THE POST OFFICE
ELECTRICAL ENGINEERS' JOURNAL
Vol. 49 July 1956 Part 2

The New, 700-Type Telephone

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U.D.C. 621,395.721.1

The development of a new telephone receiver, described in the last issue of the Journal, has made possible the design of a range of new telephone sets with transmission performance substantially better than that of the 300-type telephones which have been the standard instruments used in the British Post Office network for the past 20 years. This article discusses the problems that arise when a new telephone is to be introduced into an existing network, and describes the development of the new, 700-Type Telephone for the British Post Office and the advantages to be gained from it.

INTRODUCTION

To engineers concerned with the transmission of speech a telephone is not so much a particular physical instrument as a collection of transmission components, the transmitter, receiver and induction coil, and the circuit that connects them. The telephone manufactured at the present time for the British Post Office is summed up in the shorthand description "13-2P-27," indicating that its vital components are the Transmitter, Inset, No. 13, the Receiver, Inset, No. 2P and the Coil, Induction, No. 27. This "telephone" exists in a number of different physical forms, but of these the combined-set table-telephone, Telephone No. 332, is by far the most common: This article describes both the development of a new telephone in the general sense of the word and a combined-set table-telephone embodiment of it, Telephone No. 700.

There are many reasons why the design of an administration's telephone should not be changed, but there comes a time when the accumulated improvements in material available and in manufacturing techniques, and the increased knowledge of circuit designers, promises a sufficient improvement in performance, and consequent economy in use, to justify major changes. By the end of the 1939-45 war, "Telephone No. 332 was nearly 10 years old, the handset and transmitter being even older, and although little had been done on telephone design during the war it was clear from the progress made in allied branches of the electrical art that more-efficient telephones could be designed. A program was therefore initiated, through the British Telephone Technical Development Committee,[1] to develop new transmitters and receivers as the starting point for a new telephone, and this resulted in a new receiver of greatly increased efficiency becoming available by 1952.

The design of a better transmitter than the Inset No. 13 proved to be more difficult, but the work on transmitters had shown that a significant increase in their output was unlikely; the more likely improvements being greater uniformity of frequency response and less amplitude distortion. Thus, a new transmitter, provided that it was made physically interchangeable with its predecessor, could be included in a new telephone at a later date without appreciably affecting the balance struck between sending and receiving efficiencies. It was decided, therefore, to design a new telephone using the existing standard transmitter, and to obtain the required improvement in transmission efficiency from the increased efficiency of the receiver and the re-design of the transmission circuit.

Not the least problem in designing a new telephone is deciding the kind of performance that is wanted from it, and this is greatly influenced by the local line network in which it is to be used, by the performance of the telephones already in use and by the method used to plan the network. The early part of this article therefore touches briefly upon these factors, showing how they have influenced the resulting telephone. The remainder of the article describes the components used in the new telephone, its circuit and performance, its design for flexibility in use, and the complete telephone.

THE BRITISH POST OFFICE METHOD OF EVALUATING TRANSMISSION PERFORMANCE FOR LOCAL NETWORK PLANNING

Assessment of Transmission Performance.

The evolution of a new telephone instrument involves many intermediate designs, the difference in performance between successive instruments often being very small. Good design relies upon the ability to compare experimental telephone sets with each other and with the existing telephone so that the value of each improvement can be assessed. The problem is how to compare two telephones, and in what terms. Unfortunately, there is yet no simple solution involving a single method, for, bearing in mind that the only true assessment of the efficiency of a telephone is obtained from human reactions, and considering the enormous ranges of speaking and hearing qualities which are characteristic of telephone users, it is obvious that accuracy is not easily obtainable.

The two instruments can be connected in turn to an exchange line, a connexion set up and comparison made between them for both sending and receiving, but this is not very practical. If the telephones are almost equal in performance, it is quite possible that, in choosing which is the better, a second pair of observers will not have the same preference. Also, the sets are compared under one line condition only, and it can be shown that the performance of a telephone is affected to a considerable degree by the circuit into which it works. Thus, to compare accurately the usefulness of two sets, it is necessary to obtain the mean of many opinions and repeat this whole procedure under several line conditions; a formidable task which has to be eased as much as possible by somewhat artificial but less time-consuming methods.

To this end the British Post Office has so far adopted

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[1] For numbered references see end of article.

the practice of using articulation tests as a basis for assessing the performance of any telephone on a single specified line and transmission bridge (for convenience, any combination of set, line and bridge will be given the general title "local telephone circuit") relative to that of a "standard" local telephone circuit (defined later). Calculation techniques based on the results of electrical measurements and subjectively obtained data are then used to extend the information to obtain both sending and receiving performances of this set as a function of cable gauge and length, from the single-valued articulation ratings. These relative performances are known as Transmission Performance Ratings.

In the articulation test[2] consonant-vowel-consonant combinations (often meaningless) are spoken into the sending transmitter of the connexion at a controlled vocal level and speaking distance, while listeners record what they think is said. Some 1,500 monosyllables are received over the connexion for each of several junction attenuations, so obtaining a percentage score of sounds correctly received for each setting. The attenuation for an 80 per cent correct score of sounds is then determined. Repetition of the procedure for another connexion enables the necessary comparisons to be made. In this type of test the actual level of listening is made very low because the testing team is highly trained and at normal telephone listening levels on most circuits their scores would approach 100 per cent. To cater for room noise experienced by subscribers, a standard, controlled level of noise[3] is generated by loudspeakers in the rooms in which the listeners are seated.

It will be noted that several artificialities have been introduced into the tests; control of talking level, talking distance, listening level, listening-room noise conditions, and the use of non-representative subjects. These have been introduced in order to obtain reasonable precision with minimum testing. The room noise enables the test to include weighting for the side-tone performance of the instrument, for under noisy conditions poor side-tone suppression adversely affects receiving performance. The noise is presented to the ear by the receiver via the sidetone path, in conjunction with tire wanted signal. The signal/ noise ratio is thus lower for high side-tone and for loud room noise. In addition, a telephone handset introduces an unnatural transmission path between the mouth and one ear of the user; the subconscious effort made to adjust the voice to the accustomed loudness results in a change in the talker's voice level; for high side-tone levels the voice level is lowered and for low side-tone levels it is raised.[4] For sending, a correction is made for the effect of the sidetone that has been lost by the artificial control of the voice level.

The calculation technique[5] involves pure-tone comparisons wherever these are shown to be practicable; that is, when comparison of the transmission performance of any similar telephone connexion links (e.g. induction coils, subscribers' lines, transmission bridges) by a pure-tone method produces a similar answer to that which would be obtained subjectively. An example is the use of the attenuation of trunk lines at 1,600 c/s as a measure of their speech transmission loss. The number of frequencies to be used in other cases depends on the degree of irregularity in the characteristics being compared.

Thus, the performance of one local telephone circuit can be expressed relative to that of another. If the two local telephone circuits contain the same subscriber's line and transmission bridge, but different telephone sets, then the relative performance of the sets is obtained. By repeating this procedure over a range of line and transmission-bridge conditions, an estimate of the improvement of a new set over any other telephone set can be made.

Control of Network Transmission.

There is obviously a limit to the overall transmission loss which any two subscribers should experience on a call. What constitutes a satisfactory service is a question difficult for a subscriber to answer and almost impossible for an administration to determine when the needs of all its subscribers are considered in conjunction with the balance between cost and service. It is not intended here to consider the problem in detail, but to show simply and briefly the Post Office method of planning so that discussion of the performance of the new telephone will be appreciated.

For transmission planning, the British network is divided into two parts: the local network of subscribers' installations, subscribers' lines and exchange-transmission bridges; and the junction and trunk network. The local network is planned so that no local telephone circuit has a transmission performance worse for either sending or receiving than that of the Standard Local Telephone Circuit. Similarly, the junction and trunk network is arranged so that the total losses do not exceed that value which, when interposed between two of the Standard Local Telephone Circuits, would produce "just satisfactory" transmission performance. Guidance on what constitutes a "just satisfactory" transmission performance was obtained several years ago by asking some 1,700 persons to converse over telephone connexions of various grades of performance so that a relationship between "opinions of usability" and attenuation could be obtained.

