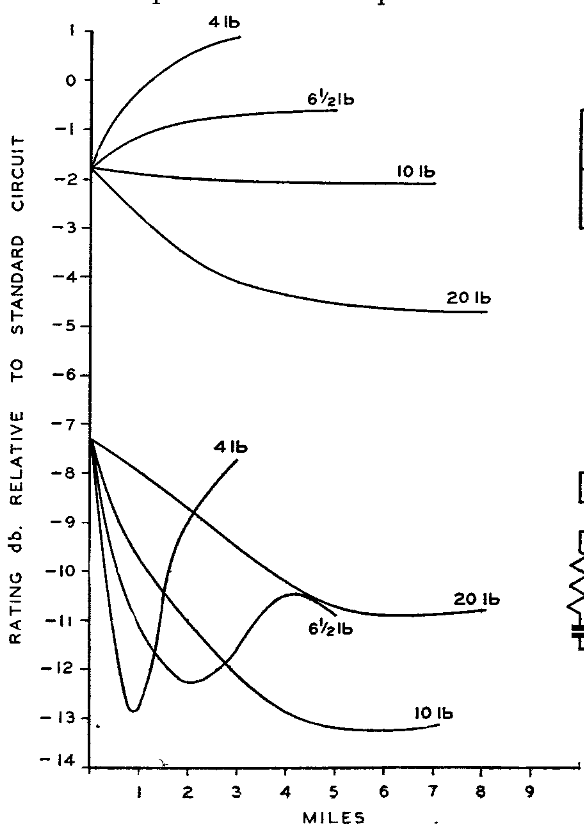
(ii) *Transmitter Feeding Current,* or the operational current of the transmitter, affects, to a large extent, its output performance. The magnitude of the current will depend on the line and apparatus resistance and the exchange or local battery voltage.

(iii) *Speech transmission loss* of the exchange transmission bridge which allows for the attenuation/frequency characteristic of the type used.

(iv) *Sidetone Effect.* This effect depends on :—

(*a*) The efficiency of the receiver and transmitter, the latter being dependent on the feeding current effect mentioned in (ii) above.

(*b*) The impedance of the line which forms one arm of the A.S.T.I.C. bridge network. As the impedance varies according to the length and composition of the line, the efficiency of the bridge network and hence, the degree of sidetone suppression will also vary. Fig. 2 shows the sidetone efficiency of a Tele.



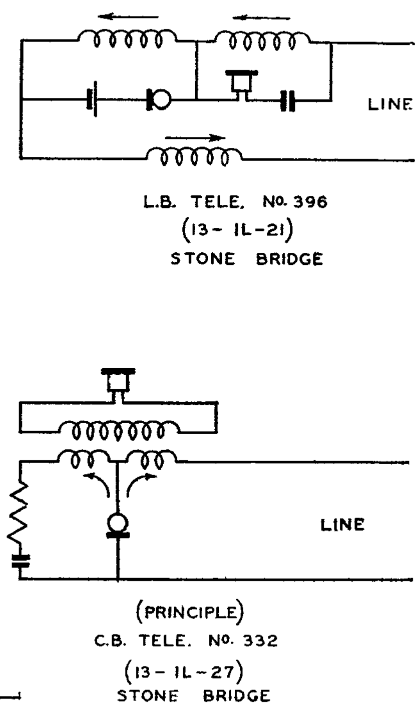


Fig. 2.—Sidetone Rating

No. 332 (Transmitter No. 13, Recr. No. 1L, Ind. Coil No. 27) connected to a Stone type bridge from which the degree of sidetone suppression for various conductor gauges and lengths may be seen. The sidetone characteristics of a local battery Tele. No. 396 (Xmtr. No. 13, Recr. No. 1L, Ind. Coil No. 21) which does not include an anti-sidetone arrangement, are illustrated in the same figure. These two characteristics show the wide differences of sidetone performance between the two instruments.

(*c*) The subscribers' reaction to the presence of sidetone and room noise. Some idea of the magnitude of the sidetone effect may be gathered from Fig. **3**, derived from tests made with subscribers' instrument 13—1L—18.35 and room noise 60 phons,

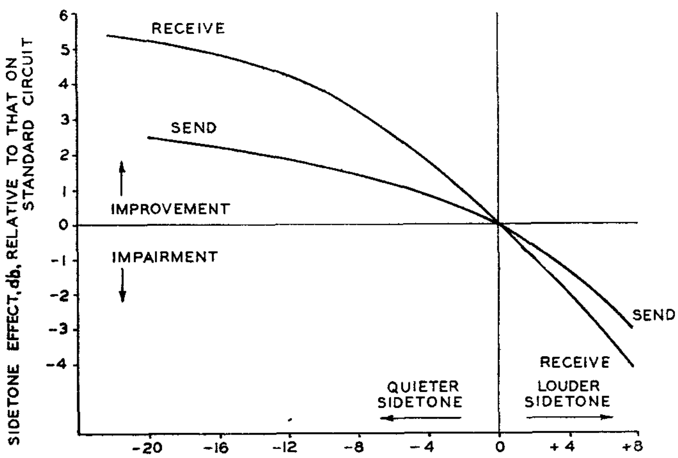


FIG. 3.—SIDETONE EFFECT. SEND AND RECEIVE.

continuous spectrum. Other conditions being equal, a change in sidetone rating shown in Fig. **2** will result in a similar change in sidetone level. Assuming a condition where the sidetone level is reduced, that is, quieter sidetone, at the talker's end, then curve SEND shows there will be an improvement in sidetone effect (sending) due to the talker subconsciously raising his voice and consequently improving the reception at the listener's end.

Assuming again quieter sidetone at the listener's end, curve REC shows the improvement in sidetone effect (receiving) due to the lessening of the masking effect of room noise.

The precise effect will depend on the impedance of the line network and feeding current conditions.

(v) Speech transmission loss of the line, that is, the loss taking into account the attenuation/frequency characteristic of the line. The magnitude of this loss depends on the type, length and conductor gauge employed. Fig. **4** shows the attenuation with frequency of the conductors commonly used in the local line network, and the attenuation per mile at 1600 c/s accepted to represent the speech transmission loss of an unloaded line.

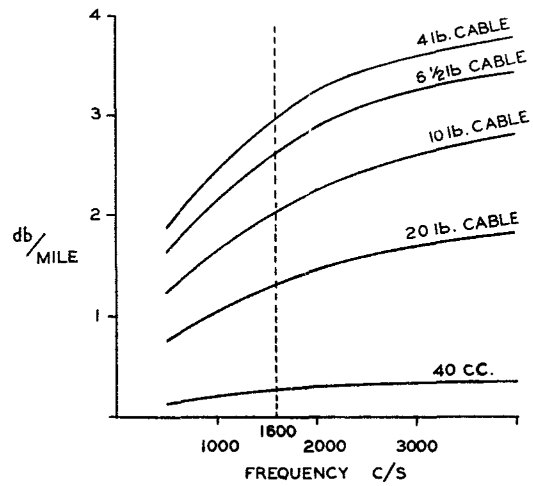


FIG. 4.—ATTENUATION/FREQUENCY CABLE CHARACTERISTICS.

6. TRANSMISSION PERFORMANCE RATINGS

6.1. Definition

For a particular combination of line, instrument and bridge, db values of improvements or impairments may be assigned to each item, as compared with its counterpart in the standard reference circuit. Improvements are assigned positive values and impairments negative values. These values are known as the Transmission Performance Ratings of the item concerned. Similarly, sidetone and feeding current effects are assigned positive or negative db values appropriate to the particular circumstances.

The term "transmission performance rating" has, therefore, a QUANTITATIVE meaning and is defined as follows :—

"The transmission performance rating of telephone equipment (includes line plant) : The loss, constant at all frequencies transmitted, which it is necessary to add to, or remove from, a specified reference circuit, so as to give the same transmission performance when the equipment is added to, or used to replace the whole or the appropriate part of the reference circuit."

6.2. Comparison of Subscriber's and Junction Line

The factors affecting the transmission performance of a subscriber's line in contrast with that of a junction are illustrated in the following example.

Consider a junction made up of 10 lb. cable connected via a 50V non-ballast exchange bridge to a subscriber's line comprising a Tele. No. 162 and 10 lb. cable. If the junction circuit is increased by one mile of 10 lb. cable, the additional loss is 2.0 db., that is, the T.E. at 1600 c/s as derived from primary constants or based on power ratios. If, on the other hand, the subscriber's line is increased from two to three miles of 10 lb. cable not only is there an additional loss due to the T.E. of the cable but the sidetone and feeding current effects have been altered and thus an additional allowance must be made for these. In this example, the overall additional impairment in the sending direction will be 3.1 db. and in the receiving direction 1.2 db., made up as follows :—

Sending direction :

(*a*)	Speech transmission loss (T.E. at 1600 c/s)	impairment	- 2.0 db.
(*b*)	Feeding current effect	,,	- 1.5 ,,
(*c*)	Sidetone effect	improvement	+0.4 ,,
	Overall additional impairment		- 3.1 ,,

Receiving direction :

(*a*)	Speech transmission loss (T.E. at 1600 c/s)	impairment	- 2.0 db.
(*b*)	Sidetone effect	improvement	+0.8 ,,
	Overall additional impairment		- 1.2 ,,

It is therefore apparent that the effect of a similar change of component in the junction and subscriber's line will not present the same transmission impairment or improvement in the connection. This example emphasises that the transmission performance of the line plant portion of a subscriber's circuit takes account not only of the physical component concerned but also of its effects on other components of the circuit. In this example, had the subscriber's line been increased by one mile from any other section length than two to three miles, the sidetone effect and consequently the overall impairment would normally be different.

