THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 31 OCTOBER, 1938 PART 3

CONTENTS

Price 1/- net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

THEY BUILDED BETTER THAN THEY KNEW

SOME forty years ago the pioneers of the Strowger system of automatic telephony produced their first switching mechanism for the automatic connection of subscribers. It operated upon the decimal principle and it appeared to its originators to be fundamentally sound, although naturally capable of improvement as automatic telephony developed.

Just how sound the principle was is evidenced by the introduction into service of the new type 32A Selector, for this mechanism, which may without exaggeration be described as one of the most important contributions yet made to automatic telephone switching methods, operates upon the same decimal basis of subscriber selection first enunciated forty years ago. This retention of the original principle was by no means regarded as essential when the technicians at Strowger Works commenced their efforts in 1930 to produce a mechanism which would be superior both in operating characteristics and in construction to the highly efficient Strowger Selectors already in service. Those concerned were so bent upon achieving their end that they were prepared to abandon the principle which had proved so successful in the past and to embark upon a new system of operation if one could be found which was definitely superior from every viewpoint.

But their early investigation and the intensive research and exhaustive tests which followed only served to prove that the Strowger principle of decimal working coupled with a selector operating upon the two-motion principle is unsurpassed by any other. Two triumphs are thus typified in the new 32A Strowger Selector. It represents the continued superiority of a forty years old principle and the successful culmination to six years of research and development.

When the lumbering, creaking waggon trains wound their way into the open lands the making of homes was the thought which drove the settlers onward into an unknown country. The building up of a great nation was then something to be talked of around the evening fire, when the work of the day was done and rest-time left imagination free to dwell upon the dreams of to-morrow. The "baseless fabric" of these visions has materialised into great cities and vast communities, relying for their continued existence largely upon facile inter-communication. Automatic telephony meets this need, and also, by a record of continual development and progress, provides evidence that the pioneer spirit is still alive.

AUTOMATIC TELEPHONE & ELECTRIC COMPANY

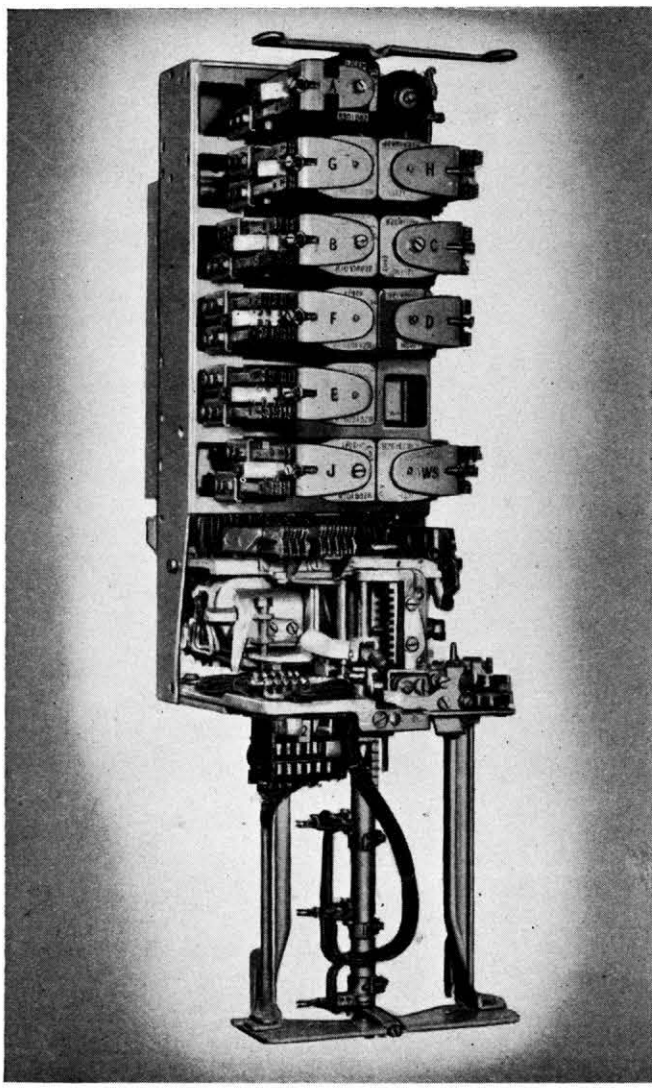
THE STROWGER 32A SELECTOR
(Standardised by the British Post Office as type 2,000)

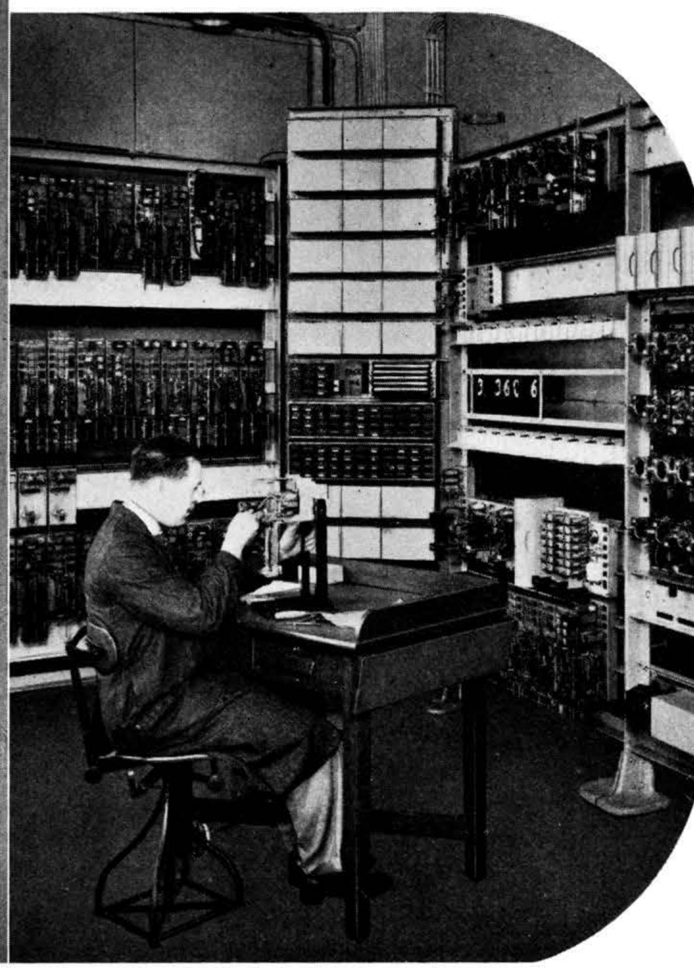
The improvements which the Strowger 32A Selector embodies cover both its operation and its construction. The hunting speed is now almost twice that attained by the previous Strowger selector. It is possible for any one of 2,200 contacts to be selected in 600 milli-seconds—a performance, incidentally, beyond the capacity of any other selector mechanism. The 32A Selector also operates over wider limits of impulse speed and ratio variation. An operational advantage which combines with a constructional improvement is the arrangement made for the return of the wiper carriage to normal after contact selection. The release action is effected by rotary movement in the forward direction off the level and then vertically downwards and back to the normal position, and there is consequently no need for a separate release magnet.

The cubic capacity of the selector is now reduced to approximately 60 per cent. of that of the previous model, with resultant economies becoming possible in floor space and building costs. Yet, although of less dimensions, the selector is of such advanced design, and is so generally flexible, that it can accommodate three times as many contact banks as its larger predecessor, and it is even more robust.

The 32A Selector can be "jacked-in" with a single movement, it being unnecessary to use nuts or screws. Curved "tongues" are fitted at the foot of each of the brackets on the frame extension, and these fit into slots in the cradles attached to the racks. When in position the selector mechanism seats into the cradle, and as the contact banks are themselves mounted on the cradle the selector can be removed or replaced without disturbing the banks or bank wiring, and without any need for re-adjustment of the wipers.

The majority of adjustments to the selector itself can be effected whilst it is in position, and this, combined with the fine limits to which the component parts are manufactured, effects a considerable reduction in maintenance costs.