Since more-sensitive telephone instruments can tolerate longer or smaller-gauge lines for equivalent transmission performance, the method of determining the lengths of the various gauges of subscribers' cables which, in conjunction with a particular telephone instrument and transmission bridge, will make up a local telephone circuit having a transmission performance equal to that of the Standard Local Telephone Circuit, is of particular interest.

The Standard Local Telephone Circuit consists of a Telephone No. 162 with Bell Set No. 25, connected via 2.56 miles (450 ohms) of 10-lb cable to a 50V Stone transmission bridge with 200 + 200-ohm relays. It has recently become apparent that when telephones with modern anti-sidetone circuits are compared by articulation-testing techniques with the Standard Local Telephone Circuit, which does not include a true anti-side-tone telephone, receiving ratings are consistently obtained which are about 6 dB higher than those obtained by less artificial techniques. (The sending ratings obtained by the different methods of comparison are in reasonably close agreement.) These differences are probably attributable to the artificial nature of articulation tests, although the exact contribution of each of the various subjective factors involved is still being investigated. From this consideration, with others involving international connexions, it has recently become clear that while articulation tests form the basis of line-planning transmission-performance assessments, the receiving limit should be reduced by 6 dB. Telephone No. 332 meets this raised limit for receiving when connected to its limiting line, the limit being set by its sending performance.

Curves are plotted of the Transmission Performance Ratings of any given telephone for sending and receiving relative to the Standard Local Telephone Circuit (with the 6-dB correction for receiving) against line length, for different gauges of conductor. The line lengths at which these curves cross the zero performance line are therefore the maximum permissible. As different maximum lengths are normally obtained for sending and receiving, the lesser one becomes the transmission-planning limit. This is usually quoted in Transmission Equivalent Resistance (T.E.R.)[6] the resistance of the limiting 61-lb conductor line. Where, in practice, other or mixed gauges of conductor are used, conversion factors are employed to obtain their T.E.R. Signalling must also be possible for the particular instrument on its limiting line; if not, then the signalling line limit takes preference.

THE DESIGN OBJECTIVES FOR THE NEW TELEPHONE

The increased sensitivity of a new telephone may be utilised in one or both of two ways. It may be passed directly to the subscriber by improving the existing grade of transmission performance, or it may be absorbed by maintaining this grade of performance at lower overall cost by exchanging sensitivity for increase of line length or decrease of conductor gauge. Thus, the introduction of a new telephone with its potentialities of effecting some saving in the provision of underground plant was considered an attractive engineering proposition, especially as its use would often also result in an improved grade of transmission. In addition, longer exchange lines become practicable, with the possibility of larger exchange areas and absorption of very small ones. The saving is not, of course, immediately realisable because line plant changes very slowly, and thus the savings are small at first but progressively increase with time.

It is also important that savings in line plant should not be offset by increased cost of the telephone nor by increased exchange-equipment costs due to changes necessary for efficient signalling over higher-resistance lines. Thus the cost of the new telephone has been as important a factor as performance and the primary design objective became that of obtaining increased sensitivity without significant increase in cost. The whole problem of estimating the savings to be obtained by introducing a telephone of increased sensitivity is extremely complex and is resolved only by considering instrument and exchange costs, the rate of numerical growth of the new instrument in the network and the rate of provision of lines on which the increased sensitivity may be used to advantage, bearing in mind that there is a limit to the practicability of reducing conductor gauge.

From knowledge gained by the critical examination of existing components and the assessment of experimental transmission circuits, the British Post Office was enabled to draw up a target specification for the guidance of telephone manufacturers. This laid down that,

(i) the impedance of the telephone at 2,000 c/s when carrying 30 mA line current should have a modulus of 600 ± 50 ohms,

(ii) the signalling resistance should not exceed 300 ohms when measured with 20 mA line current, and gave

(iii) the desired shape of the pure-tone sending and receiving sensitivity/frequency characteristics for maximum overall intelligibility with the greatest economy of transmitted power,

(iv) line impedance values on which the set should have minimum side-tone so that the best overall side-tone performance would be obtained in the British network, and

(v) the proposed method of testing any new handset. It was stated that tests would be necessary using free-conversation techniques so that the transmission difference between the new and existing handsets could be assessed with the handsets held as in normal use, and a correction made, if necessary, to the relative transmission performance ratings found from articulation tests.

In addition, guiding principles were stated for the desirable limits of amplitude and non-linear distortion and control of sensitivity.

No hard-and-fast figure for the increase of sensitivity was given, but the view was expressed that the telephone should be suitable for use on 1,000-ohm T.H.R. lines when connected to exchanges with 50V ballast Stone transmission bridges.

THE COMPONENTS OF THE NEW TELEPHONE

The main objective of the re-design of the telephone was improved transmission performance without significant increases in cost. The transmission performance of a subscriber's telephone is determined entirely by the handset, which includes the transmitter and receiver, and the induction coil with its associated circuit, and it is in these components that the principal differences between the new telephone and its predecessors are to be found. Of these components, the greatest improvement has been made in the receiver, and the better transmission performance of the new telephone springs almost entirely from this source.

The Handset

The new telephone uses a handset of the "hollow-handle" type which has been titled "Handset No.1" It is illustrated, complete with mouthpiece and earpiece, in Fig. 1, and the position of the tunnel through the handle is shown in Fig. 2. The tunnel is formed when the handset is moulded by a tapered core which passes through the cord-entry hole. To allow this core to be withdrawn when the moulding is completed, the tunnel and the cord-entry hole follow a curve of constant radius and this, together with the need to position the mouthpiece and earpiece in the correct relative positions, largely determines the shape of the handset.

FIG. 1 - HANDSET NO 1

In the new handset the cord is connected directly to terminals of the transmitter and receiver (apart from one connexion to the transmitter which is made by a floating spring), the receiver conductors passing through the hollow handle. This method of connexion, together with the use of a screw-on mouthpiece, enables a simple moulding to be used for the handset body without any of the threaded inserts, wires and bayonet fixings that had to be moulded into the previous handset.

The mouthpiece of the new handset is of the screw-on type, and the elimination of the bayonet fixing not only simplifies the body moulding but also enables a simpler moulding tool to be used for the mouthpiece. The thread used on both mouthpiece and earpiece has a coarse pitch

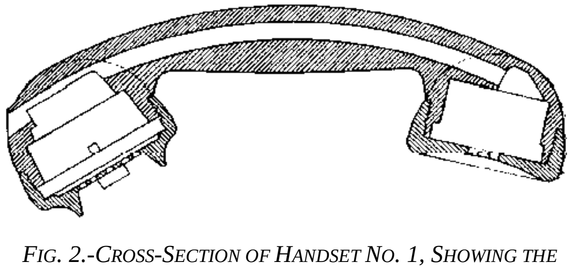


FIG. 2.-CROSS-SECTION OF HANDSET NO. 1, SHOWING THE POSITION OF THE TUNNEL THROUGH THE HANDLE

and a slight taper, which speed the release. of the finished mouldings from the moulding tool. The position of a screw-on mouthpiece relative to the handset body when it is screwed on tightly cannot be controlled accurately, as the position of a bayonet-fitting mouthpiece can, and this means that the mouthpiece must be symmetrical about the thread axis; hence a shaped horn cannot be used.

The shaped horn was an essential feature of the telephone No. 164 handset, as it contributed to some extent to the sending performance, but it had been frequently criticised as unhygienic. While the opinion of the medical profession in this country and elsewhere is that the telephone does not contribute at all to the spreading of germs, the collection of dirt within the horn, particularly in call office telephones, undoubtedly creates a bad impression, and the elimination of the horn is advantageous, although it entails a slight sacrifice of sending efficiency.

To compensate for the loss of a horn the angle of the transmitter diaphragm relative to the axis of the new handset has been increased compared with the Telephone No. 164; bringing the diaphragm more nearly opposite the user's mouth. When the handset is used by the majority of subscribers, the change of angle also results in the transmitter being held at an angle at which it is more sensitive than when used in a Telephone No. 164, giving a greater electrical output for a given speaking level.

Free-conversation tests using a large number of subjects have shown that the electrical output from a Transmitter, Inset, No. 13 is, on average, the same whether used in the new handset without a horn, or in the Telephone No. 164 with its horn. Subjective tests have also been carried out to find the effect of variations in length of the new handset and in the angle between the transmitter and the receiver, and these tests have shown the chosen shape to be the optimum for sending and receiving efficiency.