6.3. Rating and Line Limits of complete connection

Full details of the method of compiling the rating and enumerating the line limits of a subscriber's circuit are given in I.P.O.E.E. Journal, Vol. 39, Part 4 and Vol. 40, Part 1. Briefly it may be described as follows. For a particular subscriber's circuit, the telephone instrument, bridge, line, feeding current and sidetone effects are assigned db values of impairments or improvements in relation to similar components or characteristics of the reference circuit. The algebraic sum of the values, appropriate for a given direction of transmission, will indicate the transmission performance rating of the particular combination of bridge, line and telephone. By retaining the same telephone instrument and bridge, and varying the length and composition of the line, a series of values are obtained for the sending and receiving direction of transmission from which the limiting line length for various types of lines may be derived.

Fig. **5** shows typical standard characteristic curves for a Tele. No. 332 (induction coil No. 22) on a 50V non-ballast Stone bridge. The line lengths for zero dbs., which are equivalent to the performance of the reference circuit represent the permissible transmission limit in the sending and receiving directions. The lesser of the two limits for one type of line is accepted as the transmission limit of that type of line for the particular make up of the circuit. For simplicity in practice, the limiting line lengths are usually expressed in their resistance values, in ohms.

7. LINE LIMITS SELECTED FOR APPLICATION

There are numerous types of instruments, bridges and conductor gauges in the local line network, and for every combination, there will usually be a different permissible limit. Obviously, a system of averaging the different limits to produce a workable scheme, without at the same time losing seriously on economics of plant provision, is desirable.

7.1. C.B. Telephones

In order to avoid any need for discrimination as to whether a Tele. No. 162, 232 or 332 (plus induction coils Nos. 22, 24 and 27) is to be used and to simplify the application, a single limit has been selected for all types of C.B. telephones. The limits quoted for a given type of conductor gauge and bridge includes therefore, an allowance for instruments irrespective of the type used. The limits published are slightly lower than the best obtainable with Tele. No. 332 and Ind. Coil No. 27 to allow for the large number of older type instruments still in use.

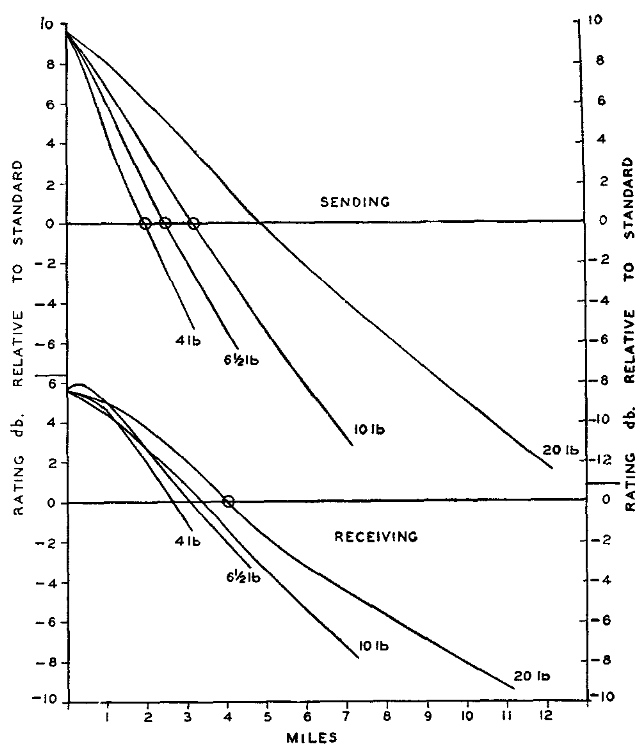


Fig. 5.—Transmission Performance Ratings. Tele. 332 (13-1L-22). 50v. Non-Ballast Bridge

7.2. Exchange Transmission Bridge

All common types of transmission bridge have been classified under four basic types, namely :—

22V C.B. Repeating Coil.
40V C.B. Stone 200+200 ohm relay.
50V Auto. non-ballast 200+200 ohm relay.
50V Auto. ballast 50+50 ohm relay.

There is one set of limits for each of the four main types.

As would be expected the higher exchange voltage results in a greater feeding current and consequently better performance. Likewise, the replacement of the 200+200 ohm relay by 50+50 ohm relay with ballast resistor, ensures a higher feeding current for the more distant subscribers and thus a higher working limit is obtained under these circumstances.

7.3. Transmission Line Limits

The wide differences between line limits applicable to different conductors preclude further compromise. To summarise, there are four sets of limits for the main types of bridge with individual limits for the overhead and underground conductor gauges, while the limits apply to all types of instrument. Fig. **6** shows these limits in ohms and miles together with the old volume limits for these standard types.

It will be seen that for the lighter gauge conductors, the limits are higher than the old volume limits, thus permitting economies in cable and duct space to be made by greater use of lighter gauge conductors. For heavier gauges (20 lb. cables and over) the limits are lower, or worse, than the old volume limits. For a given length, a heavy gauge conductor will always give better results than a lighter gauge. Long lines, which are only encountered in heavy gauges, have a high capacitance and this adversely affects sidetone. Consequently, limits based on transmission performance ratings taking into account sidetone are lower, or worse, than the limit based on the old volume ratings which ignores sidetone characteristics. The circumstances when extended limits are applied are enumerated later.

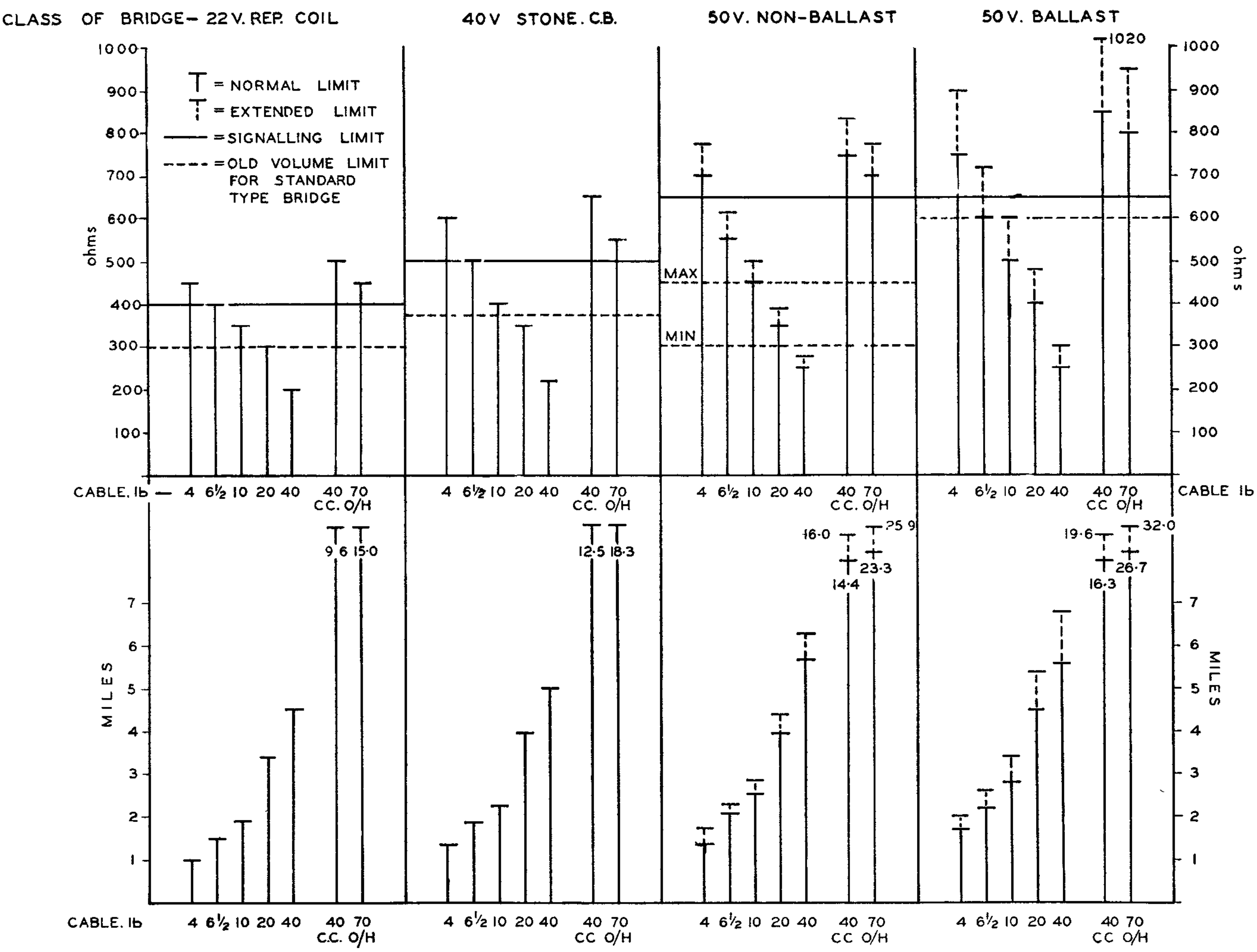


FIG. 6.—MILEAGE AND RESISTANCE LIMITS FOR D.E.L s.

7.4. Signalling Line Limits

Besides the transmission limits it is necessary to consider the signalling limits which exchange lines are designed to meet. The signalling limits for the respective types of bridge are shown in Fig. **6**. As a general rule, the transmission limit is the overriding factor for all subscriber's lines made up of 6½ lb. or heavier cable conductors. The use of comparatively long lengths of aerial wire or 4 lb. cable would tend to make the signalling limit the overriding factor.