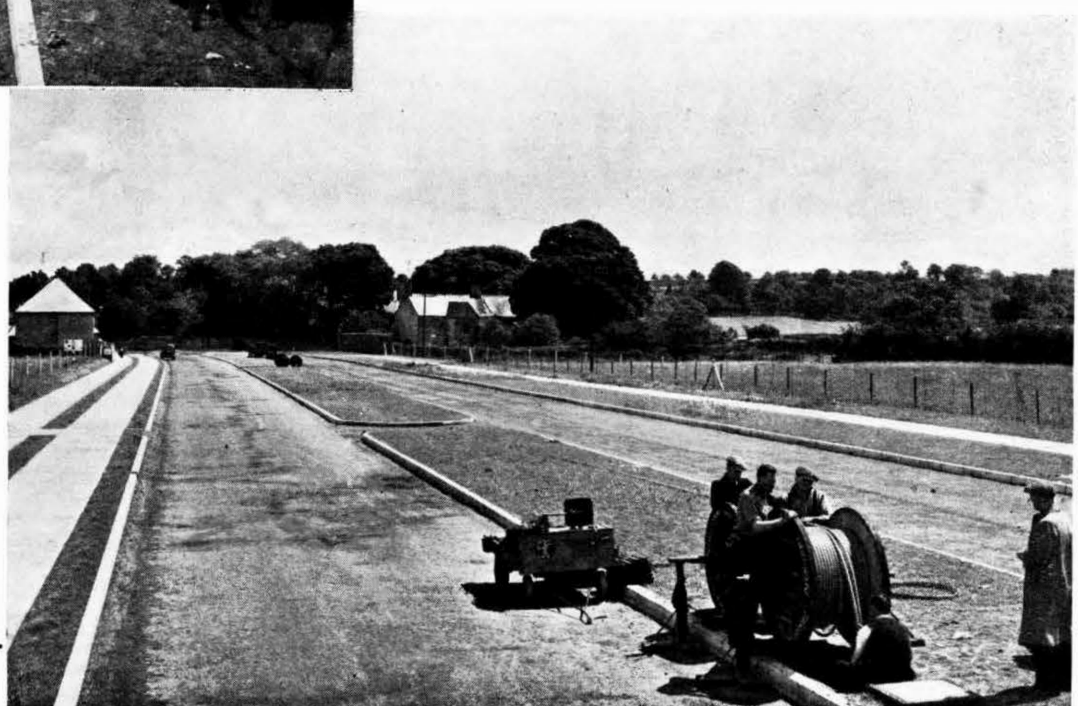


LIMITED · Strowger Works · Liverpool, 7 · England

TRUNK DEVELOPMENT

SIDE by side the development goes on, trunk roads to carry the increased load of motor transport, and *Standard* cables to carry the increased load of telephone traffic.

It is noteworthy that in the latest development "go" and "return" traffic is completely separated both in the arterial road and in the trunk cable. These photographs were taken on the Gloucester-Newport-Cardiff 12-channel carrier telephone cable, manufactured and installed by Standard Telephones and Cables Limited.



Standard Telephones and Cables Limited

NORTH WOOLWICH, LONDON, E.16

Telephone : Albert Dock 1401

BRANCHES AND REPRESENTATIVES THROUGHOUT THE WORLD

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. XXXI October, 1938 Part 3

The Telephone Transmitter: A Suggested Theory of Operation

D. McMILLAN, B.Sc., A.M.I.E.E.

Contemporary theories of the carbon granule transmitter are discussed and found to be unable to explain all the observed performance characteristics of such transmitters. A series of tests, devised to illustrate certain aspects of the operation of telephone transmitters and having particular reference to the phenomenon of amplitude distortion, are described and inferences drawn from the observed results. These inferences lead to the suggestion of a new theory of operation of granular contact transmitters. Examination of this suggested theory indicates that it is well able to explain, both quantitatively and qualitatively, the observed performance characteristics of telephone transmitters. The theory has not yet been proved to be correct by proper experimental investigation, but nevertheless provides a useful basis for design of new transmitters which show much improved operating characteristics.

Introduction.

IN an earlier article in this JOURNAL[1] the author described a series of measurements made with the subscribers' telephone transmitter in order to define the extent and types of distortion introduced by the instrument. A number of distorting influences were noticed and it was obvious that considerable improvement in telephonic communication might be effected if it should be possible to mitigate the severity of the distortions observed. Nevertheless it was thought proper to say (in 1935) that "the distortions produced by the carbon granule microphone are intimately connected with its *modus operandi*, upon which the success of commercial telephony still depends. Attack on these distortions must therefore be made with circumspection and must be based on the results of careful analysis." With this point borne in mind a fresh series of experiments was commenced with a view to elucidating the precise nature of the operation of the carbon granules and so furnishing a more detailed explanation of the sources of the various distortions. These tests have now reached the point where it has become possible to suggest a more or less complete theory of operation of the subscriber's transmitter and to apply this theory to the design of instruments having improved performance characteristics.

It has been found that the suggested new theory can account for the existence of most of the phenomena observed with the carbon granule transmitter and can explain the extent of the effects involved. The new theory has not been rigorously proved by exhaustive experimental investigation, but it nevertheless provides a useful working basis for design and appears to explain the observed phenomena more completely than do other contemporary theories.

It will perhaps be convenient to recall at this point the outstanding distortions which have been observed with carbon granule transmitters. They are:

(*a*) Frequency characteristic distortion which occurs due to the variation of sensitivity of the transmitter as the frequency of the impressed sound pressure is changed;

(*b*) Amplitude distortion which is manifested by a lack of proportionality between the R.M.S. value of the input sound pressure to the transmitter and the R.M.S. value of the E.M.F. generated by the transmitter;

(*c*) Non-linear distortion which is manifested by the generation of unwanted components, e.g. higher harmonics, sub-harmonics, difference tones, etc.

(*d*) The generation of unwanted noises, not harmonically related to the component frequencies of the sound input to the transmitter.

These generalised distorting influences result in a number of undesirable effects, most of which were noted in the earlier article to which reference has already been made.

A good deal of the experimental work carried out on carbon granules (and described in the following pages) was undertaken with a view to clearing up certain anomalies which appear to exist in contemporary theories as at present published. It is thought, therefore, that a brief description of these various theories may form a useful preliminary to the discussion of the experiments and of the deductions to be drawn from them.

Contemporary Theories of the Carbon Granule Transmitter.

A number of important publications recording the work of various authorities on the problem of the carbon-granule transmitter have appeared during the past three years. These recently published works all indicate that the various investigators are concentrating rather on the mechanical than on the electrical properties of the instrument. This represents a new phase—practically all earlier work having considered the problem from the purely electrical point of view.

Drs. F. S. Goucher and J. R. Haynes (Bell Labs.) have published the results of a series of measurements relating the displacement and applied force for a single pair of carbon granules held in contact.[2]

[1] *P.O.E.E.J.*, Vol. 28, pp. 167 and 313.

[2] *Bell System Tech. Journal*, Vol. 13, p. 163, April, 1934; and *Bell Lab. Record*, Vol. 13, No. 11, July, 1935.

Dr. G. W. Sutton has produced a number of papers considering the mechanical performance of complete transmitters.[3]

G. Madia[4] and G. Hara[5] have considered the propagation of mechanical disturbances through long columns of granules and found a form of wave transmission.

Dr. F. S. Goucher (in America) and Dr. G. W. Sutton (in England) appear to be the only workers who have attempted a more or less complete theory of operation of the carbon transmitter.

Drs. Goucher and Haynes have considered the performance of a single carbon contact. They have measured the displacement resulting from the application of a given force (unidirectional) and deduced a law relating displacement to force (see the references quoted above). Fig. **1** (a) illustrates a typical curve published by Haynes.

Dr. Goucher states that

$$F = KD^x \qquad \ldots\ldots (1)$$

where F is the applied force, D is the resulting displacement, K is a constant and x is experimentally determined to be **3** (above a small limiting value of D). If the granules are considered as spheres, x may be calculated and is found to be **1·5**. Goucher concludes, and indeed verifies experimentally, that the granules may be considered as spheres which carry small hemispherical " hills " on their surfaces ; x then becomes nearly **3**.

Dr. Goucher proceeds to the theory that, when operating in a transmitter and subjected to an alternating force, the granules are held in contact by a fixed force and displaced about this reference position according to the curve of Fig. **1** (*a*) ; i.e. the granules are subjected to a total force which oscillates about a fixed value and displacements occur according to the curve. In this connection it should be observed that equation (1) applies only so long as the granules remain in contact with one another. If they separate a different equation must be used to take into account the discontinuity at $F = 0$. At first sight this theory is quite promising. It can immediately be deduced :

(*a*) that a decrease in the static force holding the granules in contact will result in an increase in the sensitivity of the transmitter ;

(*b*) that an increase in the alternating force applied to the granules will result in a reduction in the effective force (static) holding the granules in contact, due to the curvature of the force/displacement characteristic, and hence in an increase in the sensitivity of the transmitter. A reduction in the effective granule stiffness is implied ;

(*c*) that this reduction in the effective static force holding the granules in contact will result in an increase in the resistance of the transmitter.

All these effects are observed in practical transmitters, but considerable difficulties are encountered when attempts are made to account for the amount of the effects by the theory.

Consider first the stiffness of the granule column.