The bayonet fixing of the mouthpiece on the Telephone No. 164 handset incorporated an elementary form of loci: to guard against interference with the transmitter, but no such device was used for the earpiece. Experience has shown that the receiver in the Telephone No. 164 is no more subject to interference than the transmitter, and so no such lock has been provided for the mouthpiece of the new handset.

A rubber sleeve is fastened to the cord to reduce wear where it passes through the rectangular entry hole in the handset. The sleeve is enlarged within the handset and has a rectangular section so that it cannot be pulled through or twisted in the hole, so protecting the cord conductors from strain. The cord is fitted by passing its telephone end through the. hole in the handset from inside the transmitter cavity.

For maintenance the new handset. will be a considerable improvement over older ones. The direct connexion of the cord to the insets is a big improvement as it eliminates a number of connexion points, each a potential fault; also, the coarse-pitch threads should speed removal of the mouthpiece and earpiece for inspection and prevent the occasional seizures which occur with the, present design of earpiece with its fine thread.

The Receiver.

The receiver is of the "Rocking - Armature" type and has been titled Receiver, Inset, No. 4T. It is illustrated in Fig. 3, and has been described in a previous issue of the Journal.[7] For circuit-design reasons it has been wound to have an impedance of 150 ohms, measured at 1,000 c/s, and has a d.c. resistance of 20 ohms.

In the rocking-armature receiver the functions of the acoustic diaphragm and of the moving-iron part of the magnetic circuit have been split between two mechanically linked parts, cacti of which can then be designed for optimum performance of its particular function. Because of this, and because in the magnetic circuit used the reluctance of the permanent magnet is excluded from the path of the alternating flux, the rocking-armature receiver is more sensitive and has a greater frequency range than the magnetic-diaphragm receivers previously used in telephones. The improvement of the now receiver over its predecessors is shown by the curves of Fig. 4.

Fig 3 - Receiver Inset, No 4T

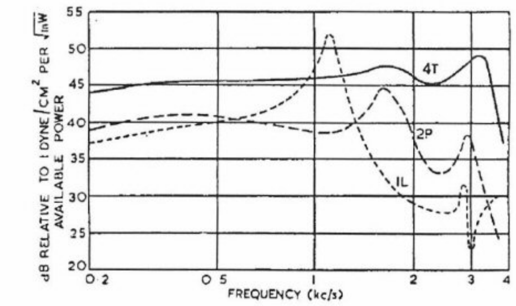


Fig. 4. - Sensitivity/ Frequency Characteristics of 4T 2P and 1L, Receiver Insets

The new receiver is a scaled capsule unit provided with terminals oil the rear of its case for the direct connexion of cord conductors. The terminals, like those ear the transmitter-connexion springs, have nuts slotted for screwdriver tightening to avoid the use of lox spanners. The capsule form of construction should result in the receiver having a more stable performance in service than the open-construction magnetic-diaphragm types, which are always liable to changes of sensitivity after opening due to distortion of the diaphragm and dirt getting in and collecting in the air gaps.

Fig. 5 is a cross-section of the receiver end of the handset showing the fitting of the receiver. It is pressed into contact with the earpiece by a spring ring and at its rear is space for fitting a click suppresser, if required.

The Transmitter.

In the absence of a completely developed and proved alternative, the well-tried Transmitter, Inset, No. 13 has been used in the new telephone. This is a development of the No. 10 inset transmitter, which has been described in a previous issue of the Journal.8 It differs from the No. 10 inset in that it does not have an oiled silk membrane behind the front guard, the diaphragm being protected by a coating of tough flexible enamel. The breathing hole, which in the No. 10 inset was in the diaphragm, has been replaced

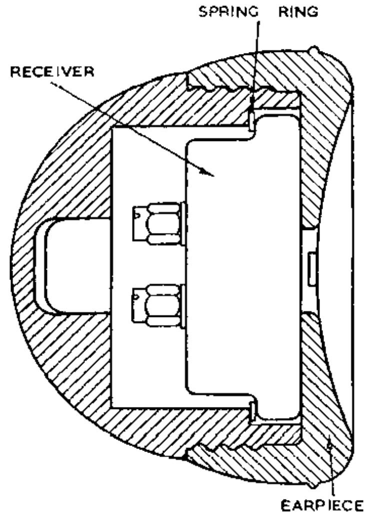


Fig. 5 - Cross-Section of the Receiver End of the New Handset

by a hole through the rear electrode. These changes were introduced to improve the resistance of the transmitter to the penetration of moisture.

The Transmitter, Inset, No. 13 was not designed for use with hollow-handle handsets and means have had to be devised for connecting the cord conductors to it. Connexion to the front electrode, which is in contact with the case via the diaphragm, has been made by replacing the usual spring ring on the rear of the case by one which incorporates a terminal post for the connexion of one cord conductor. 'fire new spring ring has a small tongue bent down to engage in a slot in the handset moulding, so preventing the transmitter from turning and straining the cord connexions as the mouthpiece is screwed on. The tongue is split and is wider than the slot in the handset, so that when it is pressed into the slot, the transmitter is held in position, tints facilitating the fitting of the mouthpiece. Contact with the rear electrode is made by means of a loose springy nickel-silver plate within the transmitter cavity of the handset. This plate, which includes a terminal post to which the other cord conductor is connected, has a contacting cone raised in its centre which engages with the hole in the rear of the transmitter. It is field firmly in contact with the transmitter by a step in the side wall of the transmitter cavity in the handset.

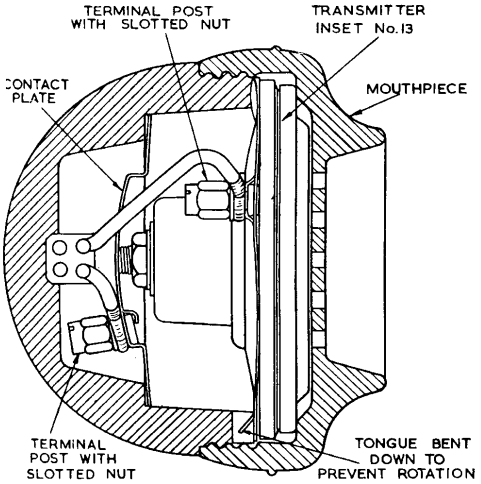


Fig. 6 - Cross-Section of the Transmitter End of the New Handset

When flat, the plate is slightly larger than the diameter of the transmitter cavity at the step, and when the transmitter is removed and the pressure on the plate is released, its edges grip the moulding and it is held securely in position; in fact, it is quite difficult to remove. The contacting cone in the plate is perforated to avoid blocking the breathing hole in the rear electrode of the transmitter. Fig. 6 is a cross-section of the transmitter end of the handset, which shows the means of connecting the conductors to the transmitter.

The Induction Coil.

The induction coil designed for the. new telephone, "Coil, Induction, No. 30," is illustrated in Fig. 7. Its shape and mounting brackets are designed so that the coil is physically interchangeable with the Coil, Induction, No. 27.

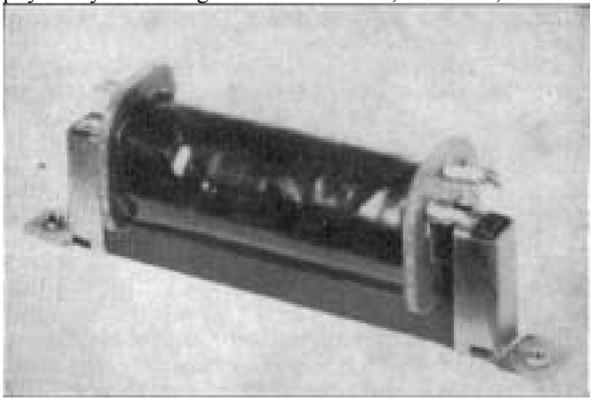


Fig. 7 - Coil, Induction, No. 30

The coil has three inductive windings of No. 33 S.W.G. enamelled wire connected in a series-aiding; these windings are:

Winding	Turns	Resistance (ohms)
1 (line)	1,220	15.0
3	666	10.5
3	420	7-5

In addition, two balance resistors for the transmission circuit are wound non-inductively on the same bobbin. Design for good side-tone suppression requires windings of high inductance, and for efficiency low winding and core losses are required. These properties have been achieved by use of a closed magnetic circuit of grain-orientated silicon-iron. The grain-orientation process;[9] which consists of cold rolling and annealing silicon-iron strip to orientate the crystal lattices of the grains in the same general direction, results in the material exhibiting much lower core losses together with greatly increased permeability, and at comparatively low cost. Maximum efficiency is obtained when the flux path through the core is parallel to tire rolling direction, and the elongated shape of the core (the mean length is almost five times the breadth) makes it particularly suitable for the efficient use of this type of material.