Apart from the four main types of bridge there are a few cases when the transmission and signalling limits are not correlated, that is, the signalling and transmission exchange batteries are not identical.

8. TRANSMISSION EQUIVALENT RESISTANCE (T.E.R.)

Lines in the local network are usually composed of several lengths of different types. It has therefore been essential to evolve a simple means of expressing the overall performance of such lines. This has necessitated some approximation, the main points of which are :—

(i) The disregarding of reflection losses at the junctions of differing conductor gauges.

(ii) That the transmission loss of a length of any uniform conductor in a line of mixed gauges is identical with the loss of a similar length of the same conductor in a limiting line of the gauge, and is independent of the order in which the sections are connected.

It is therefore accepted that all gauges having resistance values which represent the same proportion of their respective limiting resistances will afford the same grade of transmission. Consider Fig. **7** (points of equal transmission performance, 50V ballast bridge). Lines of limiting resistance values 750 ohms 4 lb. ; 600 ohms 6½ lb. ; 500 ohms 10 lb. ; 400 ohms 20 lb. ; have an equal grade of transmission. It follows therefore that lines of half, quarter or any ratio of the limiting resistance values also have an equal grade of transmission.

Thus, from a transmission aspect, it is possible to consider all lines on a common basis and to express all types of local line conductors in terms of one particular gauge of conductor. The datum or reference gauge arbitrarily selected is 6½ lb. cable. The resistance of each gauge is expressed in terms of an equivalent resistance of 6½ lb. cable of same grade of transmission. The resistance value obtained is termed the Transmission Equivalent Resistance (T.E.R.).

The T.E.R. of a line is defined as the resistance of a 6½ lb. line of the same grade of transmission and is expressed in ohms. From Fig. **7**, the T.E.R. of the limiting resistance values for all gauges is 600 ohms, *i.e.*, the limiting resistance of 6½ lb. Likewise the T.E.R. of half the limiting resistance values, 375 ohms 4 lb. ; 250 ohms 10 lb. ; 200 ohms 20 lb. is 300 ohms, *i.e.*, equivalent resistance of half the limiting resistance of 6½ lb.

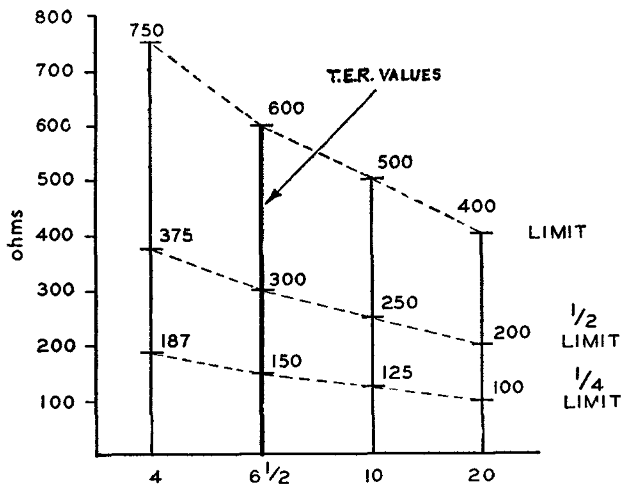


FIG. 7.—POINTS OF EQUAL TRANSMISSION 50*v*. BALLAST BRIDGE.

It may therefore be deduced that :—

(i) For each type of line of limiting resistance, a single T.E.R. value, known as the T.E.R. limit may be quoted for the four main types of exchanges, as follows :—

Table 1 *T.E.R. Limits.*

22V C.B. Rep. Coil	400 ohms.	50V Non-ballast (extended limit 610 ohms)	550 ohms.
40V C.B. Stone	500 ohms.	50V Ballast (extended limit 720 ohms)	600 ohms.

(ii) When dealing with lines composed of several lengths of different types, the T.E.R. of the whole line is assessed as the sum of the T.E.R. values of the component uniform lengths. The value so obtained is compared with the T.E.R. limit of the exchange area concerned.

(iii) When equipment, such as a P.B.X. installation, is introduced into a line and the transmission loss of the equipment can be related to an equivalent loss of 6½ lb. cable, its loss can be quoted as a T.E.R. value, in ohms.

(iv) The T.E.R. (in ohms) per mile of each gauge for the four transmission bridges may be evaluated. These values are shown in Table 2.

The T.E.R. concept has considerably simplified design calculations. A similar approach could be made with mileage instead of resistance values.

9. DERIVATION OF T.E.R. VALUES

The T.E.R. value of a conductor pair may be derived by applying a multiplying factor to its d.c. resistance. For example, in the previous illustration (Fig. **6**) for 50V ballast exchange, the limiting resistance of 20 lb. cable is 400 ohms and the limiting resistance of 6½ lb. cable (T.E.R. value) 600 ohms. Thus, the multiplying factor is in the ratio of 600 : 400, *i.e.*, 1.5. Multiplying the d.c. resistance of any length of the 20 lb. cable by 1.5 will give its T.E.R. value, in ohms.

Multiplying factors and tables for converting the mileage or ohmic resistance to T.E.R. values for all gauges associated with the four main types of bridge, are given in Engineering Instructions.

Slide rules have been specially designed to simplify the calculations involving mileages, ohmic resistances and T.E.R. values of local line plant. The principle of the slide rule is the converse of the previous illustration ; the scale lengths of the limits for each cable gauge are made equal and thus points of equal transmission performance are represented by upright parallel line (cursor line) on the scales as shown in Fig. **8**.

Fig. **9** shows a photograph of a typical slide rule. The resistance or mileage of any type and conductor

TABLE 2.

Exchange Type.	T.E.R. (ohms per mile).						
	4 lb.	6½ lb.	10 lb.	20 lb.	40 lb.	40 lb. Cd. CU.	70 lb. Cd. CU.
22V C.B.	391	270	201	117	88	42	27
40V C.B.	367	270	220	126	100	40	27
50V Non-ballast Auto	346	270	215	138	97	38	24
50V Ballast Auto ...	352	270	211	132	106	37	23

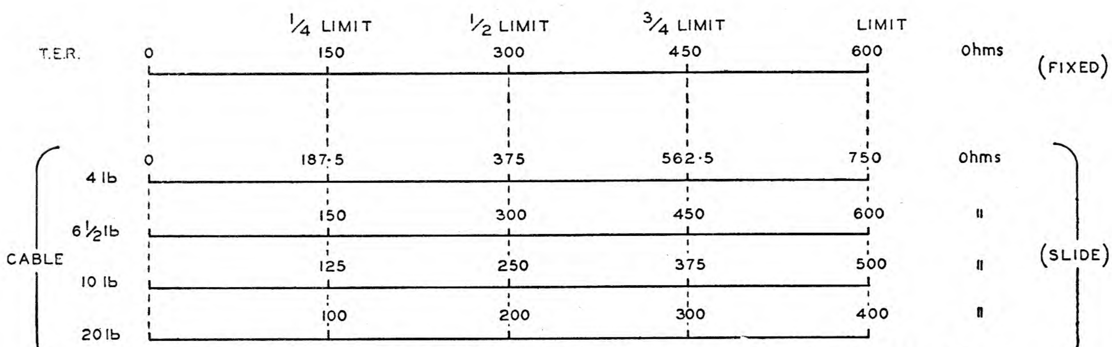


FIG. 8.—PRINCIPLE OF SLIDE RULE. LINES OF EQUAL TRANSMISSION. 50V. BALLAST BRIDGE.

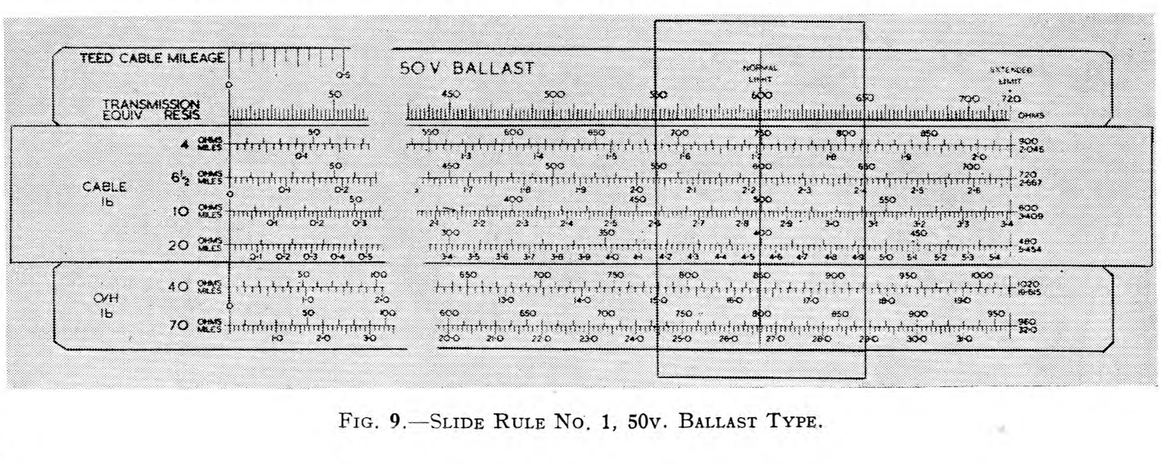


FIG. 9.—SLIDE RULE NO. 1, 50V. BALLAST TYPE.

gauge can be read on the T.E.R. scale and, by manipulating the slide, the T.E.R. of mixed gauges can be readily summated and compared with the limit. Limits for bunched pairs and allowances for teed pairs are also shown on the slide rule. There is one slide rule for each of the four main types of exchange.