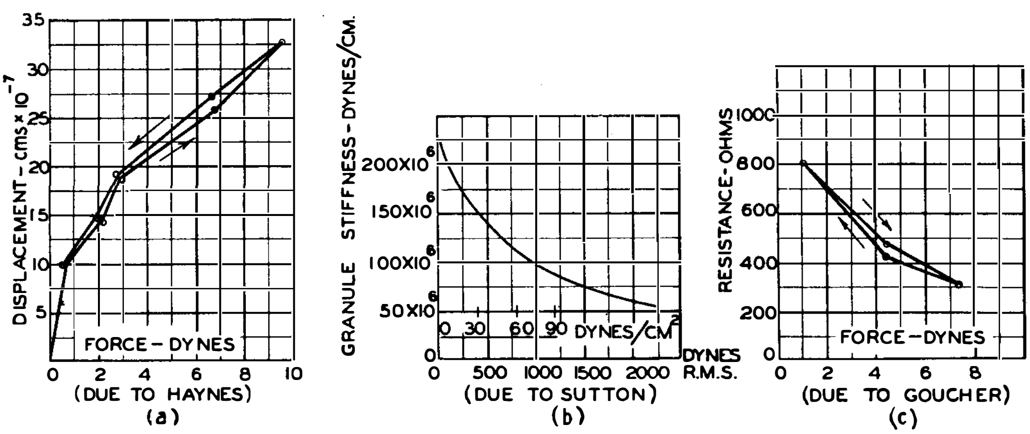


FIG. **1**.—PERFORMANCE CHARACTERISTICS OF CARBON GRANULE CONTACTS.

Stiffness is defined as the force required for unit deflection of an elastically controlled body.

Hence the stiffness of a single granule contact

$$= S_F = \frac{dF}{dD} \text{ (from equation 1 and Fig. 1 (a)).}$$

$$\text{i.e. } S_F = kF^{\frac{x-1}{x}}, \text{ where } k = \frac{xK}{K^{\frac{x-1}{x}}} \qquad \ldots\ldots (2)$$

If $x = 3$,

$$S_F = kF^{\frac{2}{3}}, \qquad \ldots\ldots (3)$$

It has already been noted that an increase in applied alternating force causes a reduction in the effective static force holding the granules in contact (F). One would therefore expect, from equation **3**, that a reduction in granule stiffness will also occur. Dr. G. W. Sutton has observed such an effect by means of vibrometer measurements and has published a curve relating stiffness and applied alternating force. This curve is reproduced as (*b*) of Fig. **1**. The author's measurements of the effective stiffness of the

[3] Engineering Supplements, *Siemens Magazine*, No. 118, March, 1935 ; No. 129, February, 1936 ; and No. 139, August, 1936.

[4] *Elektrische Nachrichten Technik*, October, 1934.

[5] *Elektrische Nachrichten Technik*, July, 1935.

mechanical system of the Post Office standard transmitter, an Inset No. 10, using an entirely different method of measurement, generally confirm Dr. Sutton's conclusions. Fig. **2** illustrates a typical

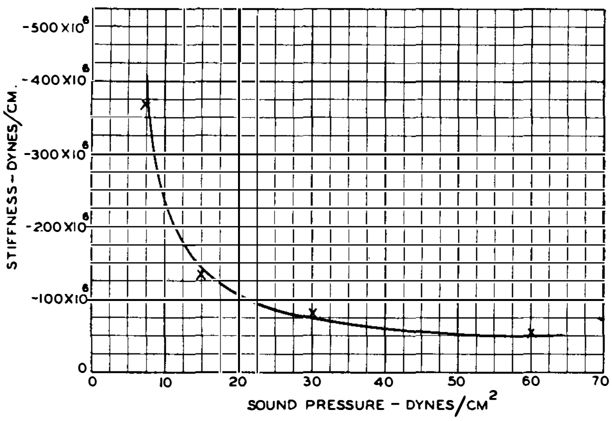


FIG. **2**.—RELATIVE STIFFNESS OF TYPICAL INSET NO. 10.

curve relating sound pressure and stiffness. From this last curve it is seen that the total stiffness has extreme values having a ratio of at least 4 : 1,

$$\text{i.e.}\ \frac{S_{F_1}}{S_{F_2}} = \frac{k\,F_1^{\frac{2}{3}}}{k\,F_2^{\frac{2}{3}}} = \left(\frac{F_1}{F_2}\right)^{\frac{2}{3}} = 4$$

Hence, $\frac{F_1}{F_2} = 8$.

This means that, if any point on the curve of Fig. **1** (*a*) is taken as the static, or rest, point, then applying an alternating force to the granules, the effective operating point must move to a value of force (static) equal to about one-eighth of the value originally chosen as the static point. A simple calculation, elaborated later in this paper, indicates that the static force holding two granules in contact is probably less than 0·5 dyne and certainly less than 1 dyne (for an Inset No. 10). Referring again to Fig. **1** (*a*), it is most unlikely that a normal static force of 0·5 dyne will be reduced to an effective value of about 0·06 dyne by the application of an alternating force having a peak value of less than 0·5 dyne. The application of larger alternating forces will cause the granules to separate and preclude the use of the equations given by Dr. Goucher. Thus the theory of elastic deformation of the granules during their alternating displacement about their mean position fails to explain the magnitude of the observed stiffness change with change of alternating force.

Consider now the amount of amplitude distortion produced by an Inset No. 10. Measurements have indicated that a fairly typical Inset No. 10 shows a change in total stiffness of from 350×10^6 to 80×10^6 dynes per cm. for a change of applied sound pressure of from 7·5 to 30 dynes per sq. cm. (12 db.) (see Fig. **2**). The output voltages (open circuit) from the inset for these two values of sound pressure at 1,300 c.p.s. were found to be in the ratio

$$\frac{E_{30}}{E_{7\cdot5}} = \frac{\cdot27}{\cdot015}$$

This is a ratio of 25·3 db. indicating that the sensitivity of the inset (volts per dyne per sq. cm.) has changed by 25·3 — 12 = 13·3 db. for the above-mentioned changes of applied sound pressure. At so low a frequency as 1,300 c.p.s. the inset will be substantially stiffness-controlled, and one would expect a change of sensitivity due to the change in effective stiffness.

From Fig. **2** $\frac{S_{30}}{S_{7\cdot5}} = \frac{350}{80}$

i.e. a ratio of 12·8 db.

A further cause of amplitude distortion, as measured by observing the open-circuit voltage, is to be found in the increase of the mean electrical resistance with increase of sound pressure. This increase of resistance results in an increased p.d. across the transmitter for a constant value of polarising current, and hence operates to increase the sensitivity at the higher levels of sound pressure. The Inset No. 10 under discussion showed a rise from 24 to 34·3 ohms at 1,300 c.p.s. for the change from 7·5 to 30 dynes per sq. cm. The ratio 34·3 : 24 may be expressed as 3 db., and hence one would expect a total change of sensitivity of about 12·8 + 3 = 15·8 db., which compares reasonably well with the measured value of 13·3 db. Thus the whole of the amplitude distortion at the higher values of sound pressure may be explained by reference to the measured values of change of stiffness and change of mean electrical resistance. This fact, coupled with the fact that similar curves relating granule stiffness and applied alternating force have been obtained by Dr. Sutton and by the author, each using an entirely different method of measurement, lead to the belief that changes of stiffness of the order of those measured do actually occur in practice. If this is agreed, then one must abandon Dr. Goucher's theory as the complete explanation of the mechanical operation of the granules.

Consider now the D.C. resistance of a carbon granule transmitter.

Dr. Goucher[2] states "The electrical current is carried through regions in intimate contact, and changes in resistance under strain are due both to a variation in the number of microscopic hills which form the carbon surface and to area changes at the junctions of these hills arising from their elastic deformation in accordance with the well-known laws of elasticity." He has measured the resistance/force relationship for a single contact between a granule and a polished plate ; Fig. **1** (*c*) illustrates the results. He points out that the performance of an aggregate of granules will be similar to that of a single contact, the scales of resistance and force being different, and that the curve of Fig. **1** (*c*) will illustrate the general shape to be expected.

It has already been noted that Dr. Goucher's theory of the operation of the transmitter leads one to expect a reduction in the static force holding the granules in normal contact upon the application of an alternating force, and that the amount of reduction to be predicted from his theory is small as compared with that required to explain the mechanical performance of a practical transmitter. A similar result is obtained if the practical resistance change measured with an Inset No. 10 is considered.

With 50 mA polarising current the D.C. resistance of the particular Inset No. 10 discussed above changed from 24 to 112 ohms when the applied sound pressure (at 1,800 c.p.s.) was raised from 7·5 to 60 dynes per sq. cm. This is a resistance ratio of almost 1 : 5 and would require a change of the effective force holding the granules in contact in the ratio of at least 1 : 10 (from Fig. **1** (*c*)). It has already been observed that such large ratios of effective static force are unlikely. It is true that Fig. **1** (*c*) is drawn for values of static force which are greatly in excess of those believed to exist in the practical transmitter, and it is certainly possible that the slope of the curve may become greater at low values of force. Nevertheless, it is difficult to imagine that the change of slope can be sufficient to account for the observed effects, for, from Fig. **1**(*a*), a normal static force of 0·5 dyne is not likely to be reduced in effective value by more than, say, 10 per cent. due to the application of a small alternating force less than 0·5 dyne peak value. This small reduction in effective force holding the granules in contact has to cause an increase of contact resistance of 400 per cent. The magnitude of the observed change of resistance is thus out of all proportion to that which would be predicted by a straightforward application of Dr. Goucher's theory.