The comparatively high permeability of the core enables the required transformation efficiency to be obtained with fewer turns than are required when the magnetic circuit includes a large air path, as in the Coil, Induction, No. 27. The cropper losses and the amount of copper used per induction coil are therefore smaller, partly offsetting the increased cost of the core. The core has a ¼-in, square cross-section and is built up in two sections, each L-shaped and comprising 18 laminations, 0.012 to 0.013 in. thick, held in place by nickel-silver clamps. A 0.002-in.

aluminium spacer provides a gap in the magnetic circuit to avoid saturation by high line currents, and Fig. 8 shows that there are no large changes of inductance for the most frequently occurring line currents, say 40-100 mA.

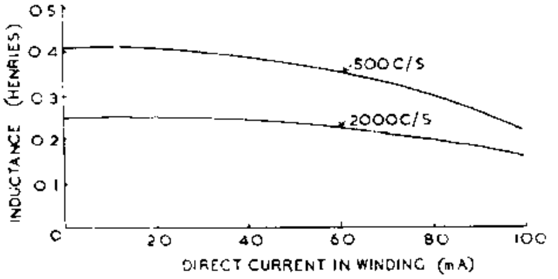


Fig. 8 - Inductance of Line Winding of an Experimental Coil, Induction, No. 30

The major effect of inductance changes is on side-tone attenuation at low- frequencies. The coil and circuit have been designed to give minimum side-tone at 40 mA line current, and a rise to 100 rnA increases the 500 c/s side-tone level by 3 to 4 dB. This is of minor importance, however, since the greatest effect of side-tone is experienced when receiving in the presence of room noise and then, because the ear is seldom completely sealed by the receiver, low-frequency noise heard directly via the imperfect seal between receiver and ear is often greater than side-tone. The same change of line current has a negligible effect on side-tone measured at 2,000 c/s.

The two curves of Fig. 8 have been plotted to indicate the fall of inductance with this type of core as frequency rises. This is clue to a decrease in incremental permeability, typical values of which are 800 at 500 c/s and 510 at 2,000 c/s, for a line current of 50 mA.

A metal sleeve with synthetic-resin-bonded-paper end cheek forms the bobbin, as shown in Fig. 9; the sleeve is split longitudinally so that it does not form a short-circuited turn.

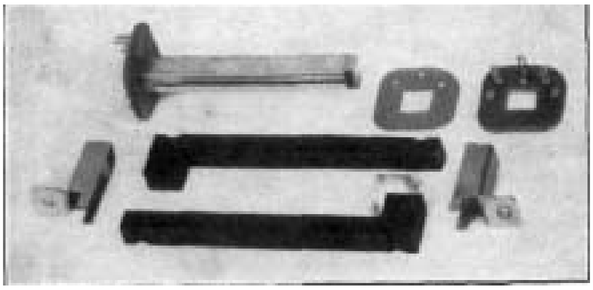


Fig. 9 - Component Parts of the Coil, Induction, No, 30

The Capacitors.

The circuit of the new telephone has a capacitor in the balance network as well as the one used for blocking d.c., but does not have a capacitor shunting the transmitter. A 0.1-µF capacitor was included in the Telephone No. 332 circuit to prevent the modulation and demodulation of r.f. currents that may be induced into telephone lines in regions of very high r.f. field strength, but investigations have shown that such a capacitor is required in only a very few cases, and that it would be more economic to provide it as an extra when required.

To enable the new transmission circuit to be contained initially within the same case as the 300-type telephones without changes to the internal layout, it was necessary to accommodate tire d.c.-blocking and balance capacitors in the space previously occupied by a total capacitance of 2.1 µF The transmission circuit has been designed with this space limitation in mind, and the values of the capacitors have been fixed at 1.8 µF and 0.9 µF respectively. It has been found possible to manufacture conventional foil and paper capacitors of these values, enclosed for economy in a common can that is small enough for the space available. Two different designs have been produced: one uses the same impact-extruded aluminium can with neoprene seal as is used in the No. 332 telephone for the 2 + 0.1 µF capacitors, the increased capacity without increase of volume being obtained by the use of interleaving paper of improved properties. In the second design the capacitors are contained in a rectangular fabricated container which, while having the required overall dimensions, makes better use of the space available in the telephone and contains more space for the capacitor elements.

The Dial.

If the improved transmission performance of a telephone allows the use of longer local lines, it is essential that signalling, particularly pulsing, should also be satisfactory over the longer lines. The pulsing performance of a telephone is determined by the distortion introduced by the telephone spark-quench and by the mechanical properties of the dial.

The dial used in the new telephone is the post Office No. 12 type, a "trigger" dial first introduced into service in 1950. Its predecessor, the No. 10 dial, owes its long popularity to the fact that it provides the inter-train pause before the pulse train, instead of after it, and the dial runs up to its governed speed before pulses are transmitted. The No. 12 dial also has this advantageous feature but avoids the known weaknesses of the slipping cam.

With the No. 12 dial mechanism the pulse ratio is affected during service by wear at the contacts, and between the teeth of the pulse wheel and the trigger. The effects of wear at these two points are compensating, whereas in the No. 10 dial, contact wear and tooth wear are additive: because of this it has been possible to assume greater constancy of pulse ratio in service for the No. 12 dial. Hitherto, both No. 12 dials and No. 10 dials have been used indiscriminately in telephones and it has riot been possible to take advantage of the improved pulsing performance, but in the new telephone, No. 12 dials are being used exclusively and the more constant performance offsets the increase of pulse distortion when the telephone is used on a longer local line.

The method of connecting the dial to the telephone has been changed. In earlier telephones it has been the practice to use a separate dial cord, connecting the dial to a terminal strip within the telephone. This practice was followed, not to allow replacement of the dial cord, which gets no wear and should outlast the telephone, but to enable C.B. versions of telephones to be provided. In the new telephone, connexion is made to the dial by flexible conductors included in the cable form. For automatic working this is more economic because it eliminates the terminal strip and the conductors have bound loops at the dial ends only. Where the telephone is not fitted with a dial the new arrangement is riot quite so economic as the old; conductors equivalent to a dial cord are provided unnecessarily and a dummy dial which includes a terminal strip is necessary to provide a point at which the telephone loop can be restored, and to prevent conductor ends being left loose in the telephone. New telephones will be used much more as automatic instruments than older telephones have been, partly because manual exchanges are being converted to automatic working and partly because, initially at any rate, the new telephone will be used mainly on long lines connected to new automatic exchanges designed for the higher resistance limits. The saving achieved by eliminating the terminal strip from the new telephone when it is used with a dial is therefore the more important factor.

The Bell.

The new telephone uses the same No. 59A bell movement as the Telephone No. 332. The impedance of the ringing circuit, particularly in the most onerous conditions when a number of bells are connected in series to one line, is so high that the extension of line limits allowed by the improved transmission performance does not affect ringing efficiency.

THE TRANSMISSION CIRCUIT

Winding Ratios.