10. MULTIPLE TEED NETWORKS

In a multiple teed network the unused end of the teed connection remains disconnected.

The effect of a teed connection is the introduction of a capacitance across the line to which it is teed, thereby introducing a transmission loss. For all types of local cable, the capacitances per unit length are approximately the same. The amount of loss introduced is therefore accepted as independent of conductor gauge and directly proportional to the length of the teed element or elements. The additional loss per mile of teed cable for the four types of transmission bridge is shown in the following table :—

TABLE 3.

Transmission Bridge Type.	T.E.R. (ohms/mile).
22V C.B.	80
40V C.B.	100
50V Non-ballast	110
50V Ballast	110

With a 50V ballast bridge, the loss per mile is 110 ohms (T.E.R.) ; for half a mile, 55 ohms (T.E.R.) and so on, irrespective of conductor gauge. Teed aerial lines introduce negligible transmission loss.

11. BUNCHED CONDUCTORS

The above presupposes that the two A wires and the two B wires of the pairs are bunched at each end so that the crosstalk may be reduced to a minimum. By this means the shunt capacitance of the bunched pairs will be doubled and the resistance halved.

The factors affecting the transmission performance of bunched pairs are as follows :—

(*a*) *Speech Transmission Loss.* The increase in attenuation due to the doubling of the capacitance, the decrease in attenuation due to the halving of the resistance, and the reflection losses due to the reduction of line impedance combine to give the speech transmission loss of the bunched conductors. For 4, 6½ and 10 lb. cables the resultant loss is slightly greater than for a similarly composed single pair.

(*b*) *Feeding Current.* Increase in feeding current due to reduced loop resistance improves the transmission.

(*c*) *Sidetone.* Change of impedance at the terminals of the subscriber's instrument will result in a degradation of sidetone suppression, especially for the heavier conductor gauge cables where the impedance of bunched conductors is very low.

The transmission effects of bunched conductors are summarised in Fig. **10.** It will be seen that the advantages to be gained by bunching, from a transmission aspect, are limited. There is no gain in bunching 10 lb. cable and the bunching of 20 lb. or heavier conductor gauges introduces a serious transmission loss. The more important application of bunching is to enable lines within the transmission limit to conform with the signalling limit.

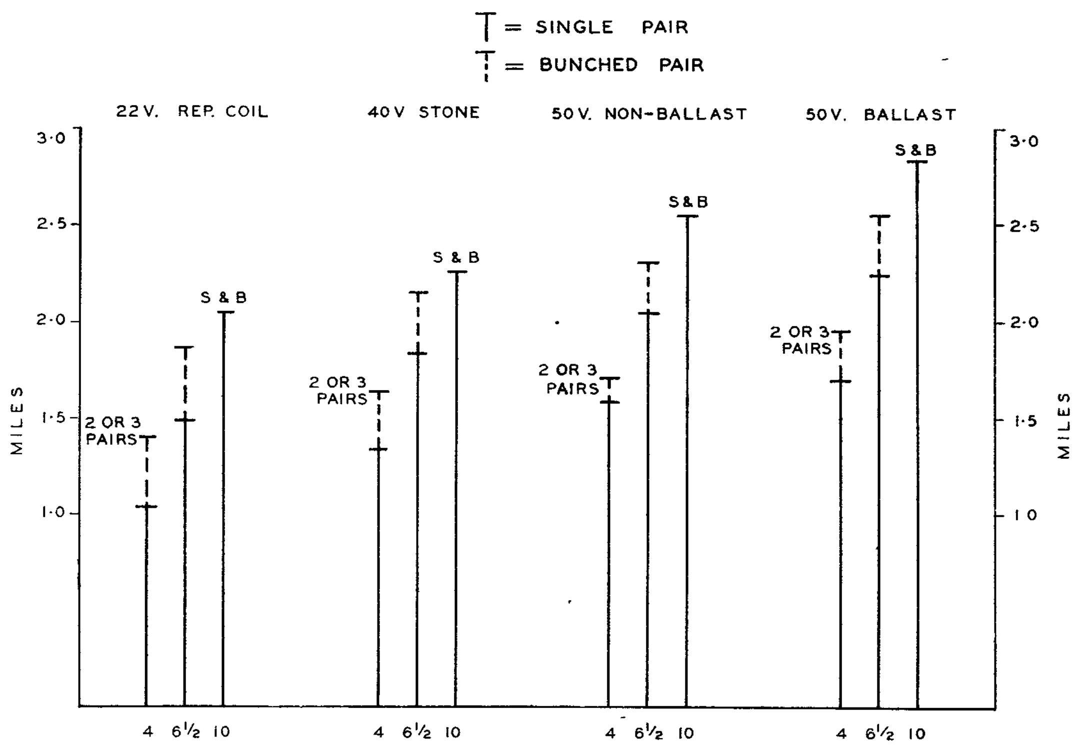


FIG. 10.—MILEAGE LIMITS FOR SINGLE AND BUNCHED PAIRS.

12. LOADED SUBSCRIBERS' LINES

Loading affects three factors in the assessment of transmission performance, namely :—

(*a*) *Speech Transmission Loss.* Due to the large mismatch which occurs at both ends of comparatively short lines, the speech transmission loss of loaded subscribers' lines (88mH/2000 yards) is considerably greater than the calculated attenuation at 1600 c/s of the loaded line. Although the cut-off frequency is raised by reducing the loading coil spacing to 1000 yards it does not appreciably decrease the insertion loss.

(*b*) *Feeding Current.* The change in feeding current due to the resistance of loading coils is negligible.

(*c*) *Sidetone Effect.* The impedance of the loaded line presented to the anti-sidetone network of the telephone departs considerably from that for which the network is designed. Consequently the suppression is slight, but, beyond about two sections, it is independent of line length.

Improvement in performance could be effected by a more suitable sidetone balance in the telephone or by the inclusion of a matching transformer at the subscriber's termination.

Fig. **11** shows the transmission limits for various loaded, 88mH/2000 yards, and unloaded cables connected to a 50V non-ballast exchange with Tele. No. 332. From the graph it will be seen that for 6½ and 10 lb. cable, the loading is not effective until the line length is beyond the limit for the unloaded line. For 20 lb. cable a small advantage is obtained, while for loaded 40 lb. cable the limit is approximately double that for unloaded.

In view of the practical difficulties and costs involved, it is doubtful whether, apart from exceptional circumstances, the loading of subscribers' lines is a worthwhile proposition.

13. LOCAL BATTERY TELEPHONES

The performance of the common type of L.B. Tele. No. 396, incorporating Ind. Coil No. 21 and 2 cells, compares most unfavourably with modern C.B. telephones. The inferior sidetone characteristics of the L.B. telephone in comparison with those for C.B. Tele. No. 332 have been described earlier. With 3 cells, the higher sending output is offset by the resultant reduction in receiving efficiency due to its poor sidetone performance. In consequence, the permissible line limits, with the exception of those for 20 lb. cable, are lower than those possible using 2 cells.

The foregoing assumes a transmitter of average resistance, 70 ohms. The resistance of the transmitter for L.B. telephones is of paramount importance as, apart from battery voltage, it mainly determines the magnitude of the feeding current. From a transmission point of view, a low resistance transmitter of about 20 ohms with 2 cells will give the same output as the average transmitter with 3 cells.

A small number of L.B. telephones have been developed incorporating an anti-sidetone induction coil No. 25. The sidetone efficiency of this instrument is comparable with that of a C.B. telephone and thus with 2 cells and average transmitter, the line limits are higher than those for the No. 21 induction coil. With 3 cells and average transmitter (or 2 cells with low resistance transmitter) a noticeable improvement in output is attained with only a slight reduction in

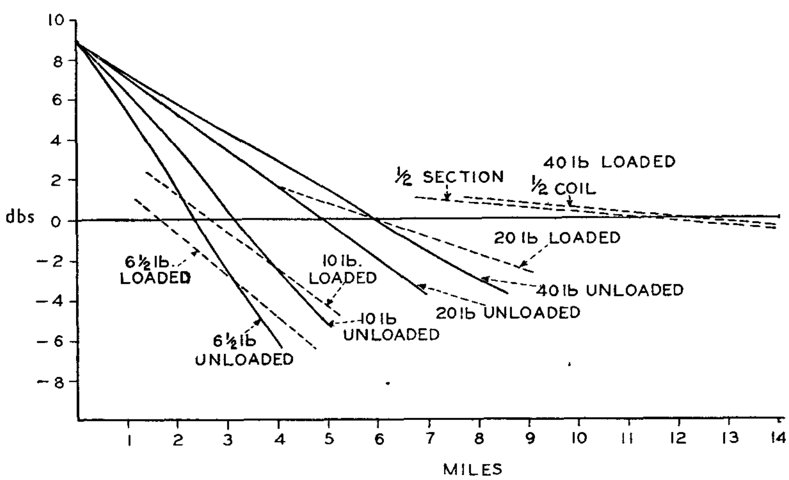


FIG. 11.—LOADED SUBSCRIBERS' LINES.
LOADING 88/1.136 HALF-SECTION TERMINATIONS.
50V. NON-BALLAST BRIDGE. TELE. 332 (13-1L-27).

receiving efficiency, the net result being considerably higher line limits.

As the transmitter feeding current is independent of exchange voltage, only limits for Stone and repeating coil exchange bridges need be considered. The limits for instruments using Induction Coil No. 21 and No. 25 with 2 and 3 cells are shown in Fig. **12**.