There is a further serious difficulty encountered in the application of the theory. Measurements show that the amount of change of resistance of a transmitter with change of applied sound pressure is dependent on the polarising current. The effect is considerable; the values of 112 and 24 ohms, respectively, for 60 and 7·5 dynes per sq. cm. at 50 mA polarising current become 180 and 25 ohms at 20 mA polarising current and 69·5 and 28 ohms at 120 mA polarising current. Consideration of these results, together with some further tests to be elaborated in a subsequent section, indicates that the effect is not due to change of temperature. Dr. Goucher's theory does not appear to admit of a simple explanation of this phenomenon.

Dr. Sutton has stated the "elastic granule" theory of operation in a somewhat modified form. As a result of his measurements of granule stiffness at various values of applied alternating force (see Fig. **1** (*b*)), he concludes that the front electrode of a transmitter will move outwards to a mean position farther away from the back (fixed) electrode when the applied alternating force is increased. This movement is regarded as likely to reduce the "fluid pressure" (Sutton) in the granules and hence to increase the resistance of the transmitter. Such a theory is satisfactory up to a point. But it really involves an acceptance of the "theory of elastic distortion" in so far as the latter applies to change of resistance of the granules and a tacit ignoring of the fact that the elastic distortion theory cannot account for the measured change of stiffness with change of applied alternating force. Also, Dr. Sutton's theory does not attempt to explain the phenomenon mentioned above, viz., the dependence of resistance change with change of applied alternating force on the polarising current.

A number of German workers have made interesting contributions to the theory of the transmitter. Notably, G. Madia has made a series of observations of the resistance change at various points along a column of granules excited at one end by an alternating force. He concludes, from experimental results, that the disturbance is propagated through the granules as a form of wave disturbance, and he observes a maximum of efficiency in the range 2,000-2,500 c.p.s. for the column of granules normally used in a particular type of German transmitter, which he attributes to wave phenomena. Dr. Sutton has also observed phase differences to exist when measuring the alternating resistance of a granule column at different points along its length.

G. Hara has made a theoretical and practical investigation of this wave-propagation theory. He considers the granules to be elastic particles of a definite mass which are in contact with one another and which operate as a mechanical low-pass filter. A velocity of wave propagation of about 44 metres per second is found for a long vertical column of carbon granules, and this figure is used to explain the peak of sensitivity at 2,000-2,500 c.p.s. observed by Madia.

The wave-transmission theory throws no light on the amplitude distortion and resistance variation phenomena which are of fundamental importance to the designer of transmitters. Nevertheless, the theory is interesting since, as developed by G. Hara, it postulates elastic granules which remain in contact with one another, in just the same way as does the more complete theory of Dr. Goucher. G. Hara uses a very long vertical column of granules for his tests and is consequently observing the performance of granules held together by much larger static forces than exist in the ordinary practical transmitter.

It has already been noted that Dr. Goucher's theory of operation of the carbon granule transmitter does not appear to explain quantitatively the observed performance characteristics of a practical transmitter. Further, it cannot easily be made to explain, even qualitatively, all the observed phenomena. The other theories considered have been either extensions or modifications of Dr. Goucher's theory or else have no reference to amplitude distortion or resistance change, and have thus been incomplete. Dr. Goucher's theory, as at present published, depends on

- (*a*) the assumption that the alternating force applied to a pair of granules is never sufficient to overcome the static force and to cause the granules to separate; and
- (*b*) arguments centred around the results of a comprehensive series of measurements of the relationships existing between the applied force and the resulting displacement and electrical resistance of a pair of granules maintained in contact with one another.

In so far as (*b*) is concerned, the work of Drs. Goucher and Haynes is original and convincing. The validity of assumption (*a*) is thus questioned and one is led to the conclusion that it is probably worth while making an experimental investigation to determine whether or not the granules of a practical transmitter do separate from one another and from the electrodes during normal use conditions.

Theoretical Considerations of the Mechanical Performance of a Transmitter Inset No. 10.

A Transmitter Inset No. 10 is a convenient instrument to use for such an investigation. The dimensions of the various parts of the granule chamber of the transmitter are easily measured and the sizes and weights, together with the density of packing, of typical granules are also fairly easy to determine. It therefore appears that the average static and dynamic forces operating on individual granules of a transmitter under various conditions of use might be calculated with a fair degree of accuracy.

Fig. **3** illustrates the granule chamber and electrodes of a typical Inset No. 10. Fig. **3** (a) shows a vertical

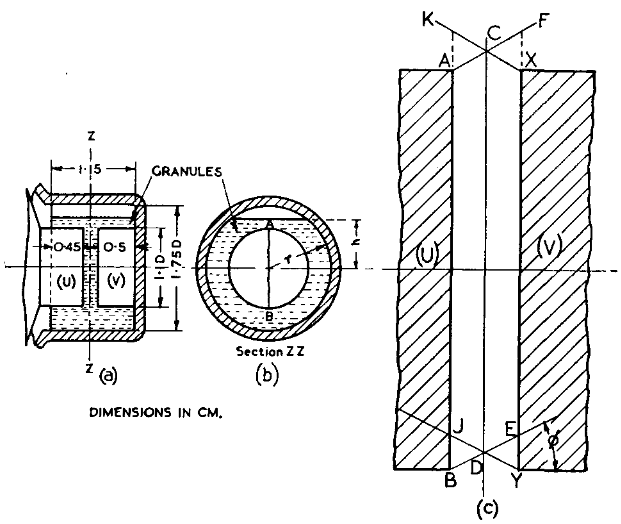


FIG. 3.—GRANULE CHAMBER OF INSET NO. 10.

cross-section of such a chamber in the plane of the axes of the electrodes; (b) shows a second cross-section in the plane at right angles to the axes of the electrodes; and (c) is merely an enlargement of part of (a).

Consider now an elementary vertical strip of electrode of width equal to the average diameter of one granule and situated about the centre of the electrode. This elementary strip is illustrated by AB in Fig. **3** (b and c). Lines ACF and BDE have been drawn on (c) such that the angle ϕ is equal to the angle of repose for typical granules. ϕ has been measured and is about 27°. The line XY represents a vertical strip of electrode similar to AB, but situated on the opposite electrode. Lines XCK and YDJ are obviously inclined at ϕ to the horizontal. The horizontal component of force on the elementary strip AB of electrode U may be considered, as an approximation, to be due to the parallelogram of granules ABEF. The pressure on the strip increases from a small value at A to its maximum value at B. The horizontal component of force holding any two granules in contact with one another is probably nearly constant along any horizontal line parallel with the common axis of the electrodes which joins the two electrodes. For example, the horizontal force on a granule situated on the line CD is due to the simultaneous and opposite action of the two parallelograms of granules CDEF and CDJK, the net effect being almost certainly very similar to the effect produced at AB by the parallelogram of granules ABEF acting in a single direction. It must be emphasised that this conception of "planes" of granules, one granule thick, is not strictly admissible. Nevertheless, it forms a useful basis for approximate calculations.

Appendix I to this article details certain calculations which have been made to determine the magnitudes of the horizontal (static) forces normally holding the granules in contact. A range of values of from 0·029 to about 0·5 dyne from A to B (on the line AB) is found. An average value of 0·1 dyne appears to be reasonable. It may be noted that the line AB is the longest possible vertical strip of granules in contact with the electrode. Other vertical strips will not experience the relatively large forces existing at the lower end (B) of this longest strip, and hence it appears that a general average horizontal component of force per granule of 0·1 dyne may be assumed without fear of a serious under-estimate of the size of the force.

The effective area of the diaphragm of an Inset No. 10 is about 15 sq. cm. The area of an electrode in the same transmitter is about 0·95 sq. cm., and the number of granules in contact with the electrode is about 1,300. If each granule exerts an average horizontal force of 0·1 dyne on the electrode we have a total reaction force of 130 dynes acting on the electrode. This force will be exceeded if the R.M.S. sound pressure applied to the diaphragm of the transmitter exceeds P dynes per sq. cm., where

$P = \frac{130}{15 \times 1{\cdot}414} = 6{\cdot}5$, say 7 dynes per sq. cm. This calculation applies accurately only at those frequencies where the moving system of the inset is "stiffness controlled"—i.e. below resonance. In this condition, for small applied sound pressures the stiffness of the granules will be large as compared with the effective stiffness of the diaphragm of the inset. Thus, since a good many granules are held in contact by static forces of less than 0·1 dyne, a fairly large proportion of the granules will part contact with the diaphragm and with one another for an applied sound pressure of 7 dynes per sq. cm., and probably all the granules will be separated for slightly larger forces. It must be remembered that, once a granule is free from the diaphragm, some of the force normally available to drive that granule becomes transferred and applied to other granules still maintaining contact, so that an increase in the force will have a disproportionately large effect in freeing further granules from contact with the diaphragm.