The new instrument is designed for an existing, well established network and it has therefore to work in conjunction with a variety of older instruments. Consider a hypothetical telephone network containing one type of telephone instrument only and assume local-line planning by the present method. If a new instrument has been designed and has a transmission performance better than that of the existing instrument by s dB for sending and r dB for receiving, then the transmission performances obtained over the existing limiting connexion for combinations of new and existing sets are:

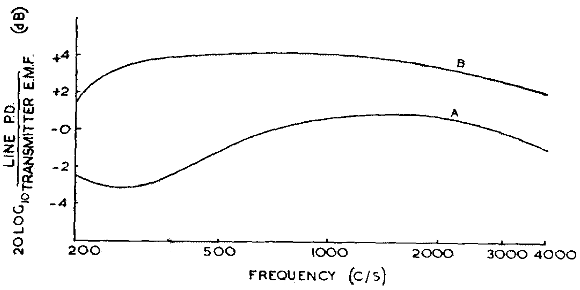
(i) Existing set sending to existing set-transmission performance = 0 dB relative to lower limit.
(ii) New set sending to existing set-transmission performance = +s dB relative to lower limit.
(iii) Existing set sending to new set--transmission performance = +r dB relative to lower limit.
(iv) New set sending to new set-transmission performance = +(s + r) dB relative to lower limit.

Conditions (ii) and (iii) are the most important, for the network will contain the older sets for a very long period, and show that new sets can only be fitted on lines of increased transmission loss to the value of s or r, whichever is the smaller. This restriction is necessary since, by introducing a new set with increased receiving efficiency (r) greater than the increased sending efficiency (s) and by connecting this set to a line with an extra transmission loss equivalent to the improvement in its receiving performance (r) the sending performance of the set on that line becomes (r - s) below the lower limit.

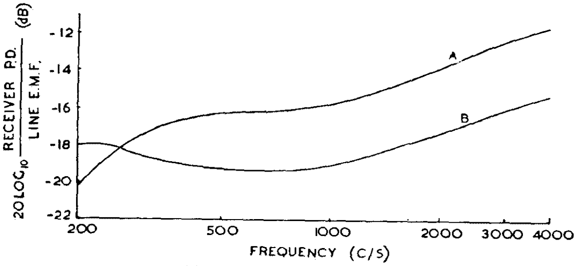
The economic advantage is clearly a maximum when s = r, and there is no economic advantage when either s or r is zero. Although the assumptions made are not completely valid under all circumstances, the example does indicate the ideal practical condition,. that the new set should be better in transmission performance by equal amounts for both sending and receiving compared with the planning standard.

An article in a previous issue of the Journal[10] showed that within the anti-side:-tone circuit sending efficiency can be increased if the receiving efficiency is reduced and vice versa. This feature is of great advantage in the design of a subscriber's set, for in the 700-type telephone the added transducer efficiency is almost wholly in the receiver and with no change in the induction-coil circuit (e.g. by continuing to use the Coil, Induction, No. 27) no economic advantage would be realised. In fact, a deterioration would be more likely because the increased side-tone would reduce sending efficiency by causing a lowering of the talker's voice, and the greater receiving loudness might easily become an embarrassment on short lines. Such considerations, followed by experimental design and trial, enabled the Y-ratio, [10, 11] of the new induction coil to be determined; the final value adopted (3) being a compromise between the degree of transfer of efficiency required and the loss of overall efficiency incurred in the process.

It has been shown that there are 136 possible 3-winding ASTIC circuits that have the same fundamental properties so far as subscriber's set design is concerned [11]. Of these, many may be rejected as uneconomical because they need additional isolating capacitors; e.g. when a winding forms a d.c. shunt across the line or transmitter. The circuit chosen from the group remaining was determined mainly from the balance-network considerations discussed later, and, for the chosen circuit, knowledge of the Y-ratio, the line impedance and the transducer impedances enabled the winding ratios to be determined; these are, winding 1/ winding 2 = 1 .83 and winding 1 /winding 3 = 2.9



(*a*) Sending-Path Efficiency.



(*b*) Receiving-Path Efficiency.

A—Coil, Induction, No. 27.
B—Coil, Induction, No. 30.

FIG. 10 - SENDING AND RECEIVING CHARACTERISTICS OF COILS, INDUCTION, NO 27 AND NO. 30

The difference between characteristics of the sending and receiving transmission paths of the Coil, Induction, No. 27 and the Coil, Induction, No. 30 are shown in Fig. 10; the new coil has a sending-path efficiency about 3.5 dB greater than that of the Coil, Induction, No. 27, but the efficiency of the receiving path is lower by about the same amount for the particular line condition and range of frequencies shown. The change of Y-ratio from approximately 1, for the 332 circuit, to 3 for the new circuit would theoretically have resulted in the 700-type electrical circuit having a sending efficiency only about 2 dB greater, while the receiving efficiency would have been some 3 to 4 dB less. That the new telephone has efficiencies materially better than this is due partly to the increased efficiency of the circuit and partly to the greater efficiency of the induction coil with its low winding resistances and low core losses.

Choice of Circuit.

So far, the performance of the new instrument has been compared with that of the existing telephone without reference to the effect of side-tone. By changing to a transmitter or receiver (or both) of greater sensitivity, the overall level of side-tone is increased and by its effect on a talker and on the signal/noise ratio when receiving in the presence of room noise it may partially offset the expected transmission-performance gains. It is thus desirable that the equivalent electrical attenuation of the side-tone path of the new induction-coil circuit should be greater than that of the Coil, Induction, No. 27 by an amount at least equal to the total sensitivity added. The degree of side-tone balance obtainable under the practical range of line conditions, and the complexity of the balance network, are important factors affecting the final choice of the induction-coil circuit. The design of the balance network for the group of usable circuits is affected by the magnitude of the self-inductance and mutual inductances of the windings of the induction coil (assuming a type of construction in which leakage inductance and winding resistance are both small), low values resulting in a more costly network. The choice of the circuit within the group is thus dictated by consideration of the balance network and a knowledge of the anticipated physical construction of the induction coil. The complete transmission circuit found to be the best compromise is shown in Fig. 11; it is very similar in configuration to the basic circuit analysed in an article in a previous issue of the journal.[10]

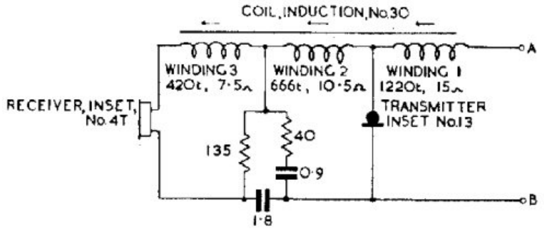


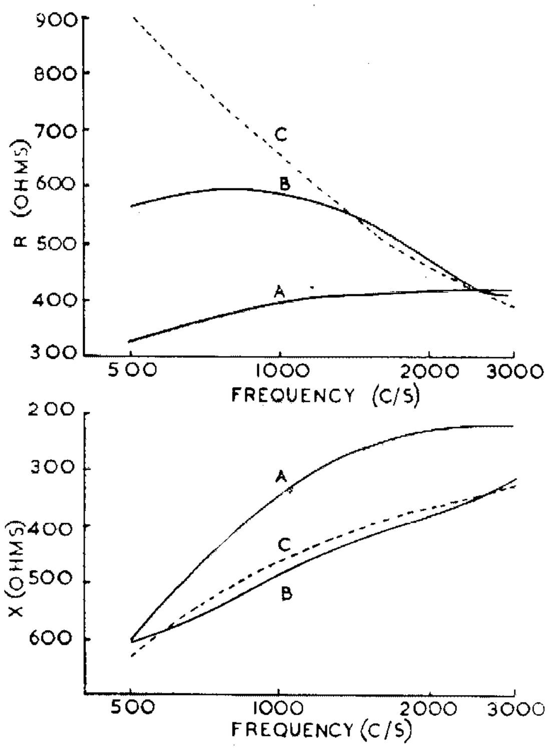
FIG. 11 TRANSMISSION CIRCUIT OF 700-TYPE TELEPHONE

The Balance Network.

The line impedances to which a telephone set may be connected vary over a wide range, both from installation to installation, due to variation in line gauge and length; and from call to call, due to variation in transmission bridges and junctions. By examining all the impedances that may confront the line terminals of a telephone in the Post Office network (and to a close approximation, many other networks), it was possible to estimate the impedance/frequency characteristic for the termination on which a telephone should have minimum side-tone in order to obtain the best mean side-tone performance. The balance circuit was then designed so that at each frequency the line impedance producing the greatest sidetone path attenuation was as near as was economically possible to that of the design characteristic. The ideal and achieved characteristics (expressed for convenience in terms of the resistive and reactive components) are shown in Fig. 12. The characteristics indicate that the new circuit has a greatly improved side-tone suppression, and this fact is substantiated by a series of actual measurements made on the Telephone No. 332 and 700-type telephone circuits over a typical range of line conditions, as shown in Fig. 13, in which mean side-tone levels over the telephone frequency band are plotted for various subscriber's line lengths and gauges.