The L.B. telephone with coil No. 21 is restricted in C.B. and Auto Exchange areas to P.B.X. extensions, etc., where it may be advantageous to consider the use of a lower resistance instrument, namely 50 ohms, for signalling purposes, in spite of its poor transmission performance. Coil Induction No. 25, incorporated in Bell Set No. 38, is difficult to supply and is not available generally.

14. PLANNING AND ROUTING OF D.E.L.'s AND EXTERNAL EXTENSIONS

14.1. Direct Exchange Lines

The conductor gauge chosen for cable routes in the local line networks is the most economical, or lightest gauge, which will ensure that the T.E.R. and d.c. signalling resistance of the subscribers' lines do not exceed the transmission and signalling limits. The network is thereby built up of large size light gauge cables adjacent to the exchange and small size heavier gauge cables near the boundary. The T.E.R. and d.c. resistance of a route is calculated from the exchange M.D.F. to the distribution point, disregarding the overhead section unless it exceeds four spans.

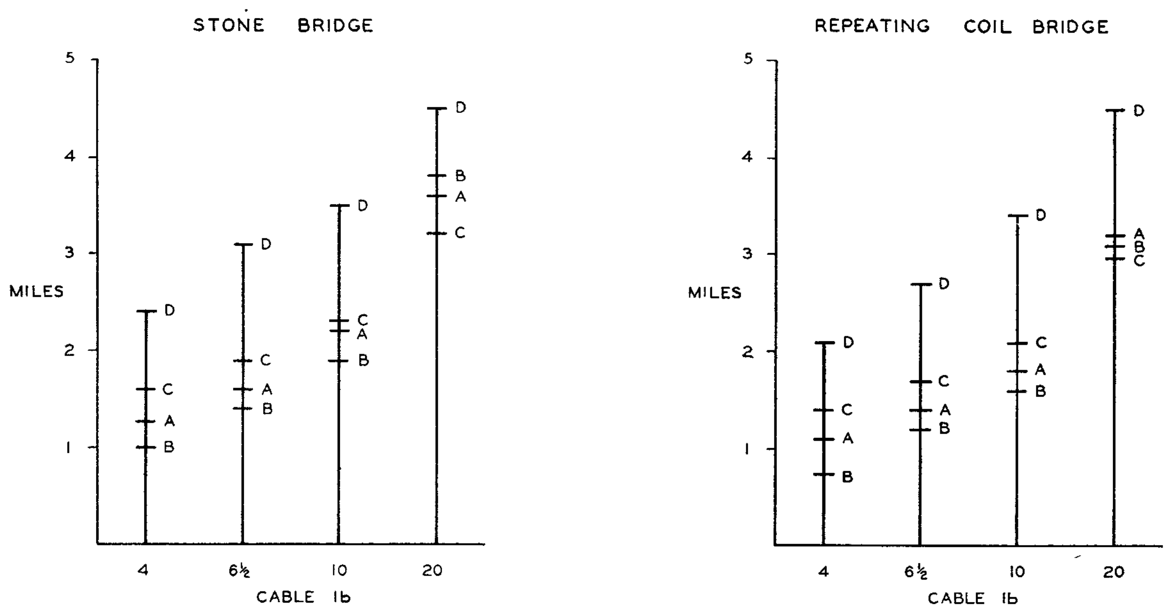
In a few instances, existing plant planned on the old volume efficiency limits will exceed the new Transmission performance limits, in which case the plant is brought up to date as the opportunity arises. Partly to overcome such difficulties, especially in rural areas where cables may be of considerable length, a second or extended limit for automatic exchanges has been introduced. The extended limits are only applied in the following circumstances :—

(*a*) Where cables of 2.8 miles or more in length are necessary in scattered or U.A.X. areas in country districts.

(*b*) Where, for minor extensions of plant, existing main cables would need to be replaced to bring the line within the normal limit.

There are no extended limits for manual exchanges as the use of the most efficient instrument gives only a slight improvement on the normal limits.

The planning engineer is presented with the problem of designing a line network to cover the greatest distance with the minimum conductor gauge taking into account anticipated plant development. Generally the lightest conductor gauge selected will result in the T.E.R. value of the route being slightly less than the T.E.R. limits, allowing for possible future provision. Transmission problems are numerous, but the following will serve to indicate the method of dealing with a more difficult problem involving mixed conductors.



A Ind. Coil No. 21 (Non-ASTIC) 2 cells average transmitter
B ,, ,, ,, ,, ,, 3 ,, ,, ,, *
C ,, ,, ,, 25 (ASTIC) 2 ,, ,, ,,
D ,, ,, ,, ,, ,, 3 ,, ,, ,, *
* or 2 cells and low resistance transmitter

FIG. 12.—MILEAGE LIMITS FOR L.B. TELEPHONES.

Fig. 13(*a*) shows part of the plant layout for a U.A.X. rural area (existing O/H plant and cable sizes have been omitted for clarity). It is proposed to replace the overhead route by underground or aerial cable and, therefore, it is necessary to calculate the most economical combination of conductor gauges which will satisfy the transmission and signalling limits for this type of exchange. As the length of route in the exchange area is greater than 2.8 miles, it is reasonable to apply the extended limit of 610 ohms (T.E.R.).

	Miles.	*Sig.Res. (ohms).*	*T.E.R. (ohms).*
Existing—			
10 lb. cable	.8	141	171
40 lb. O/H	.49	25	18
		166	189
Limits		(Sig) 650	(Trans) 610
Limits of replacing conductor	2.3	484	421

The conversion of mileage or d.c. resistance to T.E.R.(ohms) may be computed by the use of multiplying factors, ready reckoners or the whole of the T.E.R. calculations may be carried out by using the appropriate slide rule. It is necessary to find the most economical conductor gauge for a route 2.3 miles in length having a loss of 421 ohms (T.E.R.). As 2.3 miles of 10 lb. cable equals 494 ohms (T.E.R.) and 2.3 miles of 20 lb. cable equals 318 ohms (T.E.R.) a mixture of 10 lb. and 20 lb. will satisfy the condition.

From Table 2 : 1 mile 10 lb.=215 ohms (T.E.R.)
1 mile 20 lb.=138 ohms (T.E.R.)

The T.E.R. of X miles of 10 lb. and (2.3—X) miles of 20 lb. should equal 421 ohms, *i.e.*

$$215X+138\,(2.3-X)=421$$
$$\therefore X=1.35 \text{ miles}$$

	T.E.R.(ohms)	Sig. R.(ohms)
1.35m 10 lb.	=290	238
.95m 20 lb.	=131	83
	421	321

This is the only exact T.E.R. solution, and as the signalling condition is also satisfied, the route beyond Point A should be made up as shown in Fig. 13(*b*).

This solution presupposes that no further extension of the route, or further replacement of O/H plant by cable is contemplated in the near future, otherwise consideration is given at this stage to an increase in conductor gauge to allow for the later transmission and signalling requirements.

Many solutions for 2.3 miles of cable having 421 ohms (T.E.R.) could be found with a mixture

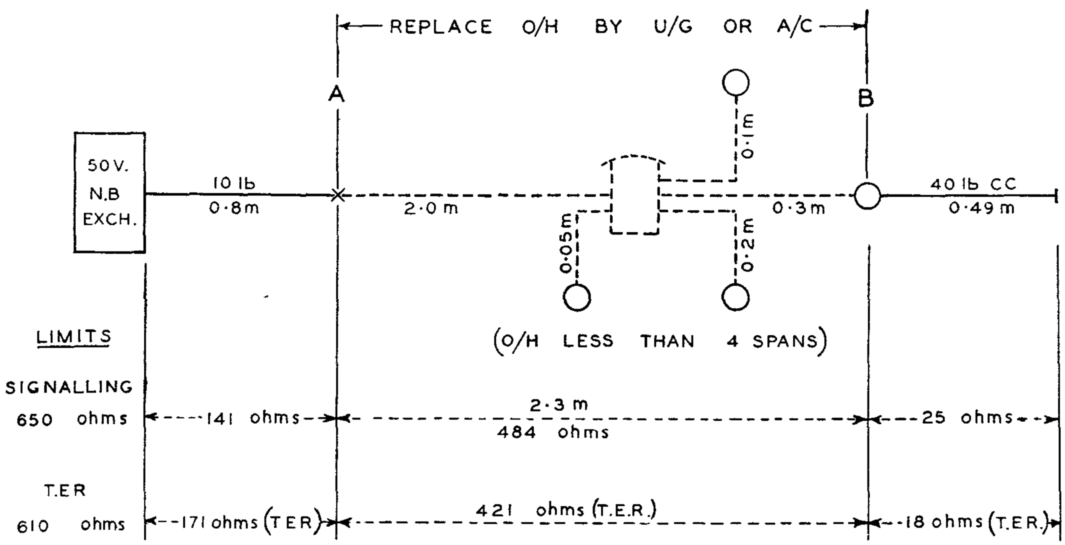


FIG. 13 (*a*).—GAUGE SELECTION—PROBLEM.