One would thus expect that, for small applied alternating forces, a number of granules near the electrode tend to move bodily with it and increase the effective mass. These granules remain in contact with one another and exert both mass and stiffness constraints on the motion of the electrode. Other granules, held together by weaker forces, e.g. those near the top of the electrode, tend to separate and to bounce about under the influence of the alternating force. As the applied force increases, so more and more granules separate from one another and from the electrode until all are bouncing about freely. For very low values of sound pressure, less than 1 dyne per sq. cm., it is probable that the Transmitter Inset No. 10 operates almost entirely according to Dr. Goucher's theory of elastic granules. Experiments show that the instrument has a relatively good amplitude characteristic at these low pressures.

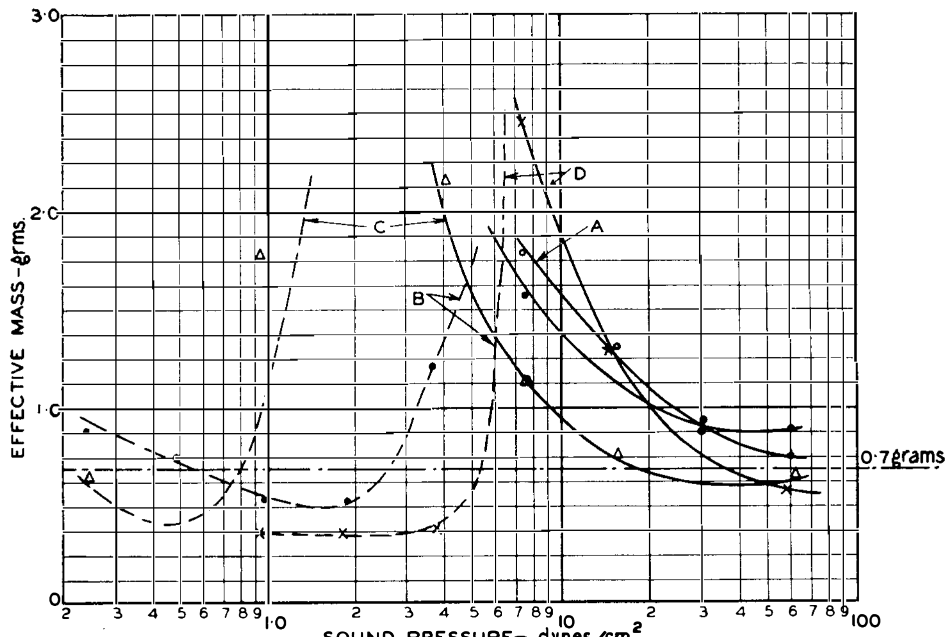


Fig. 4.—Effective Mass of Inset No. 10.

It is well known that a telephone transmitter sustains sound pressures ranging up to more than 100 dynes per sq. cm. in practice. It is probable that the range 1 to 40 dynes per sq. cm. ("free field" pressure) is the most important, and thus the granules must be considered to separate from one another over a large proportion of the range of input sound pressures to be received by the transmitter in practical operation.

Such a separation of the granules, from one another and from the electrodes, is almost certain to reduce the mechanical reaction of the granules on the moving system of the whole transmitter. One would expect that the effective stiffness of a granule column, operating according to the theory detailed above, would be reduced as the applied alternating force is increased; it also seems probable that the rate of reduction would be greater if the granules separate than if they remain in contact with one another and with the electrodes.

In discussing contemporary theories of the transmitter it was observed that a large reduction in the mechanical stiffness of the granule column occurs as the sound pressure applied to the transmitter is increased. The extent of this reduction was found to be far greater than could be explained on the assumption that the granules remain in contact. It can now be seen that a theoretical consideration of the magnitudes of the forces acting on individual granules tends to confirm the implied suggestion that the granules actually separate from one another and from the moving electrode of the transmitter.

Measurements of the Mechanical Performance Characteristics of an Inset No. 10.

A comprehensive series of tests has been made to determine the mechanical constants (effective mass and stiffness) of the various parts of a number of sample Insets No. 10. Space does not permit a detailed discussion of the experimental procedure adopted, but Appendix II contains a brief description of the method used for the measurement of the effective mass and stiffness of the complete vibrating system of an inset transmitter. The whole series of tests involved a very large number of separate measurements, the results of which can only be given in summarised form.

The effective mass and stiffness of the moving system of a number of Transmitters, Inset, No. 10, tested without the metal guard and oiled silk membrane, were first measured over a range of sound pressures. Figs. 4 and 5 show the curves of mass and stiffness respectively for four of these samples. It will be seen that, as the applied sound pressure is reduced below 60 dynes per sq. cm., the effective stiffness increases, following the general shape of the curve given by Dr. Sutton (Fig. 1 (*c*)). The effective mass changes in a similar manner, increasing as the sound pressure is reduced. It will be noted, however, that with each sample a critical value of sound pressure exists below which the stiffness and mass no longer progressively increase as the sound pressure is reduced.

The approximate values of critical pressure obtained from the curves are given in Table I.

Table I.

Transmitter	Critical Pressure
A	7·5 dynes per sq. cm.
B	6 ,, ,,
C	3 ,, ,,
D	7 ,, ,,

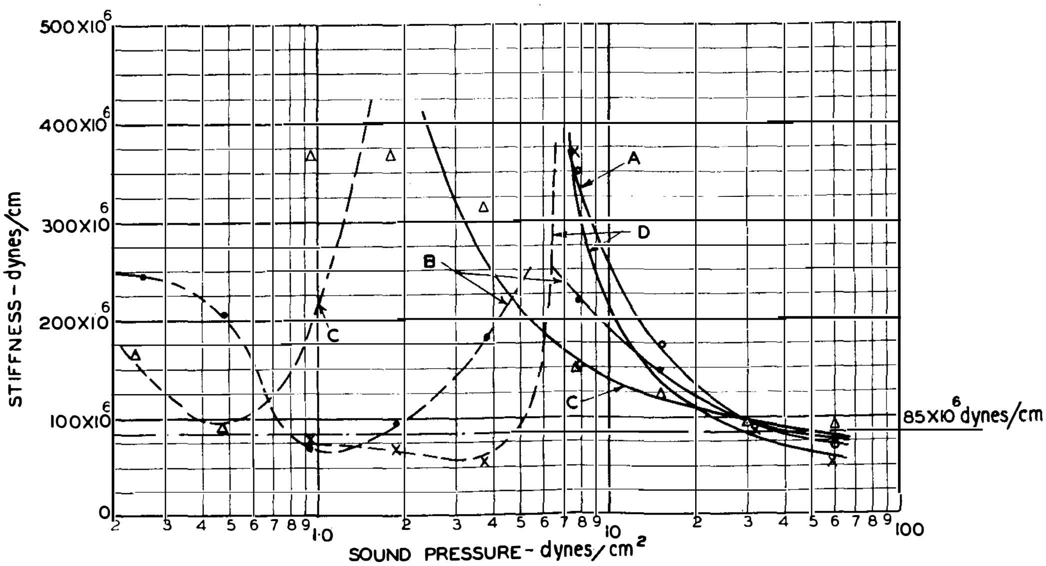


FIG. 5.—EFFECTIVE STIFFNESS OF INSET NO. 10.

As already calculated, many of the granules of an average Inset No. 10 will become separated from one another and from the front electrode for applied sound pressures in excess of about 7 dynes per sq. cm. The values of critical pressure listed in Table I are therefore very suggestive. The curves of stiffness and mass indicate a more or less sudden change of performance at or about the sound pressure value which is believed to be just sufficient to cause substantial separation of the granules of an Inset No. 10.

A further series of tests was then made to determine the effect of changing the amount of granules used in the transmitters. The four insets referred to above were each filled with about 1·5 grams of granules when received from the contractors. Samples A and D of these four transmitters were emptied and the granules replaced by new charges ranging from 1·2 to 1·8 grams. The critical sound pressures were measured and are listed in Table II.

TABLE II.