The balance network is not a simple two terminal network; it is complicated by the addition of the d.c.-blocking capacitor, making a three-terminal asymmetrical π network.

The 332-type circuit is especially economical in its use of components; the aim of the 700-type design is similar; i.e. to use certain components to perform both transmission and signalling functions. The position of the d.c.-blocking capacitor and its value are, therefore, determined by considerations additional to those of transmission. For example, it was desirable that both the d.c.-blocking and balance capacitors should be contained within the same can, the size of which was limited.



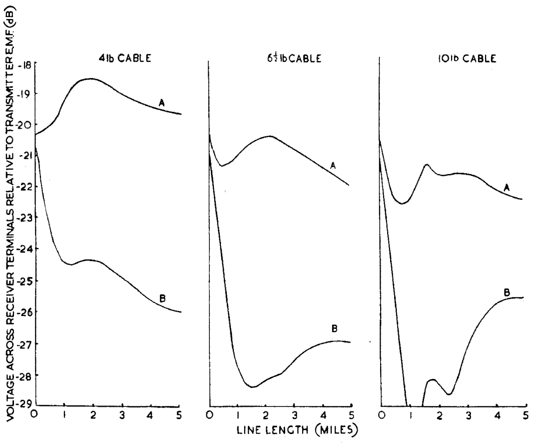
A—Telephone No. 332.
B—Telephone No. 700.
C—Ideal Characteristic for British Network.

FIG. 12 - LINE IMPEDANCE FOR MINIMUM SIDE-TONE

From all considerations (transmission, dialling and ringing) it was not possible to reduce the value very much, especially when manufacturing tolerances of some ±15 per cent are necessary, but a slight reduction from the existing value of 2 μF to 1.8 μF enabled a balance circuit to be designed to give satisfactory side-tone suppression, while easing the capacitor manufacturing problem.

TRANSMISSION PERFORMANCE OF THE 700-TYPE TELEPHONE

Methods of assessing transmission performance that produce the most realistic answers usually entail the greatest amount of work and require considerable time for precision, and as production models of the 700-type



A—Telephone No. 332.
B—Telephone No. 700.

FIG. 13 - SIDE-TONE RESPONSE OF TELEPHONES NO. 332 AND NO. 700

telephone have not been available until recently, only provisional information can be given here. This has been obtained from tests on prototypes only, but while it may be subject to small corrections when comprehensive tests have been completed, it does allow a fairly reliable estimate of the transmission improvement of the new telephone to be made.

For pure-tone sensitivity tests and for subjective tests in which a fixed handset position is used, the angle of the handset and the speaking distance used were determined from a recent series of measurements made on telephone users when holding a handset naturally.

Loudness Efficacy

The loudness efficacies of the 700-type telephone are greater than those of the Telephone No. 332 by about 5 dB for sending and 3 dB for receiving when working directly into a 50V Stone transmission bridge, 600-ohm junction and the appropriate end of the Articulation Reference Telephone Circuit.I2 The same order of improvement is maintained for most practical line conditions.

Pure-tone Characteristics.

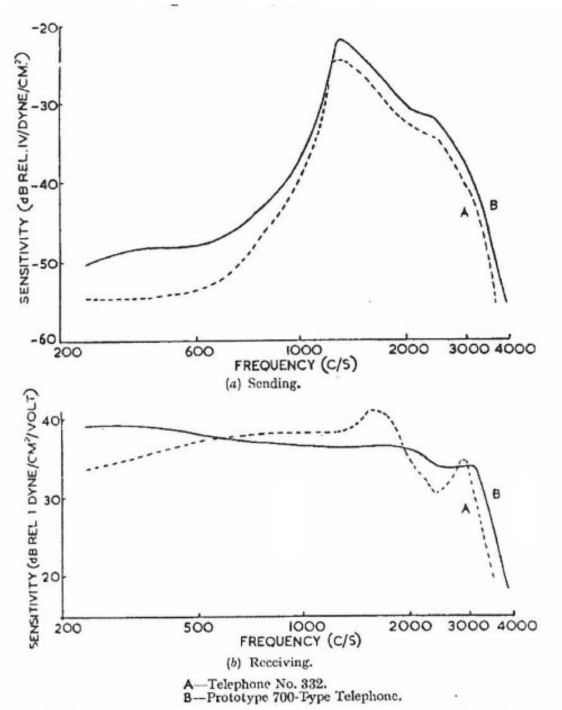


FIG. 14 - SENSITIVITY/ FREQUENCY CHARACTERISTICS OF TELEPHONES NO. 332 AND PROTOTYPE 700-TYPE TELEPHONE

Pure-tone sending and receiving sensitivity/frequency characteristics are given in Fig. 14. They are shown for one line condition only but are typical of the difference between Telephones No. 332 and No. 700 on all practical lines.

Transmission Performance Ratings.

Transmission performance ratings are probably the best method of showing the usefulness of a telephone in a network. A typical series for the 50V ballast Stone transmission bridge comparing the Telephones No. 332 and No. 700 is given in Fig. 15.

It can be seen that the controlling limits are those for sending in all cases (ignoring signalling considerations) and that the original expectation of a telephone suitable for use on lines having a T.E.R. of 1,000 ohms has been realized, thus allowing greater usable line lengths for the new set to the extent of some 40 per cent. Space does not permit details to be given of the transmission improvement on other types of transmission bridge, but the increases in usable line lengths are of the same order for all.

Alternatively, the new telephone will have transmission performance equal to or better than that of the Telephone No. 332 when used on lines of the next smaller Post Office standard conductor weight; e.g. where Telephone No. 332 requires a 10-lb/mile or 62-lb/mile conductor, the new instrument can use 6 1/2 lb/mile or 4 lb/mile respectively.

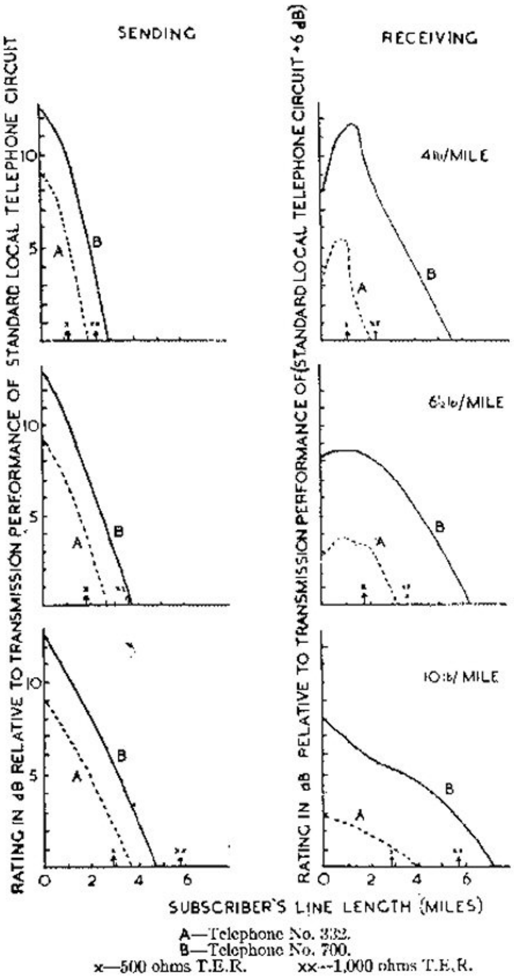


FIG. 15 - TRANSMISSION PERFORMANCE RATINGS OF TELEPHONES NO. 332 AND NO. 700

THE PRACTICAL CIRCUIT

So far, only the transmission properties of the new telephone circuit have been considered. The practical telephone must perform a number of signalling functions and these require the addition to the transmission circuit of gravity switch contacts, a dial and a bell. In the 700-type telephone these have been added without any sacrifice of transmission efficiency. The rearranged circuit is shown in Fig. 16 and it will be seen that, as in the Telephone No. 332, the d.c.-blocking capacitor of the transmission circuit is also the bell capacitor and the capacitor in the dial spark-quench. With the bell connected as in this circuit a small direct current passes through the receiver when the telephone is in use; although undesirable in principle, this is so small (a fraction of 1 per cent of the line current) that it has no effect on the receiver sensitivity, while it has the advantage of "wetting" contact GS2 which would otherwise carry only small alternating currents. The circuit requires the same

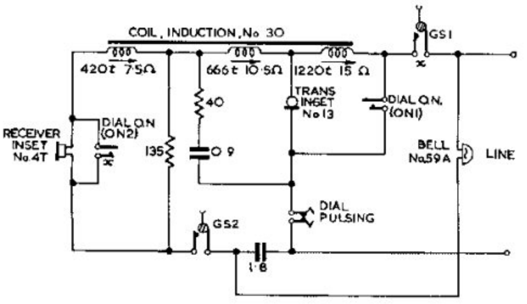


FIG. 16 - COMPLETE CIRCUIT OF TELEPHONE NO. 700

combination of dial off-normal contacts as the Telephone No. 332, so that the same dial can be used for both old and new telephones.