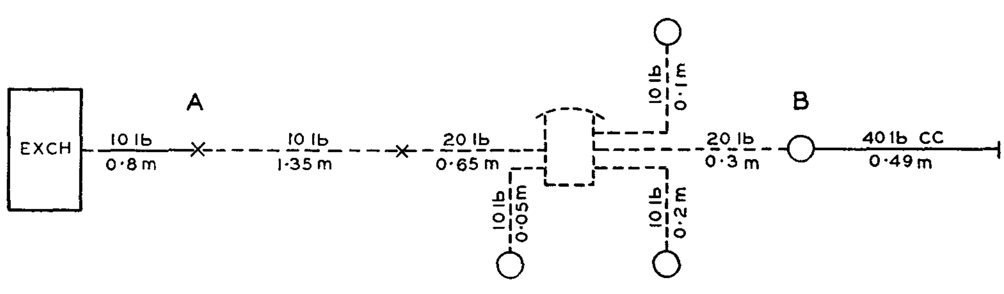
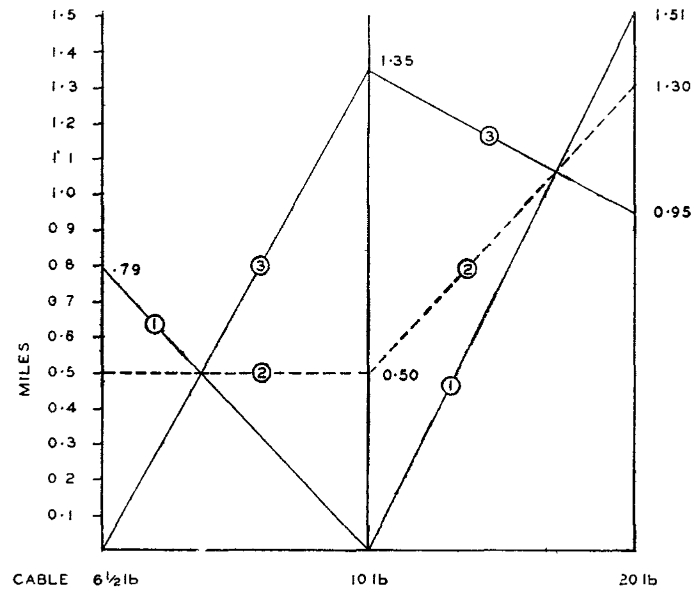


FIG. 13 (*b*).—GAUGE SELECTION—SOLUTION.

of $6\frac{1}{2}$, 10 and 20 lb. cables. By calculating firstly $6\frac{1}{2}$ and 20 lb. and secondly 10 lb. and 20 lb., the results may be depicted as shown in Fig. **14**. Lines drawn through the intersecting points will indicate the relative lengths of cables required to satisfy a mileage of 2.3 and 421 ohms (T.E.R.). Due to the very much greater cost of 20 lb. as compared with $6\frac{1}{2}$ and 10 lb. cable it will be realised that for a uniform size cable the cheapest solution will be the minimum length of 20 lb. which necessitates the maximum length of 10 lb. to the exclusion of $6\frac{1}{2}$ lb. For a tapered cable scheme, the relation between the cable costs is changed and it may then be economical to insert $6\frac{1}{2}$ lb. cable. The practical aspect of duct space, which may have a considerable bearing on the selection of conductor gauges, has been disregarded in this example.

It is possible that several cables of varying T.E.R. values may exist between, say, the exchange and cabinets, in which case, it may be advisable to reserve pairs in the cables having the lowest T.E.R. value for the furthest pillars and D.P.'s, leaving cables with the highest T.E.R. value for nearby D.P.'s. Networks are never designed with bunched conductors for subscribers' lines, except perhaps for the temporary needs of an exchange transfer.



EXAMPLES:—(1)	0.79 m	$6\frac{1}{2}$ lb	212	ohms	(T.E.R.)
	1.51 m	20 lb	209	,,	,,
	2.30 m		421	,,	,,
(2)	0.50 m	$6\frac{1}{2}$ lb	135	,,	,,
	0.50 m	10 lb	107	,,	,,
	1.30 m	20 lb	179	,,	,,
	2.30 m		421	,,	,,
(3)	1.35 m	10 lb	290	,,	,,
	0.95 m	20 lb	131	,,	,,
	2.30 m		421	,,	,,

FIG. 14.—THREE GAUGES FOR 2.3 MILES AND T.E.R. 421 OHMS.

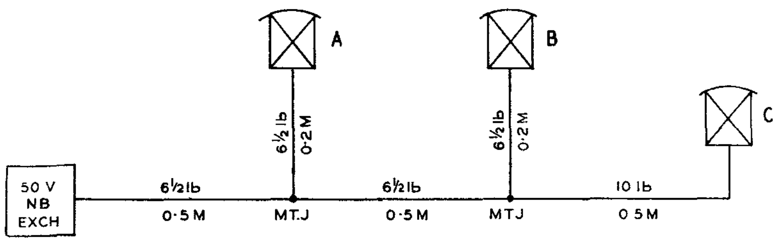
14.2. Multiple Teed Networks

In a multiple teed cable network the T.E.R. calculation of the route under consideration includes an allowance for the lengths of teed cable along the route. As shown in Fig. **15** and subsequent calculations, the lengths of the teed sections, and, consequently, the T.E.R. value for the same teed cable pair will differ at each cabinet.

(*c*) The effect on sidetone due to the changed impedance presented to the subscriber's instrument.

Each of these factors depends upon the length of the exchange and extension lines.

Transmission limits are imposed to ensure satisfactory calls between extensions on different P.B.X.'s via the public network. Transmission limits are not necessary for extension to extension calls on the same P.B.X. as such calls will be better than the allowance for the worst call over the public network.



T.E.R. Limit 550 ohms.

For teeing allowances—see Table 3.

FIG. 15.—MULTIPLE TEED NETWORK.

	T.E.R. (*ohms*).	*Amount in Hand Beyond Cabinet T.E.R.* (*ohms*).
CAB. A:		
Direct pair 0.7 m. 6½ lb.	189	
Teeing allowance 1.2 m.	132	
Total	321	229
CAB. B:		
Direct pair 1.2 m. 6½ lb.	324	
Teeing allowance 0.7 m.	77	
Total	401	149
CAB. C:		
Direct pair 1.0 m. 6½ lb.	270	
0.5 m. 10 lb.	108	
Teeing allowance 0.4m	44	
Total	422	128

15. PRIVATE MANUAL BRANCH EXCHANGES, AUXILIARY UNITS AND EXTENSION PLANS

15.1. P.M.B.X.'s.

The introduction of a P.M.B.X. between the exchange and subscribers instrument will necessarily affect the transmission performance of the circuit due to :—

(*a*) The insertion loss of the P.M.B.X. cord or connecting circuit.

(*b*) The alteration in the transmitter feeding current.

P.M.B.X.'s are normally designed with *exchange feed* cord circuits to provide for through dialling and through clearing on exchange to extension calls, and local feed on extension to extension calls. In the C.B. No. 10 type P.M.B.X. *local feed* cord circuits are provided, and therefore through clearing and through dialling are not practicable. Exceptionally, P.M.B.X.'s which normally provide for through dialling and through clearing may be modified for non-through clearing, but this is a non-standard facility.

For extension to extension calls on exchange feed P.M.B.X.'s the cord circuits may be sub-divided into :—

(*a*) Parallel feed where the transmitter feeding current to the extensions is fed in parallel from a single double-wound retardation coil, or

(*b*) Divided feed where the transmitter current to the extensions is fed via two distinct pairs of windings of relay or retardation coil.

For extension to extension calls on P.M.B.X.'s having local feed, the cord circuits function as divided feed.

As may be seen with all types of cord circuits, P.M.B.X.'s, extension plans, bunched pairs, L.B. telephones and auxiliary apparatus, innumerable combinations may be encountered. Appendix 1 has been compiled to show the transmission and signalling limits for various compositions of lines and equipment, applicable to the standard types of P.M.B.X.

15.1.1. *Exchange Feed Cord Circuits.*

A typical circuit is shown in Fig. **16**.

The switchboards included under this category are: C.B. 935 cordless type, C.B. 873 25 line cord board, A.T. 3796 65 line cord board, C.B. No. 9 and P.M.B.X. 1A.

The resistance of the series relay or indicator in the cord or connector circuit decreases the transmitter feeding current. The sum of the insertion loss and sidetone effect is, for all practical purposes, constant. The T.E.R. loss of the switchboards may, therefore, be regarded as constant for all types of exchange transmission bridge, and for any length of exchange and extension line within the prescribed limits. The actual location of the P.M.B.X. in the exchange to extension line is disregarded.

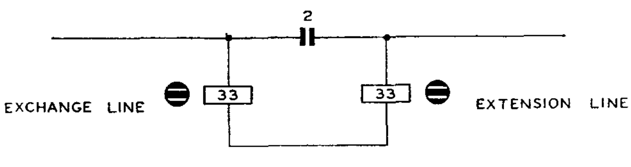


Fig. **16**.—Typical Exchange Feed Cord Circuit. Through Clearing.

The T.E.R. loss of these P.M.B.X.'s has been assessed at 50 ohms, with the exception of the P.M.B.X. 1A which is 100 ohms. In practice, the loss due to the P.M.B.X. is added to the loss of the exchange and extension lines in terms of T.E.R. values and for C.B. telephones the limits applicable are those for the direct exchange line in Table 1, excepting that for 50V ballast and 50V non-ballast the extended limits are used. For L.B. telephones, the total loss of the circuit is calculated in the same manner, but related to the exchange line limits for L.B. telephones, which are enumerated in Appendix 1.