Transmitter	Mass of Granules Grams	Critical Pressure (approx.) Dynes per sq. cm.
D	1·8	10
	1·6	6
	1·5	1·8
	1·4	2·5
	1·2	0·5
A	1·8	15
	1·6	6
	1·5	4
	1·4	Too low to measure
	1·2	

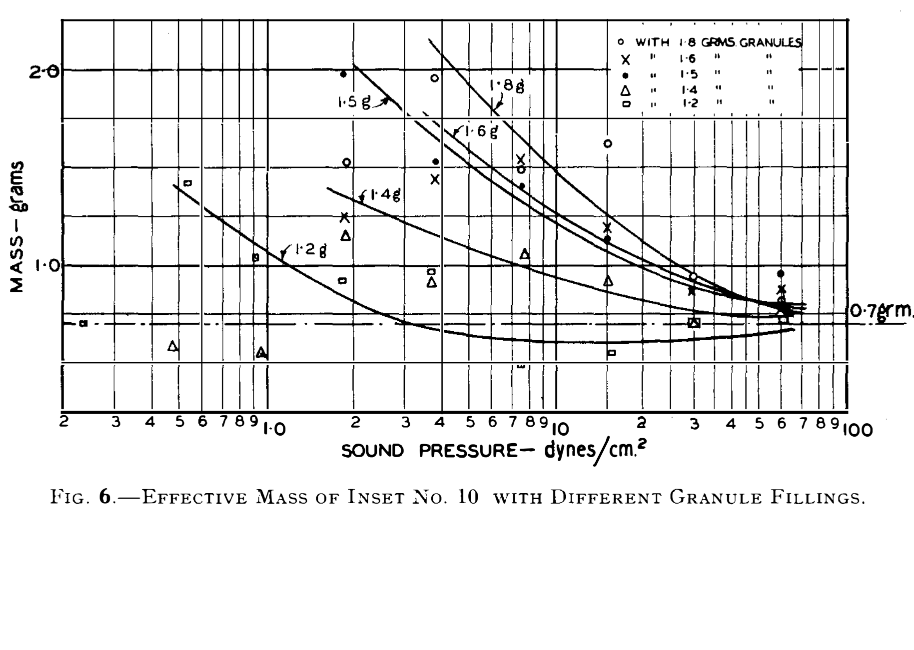


FIG. 6.—EFFECTIVE MASS OF INSET NO. 10 WITH DIFFERENT GRANULE FILLINGS.

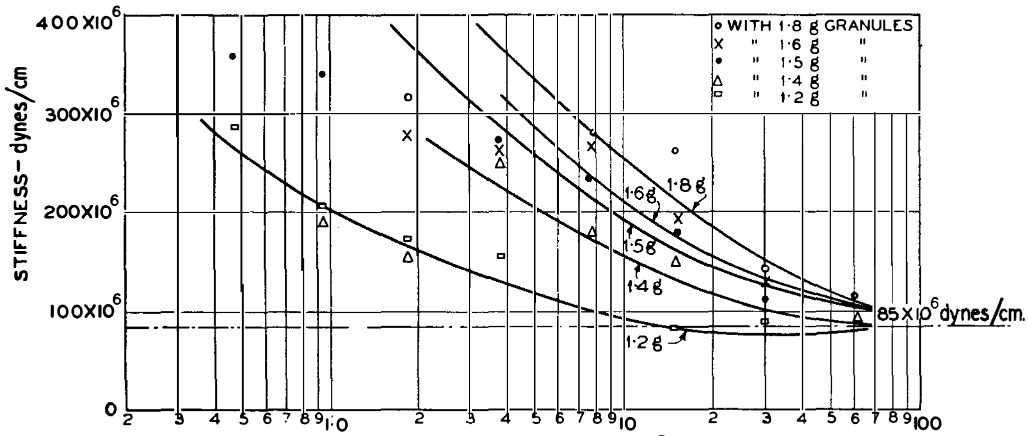


FIG. 7.—EFFECTIVE STIFFNESS FOR DIFFERENT GRANULE FILLINGS.

In general, the critical pressure becomes lower as the quantity of granules used is reduced. This is in accordance with the theory suggested above, since a reduced granule filling means a reduced head of granules and hence a smaller static force between the granules. Figs. **6** and **7** show the actual value of mass and stiffness obtained with transmitter D, over a range of sound pressures, for each quantity of granules. It is realised that the test points shown on these diagrams do not strictly justify curves of the shape shown. The shape of the curves was not determined solely from a consideration of this particular set of measurements; the results of a number of such tests were taken into account, and it is thought that some such family of curves as that shown represents a fair illustration of the effects of change of the quantity of granules. A considerable number of measurements of effective mass and effective stiffness of complete insets has been made in the manner described above and, in each case, the curve relating the mass, or the stiffness, to the applied sound pressure is of the form illustrated by the examples quoted.

The test results so far described give values of the effective mass and effective stiffness of the complete moving system of an Inset No. **10** (used without oiled silk membrane or metal guard). This complete mechanical system may conveniently be divided into three main parts, viz. :—

(*a*) The metal diaphragm and attached electrode which together introduce a component of mass and a component of stiffness ;

(*b*) The air trapped between the back of the diaphragm and the case of the inset which introduces a component of stiffness ;

(*c*) The granule column which contributes the remaining stiffness and mass required to complete the whole values as measured by the tests discussed above.

The values of mass and stiffness introduced by parts (*a*) and (*b*) have been isolated by measurement and confirmed by calculation from fundamental principles, and are found to be as follows :—

Diaphragm and front electrode: effective mass 0·7 grams and effective stiffness 12×10^6 dynes per cm.

Air trapped behind diaphragm: effective stiffness 73×10^6 dynes per cm.

The figures represent average values for a number of transmitters and indicate that the moving system of an average inset, excluding the granules, has an effective mass of 0·7 grams and an effective stiffness of 85×10^6 dynes per cm.

These values have been marked on the curves of mass and stiffness respectively (see Figs. **4**, **5**, **6** and **7**). It will be seen that, within the accuracy of the method, the values of the total mass and stiffness approach asymptotically these particular values of mass and stiffness as the sound pressure is increased. It may therefore be inferred that the effective mass and effective stiffness of the granules approach zero or a small finite value as the sound pressure is increased. Fig. **8** shows the average values of effective mass and effective stiffness of the granules over the range of sound pressures for the four insets referred to

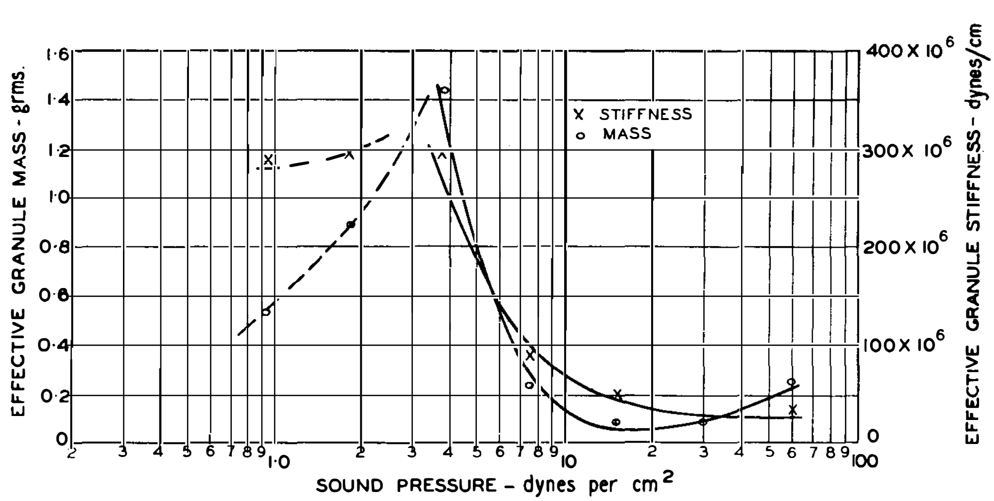


FIG. 8.—AVERAGE EFFECTIVE STIFFNESS AND MASS OF GRANULE COLUMN OF AN INSET NO. 10.

earlier—after refilling each with an accurate 1·5 grams of granules. The tendency of the effective mass to rise slightly at the higher pressures has not been investigated. The rise occurred with most of the transmitters considered, and is not likely to be due to experimental errors, the accuracy of the method of test being reasonably good at the higher values of sound pressure. The values of granule stiffness shown are lower than those published by Dr. Sutton (see Fig. **1**). No curves of the effective mass of the granules have been given by Dr. Sutton.

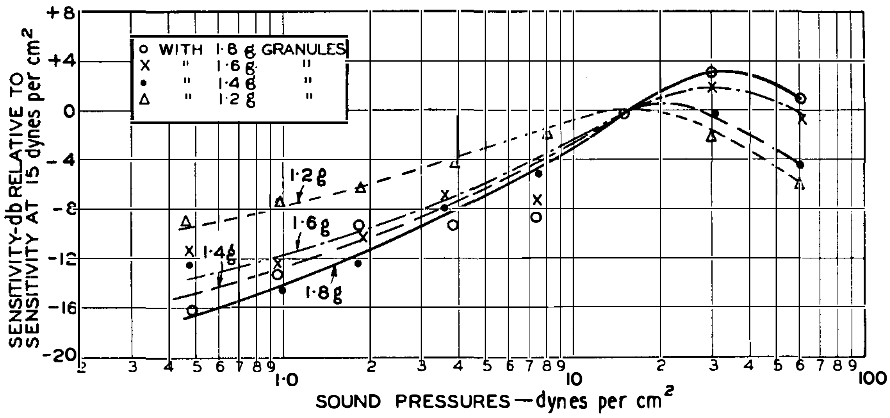


FIG. **10**.—AMPLITUDE DISTORTION WITH DIFFERENT GRANULE FILLINGS.