Gravity Switch Contacts.

The positioning of the gravity switch contacts exactly follows the practice of the earlier telephone. Two contacts are used to break the telephone loop; contact GS1 breaks the transmitter circuit while GS2 breaks an indirect circuit through the bell. To prevent an objectionable click being heard when the handset is lifted, GS1 is adjusted to make before GS2. Completion of the receiver circuit is thus delayed until the d.c.-blocking capacitor (1.8 µF charged to the full exchange battery potential while the telephone is idle) has discharged via the transmitter circuit. A click is still heard in the receiver due to the coupling between the windings of the induction coil, but its level is reduced so that it is no louder than the clicks caused by the exchange apparatus when the line is switched to a selector.

Dial Contacts.

While the method of including the dial in the 700-type telephone circuit follows generally the lines of the 332 circuit it differs considerably in detail. Contact ON1 both completes the low-resistance pulsing loop and prepares the spark-quench for the pulsing contact, leaving ON2 to short-circuit the receiver to prevent dial pulses being heard.

The spark-quench formed when the dial is off-normal consists of the 1.8-µF capacitor with a series component made up of a network of induction-coil windings, the balance resistors and capacitor, and the transmitter. This network has a d.c. resistance of about 30 ohms, varying slightly with the transmitter: the circuit of the complete spark-quench is shown simplified in Fig. 17.

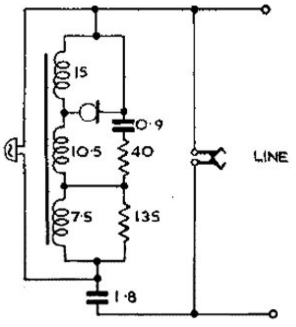


FIG 17 - PULSING CIRCUIT (DIAL OFF-NORMAL CONTACTS OPERATED).

The presence of capacity in parallel with the pulsing contacts of a dial has the effect of increasing the make/break ratio of the pulses and the exchange apparatus in the British Post Office system is designed to accept pulses from telephone dials with a spark quench as fitted to the 332 telephone, i.e. 2 µF in series with 30 ohms. Use of a spark quench of a different value would be equivalent to mina a dial with a non-standard ratio and would reduce the margin of pulsing performance of the exchange apparatus.

In the present British Post Office non-director automatic system the pulses from subscribers' dials are used, without regeneration, to control calls over several junctions, to the limit set by the cumulative pulse distortion and the margin of the exchange apparatus. Reduction of this margin would inevitably result in a reduction of the limiting distance over which the direct pulses could be used, requiring the provision of more pulse regeneration equipment at exchanges, and the cost of this equipment might easily offset the savings in other directions obtained by the use of a more efficient telephone. It is important therefore that the spark-quench of the 700-type telephone should have a pulse-shaping effect similar to that of Telephone No. 332,

For this reason the 0.9-µF capacitor is connected above the pulsing contact, in Fig. 16, instead of below it; if it were connected below, the capacitor would be in shunt with the contact and would add to the capacity of the spark quench. Connecting the capacitor in this way does not affect the transmission circuit at all, as when the pulsing contact is closed both sides of it are electrically the same point.

The effect of the spark-quench of the 700-type telephone is difficult to calculate as it contains both inductance and capacitance in the dissipative element, but laboratory tests have shown that its pulse-shaping properties are similar to those of the 332 spark-quench, while it performs the primary object of a spark-quench satisfactorily.

It will be seen from Fig. 17 that, as in the 332 circuit, the bell is shunted during dialling by the resistive component of the spark-quench. This shunt prevents the bell tinkling during dialling without recourse to devices such as bias springs. By the use of a 4-wire connexion between telephones connected in parallel to the same line this feature can be extended so that when any telephone connected to the line dials, tinkling of other bells is prevented.

The Need for a 4-way Handset Cord.

In the 332 telephone the basic transmission circuit was rearranged to make one terminal of the transmitter and receiver a common point in the circuit, so that a 3-way handset cord could be used. A similar rearrangement of the 700-type telephone circuit is possible, but has not been made owing to consequent difficulty of providing a satisfactory dial spark-quench without introducing extra components, and because a 4-way cord is more convenient for the type of handset used.

Design for Flexibility.

The introduction of a "new telephone" involves much more than the design and production of one type of table telephone. Lines with lengths between the maximum of the older telephones and the new maximum allowed by the superior transmission of the new telephone can only use telephones having the improved transmission circuit and components. Unless an administration is prepared to limit the choice of telephone, and the type of service, for subscribers having lines with lengths between the limits for the old and the new telephones, it is necessary to provide a complete range of new telephones.

The subscriber to-day has a wide choice of physical designs of telephones; two different table telephones, a wall telephone and a number of special-purpose telephones, while the varieties of service and the facilities available can be judged by the fact that a range of nine different versions of the 300-type table telephone is necessary to cater for them. The number of telephones actually stocked is further multiplied by the range of colours offered, and by the alternative dials used, so that the duplicating of the complete range of older telephones by a similar range of new telephones must be avoided if possible.

The Case Against a" Universal" Telephone.

The multiplicity of telephones of the older type makes attractive the idea of one "universal" version of each physical design of the new telephone, the universal telephone being made suitable for any purpose by simple alteration by the installer when connecting it to a line. There are two major difficulties with a universal telephone:

(a) The majority of telephones required are of the simplest type and it would be very wasteful at these installations to provide a universal telephone which, containing unused components, would inevitably cost more than one designed to fulfil the simple function only.

(b) A universal telephone would need holes for fitting the maximum number of push-buttons and for fixing a label, but the "knock out" method of providing holes, used for wiring holes in block terminals, etc., cannot be successfully applied to telephones because it often gives a ragged edge which is both unsightly and bad for push-button operation. Moulded holes would be necessary and when not wanted they would have to be filled by dummies. Since the holes are unwanted on the majority of telephones this is obviously uneconomic besides being aesthetically undesirable; although unobtrusive plastic dummies are now being used, a telephone with no holes will always look better than one having holes filled with dummies.

A Compromise Solution.

With the first telephones of the 700 series a measure of flexibility has been achieved and the types to be stocked have been reduced without paying the full price of complete flexibility in a single instrument providing all facilities. A simple telephone, coded Telephone No. 700, has been designed, which will satisfy the majority of requirements and meet the economic and aesthetic objections to the use of a telephone equipped for the installation of push-buttons, on the large number of lines on which the facility is not required. In addition, a "flexible" telephone, coded Telephone No. 704, has been designed to reduce the number of types of telephone which have to be stocked.

The Telephone No. 704 has facilities for fitting the maximum number of push-button keys and has a circuit, shown in Fig. 18, that can be adapted to perform the signalling functions of a number of different telephones in the 300 series. (In Fig. 18 the telephone circuit has been drawn to emphasise the signalling paths.)

The price of flexibility, apart from the provision of holes in the case for push-buttons and of dummies for filling the holes not required, is an extra terminal strip and an additional spring in the gravity-switch spring set.