15.1.2. *Local Feed cord circuits.*

A typical circuit is shown in Fig. **17**. The only standard switchboard of this type is the C.B. No. 10. In this case the predominating factor which influences the transmission performance is that the extension transmitter feeding current is dependent upon the local P.M.B.X. and not the exchange battery supply. Thus no standard T.E.R. loss can be formulated as the loss varies with the position of the switchboard in the exchange to extension line. With some combinations, when the P.M.B.X. is located near the limiting length, there is a gain in transmission by the insertion of the P.M.B.X. The limits for various combinations of exchange plus extension lines for Stone and repeating coil type bridges are given in Table 2, Appendix 1.

15.1.3. *Signalling Limits.*

Besides the transmission limits, the exchange line, extension line, and the exchange line plus extension line signalling limits need to be satisfied. Generally, it will be found, with standard P.M.B.X.'s that lines conforming to signalling limits will also conform to transmission limits. An exception is the C.B. No. 10 board. It is usually advisable to assess the signalling resistance before calculating the T.E.R.

15.2. Units A.A. No. 18 and CBS. No. 536

A method of overcoming signalling difficulties is the use of Units Auxiliary Apparatus No. 18 and CBS. No. 536, the latter may be used for exchange and extension lines in manual exchange areas. The Unit No. 18 is fitted on extensions only to increase the signalling limits for extension to extension working. The function of these units is: that by presenting to the cord circuit a loop resistance less than that of the C.B. telephone and line, the operation of the P.M.B.X. is made independent of the line resistance.

If the CBS. 536 unit is fitted either on the exchange or extension line, the extension transmitter feeding current becomes independent of the main exchange battery voltage, and the cord circuit in use becomes a local feed type with 22V battery supply. The T.E.R. loss introduced by this unit is, therefore, dependent upon the position of the P.M.B.X. in the exchange to extension circuit. In some positions, as

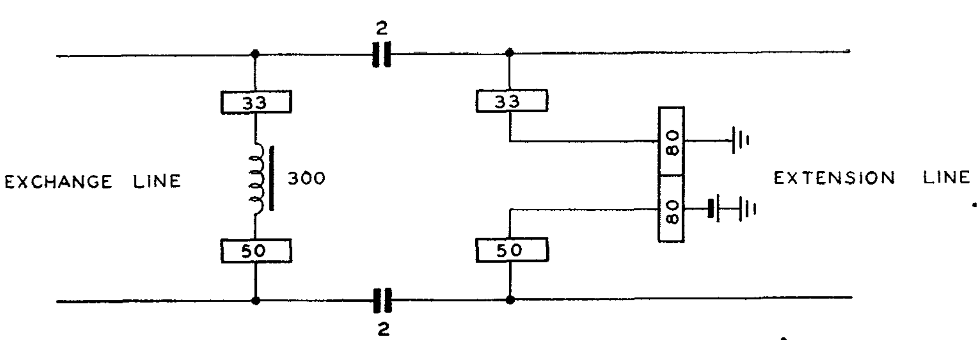


Fig. **17**.—Typical Local Feed Cord Circuit. Non-Through Clearing.

for the local feed cord circuit, there is a transmission gain. Fig. **18** shows the transmission and signalling limits for various combinations of exchange and extension lines where Units CBS. 536 and Units 18 are fitted at an A.T. 3796 (65 line cord board) installation. In these cases the signalling limit is generally restricted by the transmission limit.

15.3. Extension Plans

The transmission performance of extension plans with switching bell-sets and indicators in circuit at the main station is similar to that of the P.M.B.X. with exchange feed cord circuit, and thus the T.E.R. loss introduced is 50 ohms. The transmission performance of extension plans of the parallel connection type are the same as for the direct exchange lines and no additional loss is introduced.

16. ROUTING OF EXTERNAL EXTENSIONS

As external extensions must satisfy rather exacting transmission and signalling requirements, and as the local line network is not normally designed for their provision, the routing of long external extensions often presents considerable difficulties.

During an exchange call, an external extension routed via the exchange M.D.F. to the P.B.X. installation may be regarded as equivalent to three exchange lines in tandem. In this event, if either the P.B.X. installation or extension instrument required is located near the exchange boundary, it will normally not be possible to provide the circuit within transmission and signalling standards. In routing a long external extension, therefore, every advantage is taken of the flexibility afforded by cabinets, pillars and auxiliary joints to enable the shortest and heaviest gauge conductor route to be selected as desired. By these means, the T.E.R. and signalling resistance of the complete circuit may be reduced.

Other means in general use for improving the transmission and signalling performance of external extensions, assuming line plant is used to best advantage, are summarised as follows :—

(*a*) By raising the voltage supply at the P.B.X., or changing the cord circuits to divided feed working, to improve extension signalling condition.

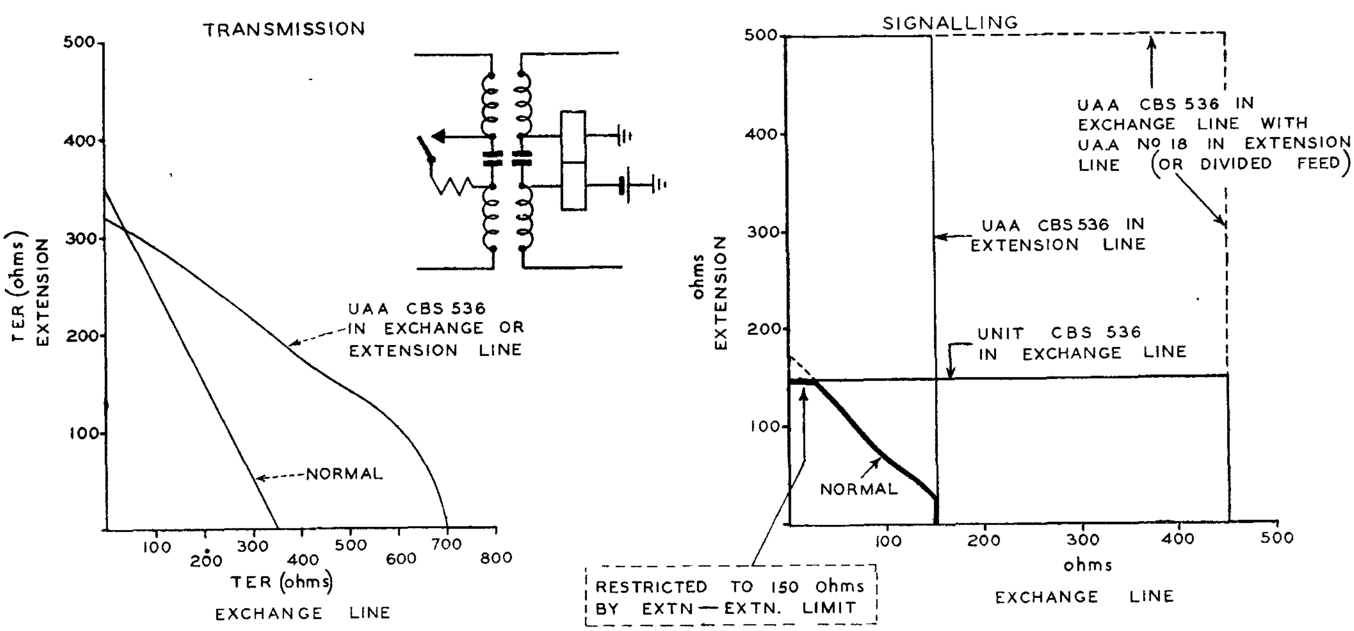
(*b*) By fitting U.A.A. No. 18 on the extension at the P.B.X. to improve extension signalling condition.

(*c*) By fitting U.A.A. CBS. 536(1) in exchange line to improve exchange line signalling condition (2) in extension line to improve extension line signalling condition. In some instances, transmission is improved. Dialling is not permissible through this unit.

(*d*) By fitting L.B. telephones of the non-ASTIC type (induction coil No. 21) at the extension to improve signalling conditions by 100 ohms. Transmission is adversely affected.

(*e*) By using bunched conductors of gauges up to 10 lb., to improve the signalling condition. Little or no improvement in transmission is obtained.

(*f*) By laying reasonable size link cables between cabinets, etc., to reduce length and resistance of circuit.



65 line board (Parallel feed). 24V supply. C.B.Teles.
22V Repeating Coil Bridge.

FIG. 18.—UNIT A.A. CBS 536. CONNECTED TO SWITCHBOARD A.T. 3796.

Where the number of external extensions and P.B.X. exchange lines on a cable route is large, heavier gauge cable than that normally required for direct exchange lines may be provided.

17. TESTING

It is not possible to measure the transmission performance of a subscriber's line in the field, nor is it possible to measure the T.E.R. To test the transmission efficiency, the test clerk may carry out only a speaking test based on personal judgment. This test may be very misleading. The d.c. resistance of the line is normally measured from the test desk to the protector or terminal block at the subscriber's premises and checked with the signalling limit. Transportable apparatus for the detection of transmission faults in subscribers' sets is under development.

18. POSSIBLE FUTURE IMPROVEMENTS

18.1. Direct Exchange Lines

On a long term basis improvements in transmission performance are likely to accrue from improved instrument design. Such instruments are anticipated to incorporate :—

(*a*) Transmitters and receivers of improved frequency response and linearity characteristics ; and

(*b*) A new induction coil with improved sidetone characteristics which may very well be achieved by line matching on a selective compromise basis.

The foregoing will meet the C.B. case whilst in the L.B. case some improvement may be expected from the general introduction of an L.B. anti-sidetone induction coil and low resistance transmitter.