The Effect of Changes of Effective Mass and Stiffness on the amount of Amplitude Distortion introduced by a Transmitter.

The test results given in the author's earlier article drew attention to the degradation of transmission which might conceivably result from the serious amplitude distortion introduced by the Tele. **164** transmitter. Reference to the frequency characteristics published in that article shows that high-frequency sounds of relatively small amplitude are liable to be badly attenuated, due to (*a*) the general shape of the frequency characteristics, and (*b*) the fact that the sensitivity of the transmitter drops very considerably as the input sound pressure is decreased. Such high-frequency, small-amplitude sounds exist alone for perceptible periods in ordinary speech, and since it is known that good articulation depends largely upon their audibility there is reason to regard serious amplitude distortion as a particularly undesirable form of distortion. It is therefore important to consider in detail the causes of the distortion and to attempt to formulate a method of controlling its severity.

Earlier in this article a simple calculation was made to show that at a frequency below resonance the change of effective stiffness and the change of mean electrical resistance of an Inset No. 10 for a change in applied sound pressure operated together and in the same sense, to cause the sensitivity of the transmitter to increase with increasing sound pressure. It was noted that the changes of stiffness and of electrical resistance were together sufficient to account for the whole of the observed amplitude distortion. The more constant values of granule stiffness and mass with changing sound pressure which result from a reduction of the amount of granules used to fill a transmitter should therefore effect an improvement in the amplitude distortion. Fig. **9** shows that this improvement is, in fact, obtained. The curves refer to sample D of those insets discussed earlier. The diagram illustrates the improvement resulting from a change of charge of from 1·57 grams to 1·2 grams. Fig. **10** is drawn to show, in another form of presentation, the variations of sensitivity occurring with an Inset No. 10 as the applied sound pressure is

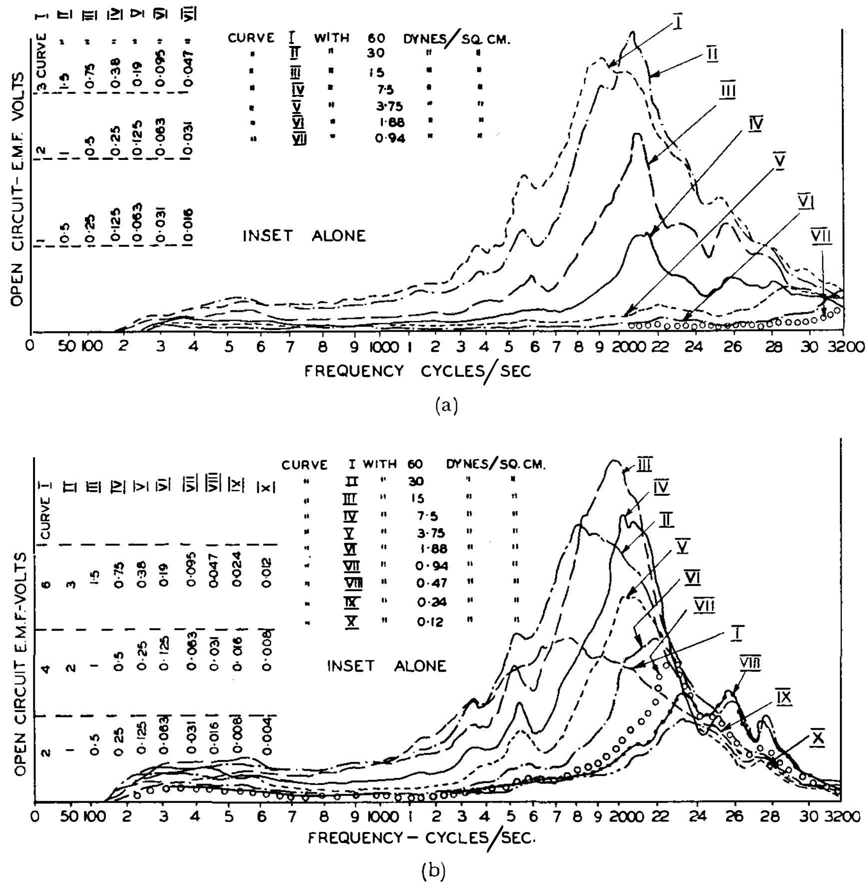


FIG. **9**.—FREQUENCY CHARACTERISTICS ON AN INSET NO. 10.
(a) WITH 1·57 GRAMS GRANULES. (b) WITH 1·2 GRAMS GRANULES.

altered. The various curves of this figure refer to different amounts of granules and it is clearly seen that the sensitivity of the transmitter tends to become more constant as the granule filling is reduced.

This effect is entirely consistent with the theory of separating granules since a reduction in granule filling would be expected to result in reduced static forces within the granules and hence in a more easy separation of the granules and more constant values of effective granule stiffness and mass over the operating range of sound pressures. More recent tests, using electrodes of various shapes each designed to cause easy separation of the granules, have confirmed that amplitude distortion may be almost eliminated by arranging that the granules are held together by comparatively small static forces and are thus encouraged to separate from one another for small values of applied sound pressure.

Such a transmitter as is described above, an Inset No. 10 with only 1·2 grams of granules, is not of great practical value. The performance deteriorates greatly when the plane of the diaphragm is moved from the vertical, and large resistance changes may be caused by violent mechanical agitation. Nevertheless, in view of the much improved frequency characteristics due to the reduced amplitude distortion, the transmitter was submitted to a few speech tests. The results indicated that the performance of the modified inset operating in the normal position was superior to that of the standard inset. It was, therefore, concluded that the use of a smaller static pressure within the granule aggregate did not introduce serious distortions which are not shown by a family of frequency characteristics.

The observed effects of mass and stiffness may be summed up as follows:

(*a*) Both the effective mass and the effective stiffness of an Inset No. 10 become progressively reduced as the applied sound pressure is increased above a certain "critical value." Both mass and stiffness approach asymptotically the values for the diaphragm and enclosed air alone; i.e. the effect of the granules on the total mass and stiffness becomes negligible at large values of sound pressure ($>$ 30 dynes per sq. cm.).

(*b*) Below the critical pressure the mass and stiffness are somewhat indeterminate—to some extent due to the difficulty of measurement of the resonance frequencies. (See Appendix II.)

(*c*) The value of the critical pressure decreases as the filling of granules in the transmitter is reduced. This results in a reduction, over a wide range of sound pressures, of the added stiffness and mass due to the granules, and hence in an improvement in the amplitude characteristic over this range of sound pressures.

(*d*) The value of critical pressure agrees very well, in general order of magnitude with the value calculated to cause substantial separation of the individual granules.

The critical pressure effect does not seem to be due in any way to the failure of piston action of the diaphragm as the resonance frequency of the transmitter increases. The frequency of resonance of an Inset No. 10 increases as the sound pressure is reduced (see Fig. **9** (a)). This seems to be proved by the fact that a given transmitter exhibits a critical pressure at, say, 10 dynes per sq. cm. with one granule filling and, say, 2 dynes per sq. cm. with a reduced filling, the frequencies of resonance being about 2,100 and 2,800 c.p.s. respectively. Thus the performance of the diaphragm at 2,100 c.p.s. cannot be held responsible for the critical pressure at 10 dynes per sq. cm. since, with a different granule filling but the same diaphragm, no critical pressure occurs until the frequency has been increased to 2,800 c.p.s.

The discussion of the mechanical performance of the Inset No. 10 has so far centred around the effective stiffness and the effective mass of the moving parts. It is desirable at this stage to examine the experimental results from a different aspect and to attempt to form some conclusions as to the amount of mechanical resistance in the moving system.

It had been observed in earlier tests that the effective damping of the resonance of the transmitter, as observed by recording open-circuit volts, depends alike on the applied sound pressure and the polarising current. More recent tests have confirmed this observation.

Consider first the effect of variation of the sound pressure. It was stated in 1935 that the resonance becomes more damped as the sound pressure is increased. This statement has to be modified, however, as the result of further tests. With the four insets No. 10 mentioned earlier it was observed that the damping is steadily decreased as the sound pressure is increased up to about 15 dynes per sq. cm. (see Fig. **9** (a)). Above this pressure the damping increases, becoming considerably greater at 60 dynes per sq. cm. At first sight it would seem that inferences may be drawn from these observations relating to changes in the mechanical resistance of the inset as the sound pressure is altered. It must be remembered, however, that the resonance curves are plotted in terms of the electrical output from the transmitter and not in terms of the velocity or displacement of the front electrode. It is known that the electrode displacement for a given applied sound pressure will steadily increase as the frequency is raised to resonance. This means that the effective force applied to the granules will similarly increase, and the effect of amplitude distortion for reasonably low values of sound pressure will be to sharpen the shape of the resonance curve. This effect is observed with increasing sound pressure up to about 15 dynes per sq. cm., and above that value of sound pressure, when the transmitter sensitivity begins to show signs of saturation, the sharpness of the resonance curve will be progressively decreased by the amplitude distortion (see Fig. **10**). Thus it is not possible to draw any conclusions relating to mechanical resistance, since the observed change of damping of the resonance curves may quite well be explained without reference to mechanical resistance.