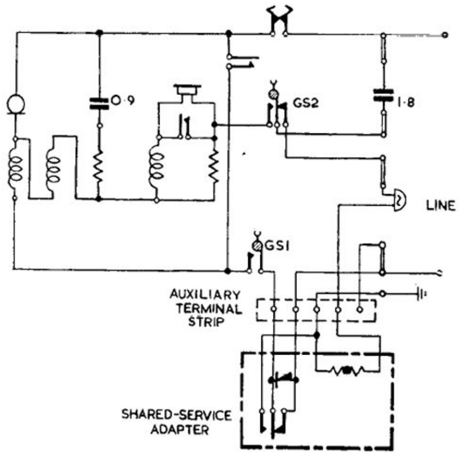


FIG. 18 - TELEPHONE NO. 704, WITH SHARED-SERVICE ADAPTER

The additional terminal strip is the one used in Telephone No.332 for terminating the dial cord. It is used for connecting the keys and other components necessary for adapting the telephone to meet various signalling requirements. The additional gravity-switch spring is required when the telephone is used on shared-service lines to disconnect the earthed bell from the rest of the telephone circuit during a call and so prevent line. noise.

A typical application of Telephone No. 704 is its use on shared-service lines with separate metering. To make the telephone suitable for this purpose an adapter unit, comprising a wired assembly of a key, a rectifier and a thermistor, is fixed within the telephone and is connected into the circuit via the auxiliary terminal strip. Fig. 18 shows the telephone with the. adapter, and an experimental adapter employing a germanium diode in place of the more usual copper oxide rectifier is shown in Fig. 19.

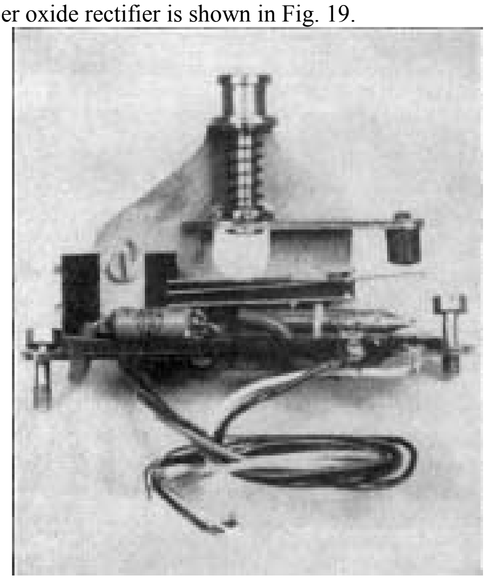


FIG. 19 - EXPERIMENTAL SHARED-SERVICE ADAPTER

The Telephone No. 704 is similarly adapted to perform other functions, the added part being often no more than a key. Apart from avoiding the provision of additional components except when they are actually needed, the use of "add-on" units allows facilities not yet thought of to be provided later by the design of simple adapters rather than complete telephones.

This method of reducing the numbers of stocked types of the new telephone has been applied recently, as a trial, to a new physical design of wall telephone based upon the 332 transmission circuit.

THE COMPLETE TELEPHONE.

Telephones No. 700 and No. 704 have been designed to utilise the case and chassis of the 300-type telephones, preserving many of their proved features. This has enabled telephones containing the new transmission circuit and components to be made available much earlier than if the complete telephone had been re-designed. These telephones will be used to gain experience of the new circuit and to meet urgent requirements for telephones with an improved transmission performance.

Externally, Telephone No. 700 is identical in appearance with Telephone No. 332, except for the change of handset. Internally the visible changes (see Pig. 20) are the replacement of the old induction coil by one with a closed magnetic circuit and the omission of the dial terminal strip.

The chassis wiring is carried out in P.V.C.-covered tinned-copper wire, as in the most recent production of 300-type telephones; this has better insulation properties than the textile and enamel insulated wire used previously, and reduces the risk of unsoldered connexions.

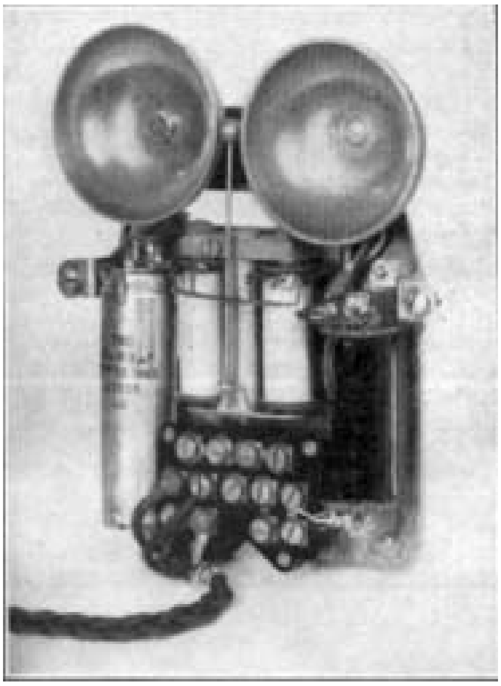


FIG. 20 - CHASSIS OF TELEPHONE NO. 700

The better receiving efficiency of the new telephone might result in its being considered too loud by subscribers on short lines and, when a large proportion of the telephones in service are of the new type, the higher sending efficiency might increase crosstalk and the loading of common equipment amplifiers on coaxial and carrier equipment.

It is probable, however, that these difficulties will not arise because it is known that telephone users lower their voices when the level of side-tone or received speech is high.

To test the reactions of subscribers under these conditions trials are being held in which the telephones are being used as extensions of P.B.X.s on which a large proportion of the calls use very short lines. Pending the completion of these trials, the new telephones will be used on long lines only. If the problem does prove to be a real one it is unlikely that a policy of zoning will be accepted as a final solution since it is uneconomic and undesirable for. the telephone industry to produce more than one basic type of telephone, and a regular supply of repaired old telephones for short lines will not continue indefinitely.

If the trial of the new telephone on short lines shows that regulation will be necessary after the initial zoning period, several different methods are possible, some of which have already been tried by other administrations.

Possible methods are:

(a) Automatic regulators can be included in the telephone circuit, Devices of this type usually regulate receiver or transmitter sensitivity, or both, according to the line current, and utilise either barretters, thermistors or varistors, or combinations of these.

(b) A fixed attenuator, either included in the telephone or fitted as an addition when required, can be included in the circuit by the installer when connecting the telephone to a short line.

(c) Graded transducers of varying sensitivity can be fitted to the handset.

(d) The subscriber can be given control of sensitivity, e.g. by means of a handset switch.

All these methods have disadvantages; it is obviously uneconomic to provide a sensitive telephone and then to provide an expensive device to reduce its sensitivity on short lines. Automatic regulators, besides being expensive, may have a considerable fault liability, relying as they do on non-linear devices whose characteristics may change over a period of years and, possibly, incorporating vulnerable filaments. Preset attenuators and graded transducers pose a difficult problem when a P.B.X. is connected to a long exchange line and its extensions use short lines. A subscriber-operated control increases fault liability due both to the fallibility of switches and potentiometers when frequently used, and to the possibility of mis-operation.

FURTHER DEVELOPMENT

In the immediate future the case of the table telephone will be re-designed to suit better the new shape of handset, with consequent changes to the internal layout of the components. A further objective will be the inclusion of the improved transmission circuit and components in other physical forms of telephones. In this connexion it is of interest that the new wall telephone, with the 332 circuit, recently put into service, was styled so that its case blended harmoniously with the new handset.

A longer-term project for improving the new telephone is the possible replacement of the inset No. 13 by a new transmitter. Tests of the 700-type telephone fitted with an experimental transmitter have shown that the shape of the sending characteristic is considerably improved by its use, and this might result in the articulation efficiency of the telephone being . increased, although the experimental transmitter is little, if any, more sensitive than the inset No. 13. Economic advantage could be taken of any increased sending efficiency 1n the Post Office network because the new telephone at present has a preponderance of receiving efficiency. There would also be physical advantages in the use of a new transmitter; it would be designed to include terminals for direct connexion of the cord and so eliminate the loose contact plate from the handset.

ACKNOWLEDGEMENTS

The valuable assistance of Engineer-in-Chief's Office colleagues in the preparation of this article is acknowledged. Acknowledgements are also due to Standard Telephones and Cables, Ltd., and to the General Electric Co., Ltd., for their co-operation in the project, and in particular to Mr. A. C. Beadle, of S.T.C., for the fundamental design of the transmission circuit.

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