18.2. External Extensions

The means, enumerated in para. 16, for improving the performance of external extensions still leaves places where long external extensions are required and transmission and/or signalling requirements cannot be satisfied. These cases may be few in number but each presents an acute problem. There appears to be an early and separate requirement for improving the performance of these circuits. A few of the possible means of effecting improvements which are under review at the time of writing or have been reviewed in the past are as follows :—

(*a*) *Composite Cables.* This proposal suggests that a few 40 lb. quads be included in the larger size P.C.U.T. type cables. The quads would be additional to the normal make up of the cable and restricted to the larger size cables between exchange and cabinets, and perhaps pillars ; but not included in the distribution network. The diameter of the composite cable would be slightly greater than a similar size P.C.U.T. but the interspersal of a few quads between the units would not present a difficult manufacturing problem and would, in fact, assist in forming a more even distribution of units within the sheath. This suggestion would improve signalling as well as transmission conditions.

(*b*) *L.B. Tele.* (*A.S.T.I.C. No.* 25 *Type*). A few of these instruments have been made, and as explained earlier, a considerable improvement in transmission is possible using 3 cells, as well as a reduction of 100 ohms in the signalling resistance.

(*c*) *Amplified Telephone.* An L.B. telephone in which the design of the induction coil gives a high sending efficiency at the expense of receiving efficiency. The loss in receiving efficiency is made good by the use of a single valve amplifier before the receiver. These instruments may cause cross talk in the line due to the high sending level and the amplified reception will no doubt allow line noise and cross talk to be more clearly heard. There are, however, signalling limit restrictions.

(*d*) *Amplified Circuits.* Improvements may be effected by means of 4-wire or 2-wire stabilised amplifiers installed either at the P.B.X. or at the exchange on through circuits. Amplifiers are hardly worthwhile for extensions where only a few db. gain is required.

(*e*) *Signalling Unit.* The question of introducing a new unit to replace the CBS. No. 536 is under consideration.

19. POSSIBLE ECONOMIES

19.1. Use of 4 lb. Cable

The use of 4 lb. cable would effect an economy of cable and duct space. The majority of subscribers in an exchange area operate at a point below half of the transmission limit. Furthermore, the replacement of manual exchanges by automatic exchanges with their higher limits results in a reduction in average T.E.R. There is, therefore, no objection from a transmission point of view to the introduction of 4 lb. cable, especially in city areas where the T.E.R. is less than average and the higher resistance of the 4 lb. is unlikely to approach the signalling limits. If 4 lb. cable is primarily reserved for subscribers near the exchange, leaving the existing heavier gauge cables for the more distant subscribers and external extensions, considerable amounts of 4 lb. cable could be inserted in the network. (Since this paper was read, the use of 4 lb. cable has been introduced.)

19.2. Relaxed Limits at Group Centres

An economy could be effected by relaxing the transmission limits for exchange lines attached to group centres due to their relative position within the trunk and junction network. The possible disbandment of group centre status and the lack of evidence that the present overall standard is so good that sacrifices can be made, are matters which discourage the adoption of the scheme. Further, signalling limitations would prevent a large advantage being obtained with relaxed transmission limits.

20. CONCLUSIONS

The new technique, introduced in 1946, for assessing the transmission performance of subscriber's lines, is a considerable advancement on the older method. Its introduction has enabled economies to be made as a result of improved instrument design, and has given the design engineer valuable data on which to design new equipment. To obtain such advantages, however, it has been necessary to sacrifice simplicity in the application of the assessments in the field. The multiplicity of circuit conditions, which are encountered in practice, and the changed transmission values of the plant involved, has resulted in a more complicated method of applying and maintaining the standard grade of transmission in the local line network.

ACKNOWLEDGMENTS

The author wishes to state that the basic transmission information contained in this paper has been deduced from Research Reports, and literature written by Mr. A. J. Jackman who has been responsible for the application of the technique. He wishes to express his thanks to Messrs. A. J. Jackman, D. L. Richards, C. J. Cameron, J. J. Perkins, R. G. Armstrong and his immediate colleagues in the L/LB Branch for their valuable assistance in the preparation of the paper.

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Appendix I.

TRANSMISSION AND SIGNALLING LIMITS FOR D.E.L.'s, P.B.X.'s AND EXTENSIONS PLANS. C.B. TELES.

IMPORTANT : LIMITS QUOTED FOR ONE CONDITION MAY BE OVERRIDDEN BY ANOTHER MORE STRINGENT REQUIREMENT

T.E.R. LIMITS :	22V Rep. Coil 400 ohms.	50V Non-ballast 550 ohms (normal), 610 ohms (extd. and applicable to Exchange+Extn. Condition).
(For D.E.L.'s and Exch. plus Extn. Conditions).	40V Stone 500 ohms.	50V Ballast 600 ohms (normal), 720 ohms (extd. and applicable to Exchange+Extn. Condition).

D.E.L., P.B.X. or Plan Number.	T.E.R. loss P.B.X. or Bell Set. (ohms) (*a*).	Signalling Limits (Loop Resistance in ohms). Exchange Line.				Exchange+Extension.				Extension.	
		22/24V C.B.	36/40V C.B.	48/50V N.B.&B.	60V S. 16	22/24V C.B.	36/40V C.B.	48/50V N.B.&B.	60V S. 16	Extension—Extension Conditions.	Extn. Line.
D.E.L. or Plan Nos. 1, 1A, 1B, 3, 4, 8, 11, 12 and 12A	—	400	500	650	650	400	500	650	650	—	—
Plan Nos. 5, 5A, 7 and 7A	50	350	450	600	600	350	450	600	600	—	—
C.B. 935 (Cordless Swbd.)	50	350 (*b*)	450	600 (*c*)	600	350 (*b*)	450	600 (*c*)	600	Min. 12V with inter-Swbd. or Genr. Sig. P.W. Min. 12V without Ditto. Min. 22V with Ditto. Min. 22V without Ditto.	100 300 400 1000
C.B. 873 (25 line cord swbd.)	50	350 (*b*)	450	600 (*c*)	600	350 (*b*)	450	600 (*c*)	600	Min. 12V Min. 22V Div. Feed Cd. Cts.	50 150 500
A.T. 3796 (65 line cord swbd.) C.B. No. 9	50	150 (*b*)	200	400 (*c*)	350	← See Table 1 →				Parl. Feed. Cd. Cts. Min. 12V Parl. Feed. Cd. Cts. Min. 22V Div. Feed Cd. Cts.	100 150 500
P.M.B.X. 1A	100	250 (*b*)	400	600 (*c*)	600	350 (*b*)	450	600 (*c*)	600	Without Line Relay With Ditto	200 300

NOTES.

(*a*) Where applicable, T.E.R. loss quoted should be added to T.E.R. of exchange plus extension lines.

(*b*) For C.C.1 exchanges with 75+75 ohms exchange apparatus resistance, these figures are reduced by 50 ohms.

(*c*) For exchanges having 250+250 ohms exchange apparatus resistance, e.g., U.A.X. No. 5 and 6 these figures are reduced by 100 ohms.

(*d*) When coils Bridging No. 6(*c*) exists at C.B. 10 P.B.X., figures are reduced to 200 ohms.

Appendix I. *(continued)*

TRANSMISSION AND SIGNALLING LIMITS FOR D.E.L.'s, P.B.X.'s AND EXTENSION PLANS.
C.B. TELES.

IMPORTANT: LIMITS QUOTED FOR ONE CONDITION MAY BE OVERRIDDEN BY ANOTHER MORE STRINGENT REQUIREMENT.

P.B.X. or Unit A.A.	T.E.R. Limits (ohms).	Signalling Limits (loop res. in ohms.) Exchange Line. 22/24V C.B.	36/40V C.B.	48/50V N.B.&B.	60V S. 16	Exch.+extn.	Extn. Line.
C.B. No. 10 ...	See Table 2 ...	400 (*b*)	500	600 (*c* & *d*)	600 (*c*)	Not Applicable	1000
CBS. 536 Exch. Line	See Table 2 ...	450 (*b*)	550	—	—	Not Applicable	As for P.B.X. Concerned
CBS. 536 Extn. Line	See Table 2 ...	←	As for P.B.X. Concerned		→	Not Applicable	500
No. 18 Extn. Line	←	— As for P.B.X. Concerned —				→	500

TABLE 1.

Exchange Line Res. (ohms).	Exch. and Extn. Sig. Res. (ohms). 22/24V C.B.	36/40V C.B.	48/50V N.B.&B.	60V S. 16
0	180	140	310	170
50	160	140	320	190
100	160	160	330	210
150	170	180	340	230
200	—	200	350	260
250	—	—	360	290
300	—	—	380	320
350	—	—	400	350
400	—	—	430	—

TABLE 2.

	P.B.X. or Unit A.A.	Main Exch. Bridge.	Exchange Line T.E.R. (ohms). 0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	780
Extn. Line T.E.R. Limit (ohms)	C.B. No. 10	Stone	460	435	410	380	355	330	300	275	250	220	195	170	145	55	20	0	—
		Rep. Coil	405	390	365	335	310	275	245	210	175	145	120	95	60	0	—	—	—
	CBS. 536	Stone	350	340	330	320	305	285	265	250	225	205	185	165	140	120	100	80	0
		Rep. Coil	320	305	290	275	255	235	215	195	175	160	140	125	110	95	0	—	—

NOTE 1. For L.B. Teles. (Non-Astic Type Coil No. 21), the exchange plus extension and extension signalling line limits are increased by 100 ohms.

The T.E.R. limits for exchange plus extension lines are as follows :—

Stone Type Bridge. 450 ohms (T.E.R.). 40V Stone slide rule applies.

Rep. Coil Bridge. 380 ohms (T.E.R.). 22V Rep. Coil slide rule applies.

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