Consider now the effect of variation of the polarising current on the shape of the resonance curves. It was stated in the earlier article already referred to that the apparent damping increases as the polarising current is increased. It has already been noted that the change of direct current resistance of a transmitter with change of sound pressure becomes less as the polarising current is increased. This means that the amplitude distortion will decrease as the polarising current is increased. Tests confirm this, and the effect may also be observed with the curves given in the earlier article. If the amplitude distortion (expansion type of distortion) decreases with increasing polarising current, then the sharpening effect should become less as the polarising current is increased, i.e. the apparent damping of the curve should increase with increasing polarising current. As already stated, this is the effect observed, and Fig. **11** illustrates the amount of change observed. This diagram is drawn from some recent test results.

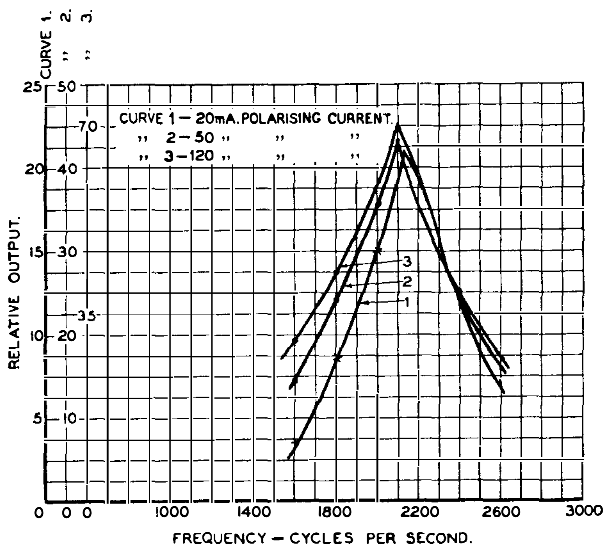


Fig. **11**.—Shape of Resonance Peak, with 1·5 grams of Granules tested at 15 dynes per c.m.^{2}

It is thus seen that, since the amplitude distortion plays such a large part in determining the shape of the resonance curve, no conclusions relating to mechanical resistance can be obtained from a consideration of the resonance curves. Resort must be made to direct measurements, e.g. by a vibrometer.

The Electrical Performance of an Inset Transmitter.

A series of tests has been carried out to determine the amount and type of variation of the D.C. resistance of an Inset No. 10, or No. 13, with various conditions of sound input and polarising current. It is not proposed to include full details of these tests in this article, but the results may be summarised as follows:

(*a*) The D.C. resistance rises as the sound pressure is increased. This effect is observed for sound pressures in excess of about 7 dynes per sq. cm.

(*b*) The amount of rise of resistance for a given increase of sound pressure becomes less as the polarising current is increased.

(*c*) The "quiet" resistance (no applied sound pressure) of an inset with a normal granule filling is substantially independent of the polarising current from 20 to 120 mA.

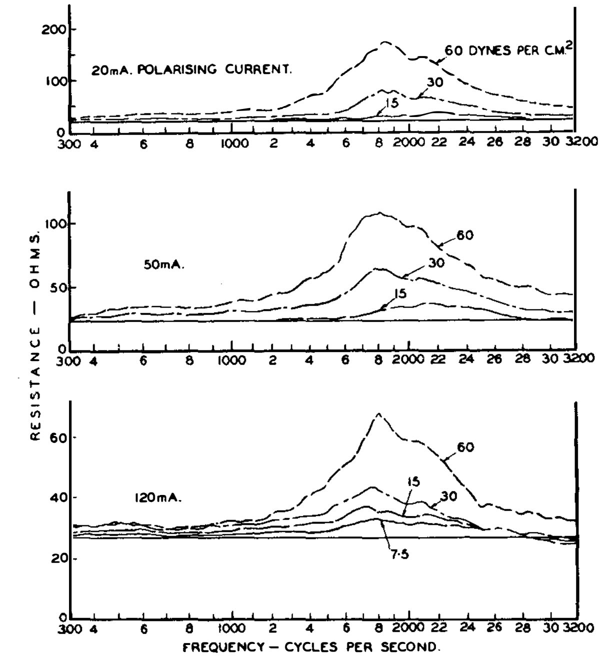


Fig. **12**.—Resistance Characteristics of Inset No. 10.

The above effects are illustrated for an average Inset No. 10 by Fig. **12**.

If the granule filling of the Inset No. 10 is reduced in amount, the following additions or modifications become necessary:

(*d*) The amount of increase of resistance for increased sound pressure becomes greater.

(*e*) The rise in resistance may be observed for lower applied sound pressures down to 3 dynes per sq. cm.

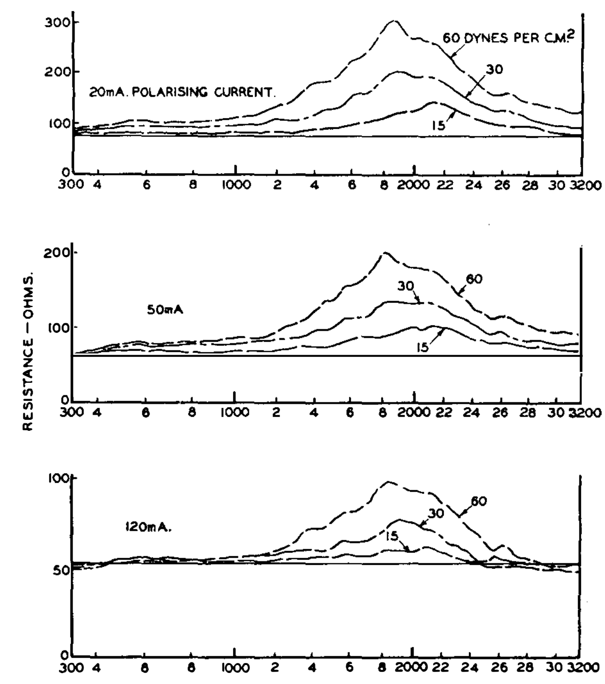


Fig. **13**.—Resistance Characteristics of Inset No. 10 with 1·2 grams of Granules.

(*f*) The " quiet " resistance is no longer independent of the polarising current, but decreases as the current is increased.

Fig. **13** shows the performance of an Inset No. 10 with only 1·2 grams of granules.

Table III comprises a list of the values of transmitter resistance for three transmitters, each average for its type, occurring with various conditions of sound pressure and polarising current. All the values of resistance appearing in the table represent the peak value of resistance occurring with the given sound pressure. These maximum values occurred at frequencies between 1,400 and 1,800 c.p.s., all being in the region of 1,800 c.p.s. with a normal Inset No. 10.

TABLE III

Transmitter	Polarising Current mA	D.C. Resistance Ohms			p.d. across Transmitter D.C. Volts		
		Quiet	Peak 60 dynes	Peak 30 dynes	Quiet	Peak 60 dynes	Peak 30 dynes
Inset No. 10	20	25	180	83	0·5	3·6	1·66
,, ,,	50	24	112	67	1·2	5·6	3·35
,, ,,	120	28	69·5	45	3·36	8·35	5·4
Inset No. 13	20	37	172	86	0·74	3·44	1·72
,, ,,	50	34	118	68	1·7	5·9	3·4
,, ,,	120	35	73	51	4·2	8·75	6·1
Inset No. 10	20	77	390	250	1·54	7·8	5·0
refilled with	50	44	200	130	2·2	10·0	6·5
1·2 grams of granules	120	27	116	69	3·24	13·9	8·3

Consider first the variation of change of resistance with alteration of polarising current. At first sight temperature effects might be expected to be the main cause of the change. Carbon has a negative temperature coefficient of resistance, and observations show a reduced resistance with the larger values of current. There is a number of serious difficulties in the way of this explanation. In the first place, the " quiet " resistance of an Inset No. 10 (or 13) does not drop as the current is raised. Further, the ratio of peak resistances (60 dynes per sq. cm.) at 20 and 120 mA respectively is 180 : 69·5, i.e. about 2·5 : 1. With a temperature coefficient of resistance of —0·0003 per degree Centigrade a temperature change of 2,000° C. is necessary to give a resistance ratio of 2·5 : 1. Such a temperature change is obviously unlikely. Also it is improbable that temperature effects would occur sufficiently rapidly to produce apparently instantaneous changes of resistance.

Earlier in this article it was suggested that the granules may become separated from one another and from the electrodes for values of applied alternating force in excess of a certain critical value. Such a theory introduces the necessity for explaining the mechanism of current conduction through the series of separate particles. The physical theory of contacts and of surfaces bounding metals and semi-conductors shows that electrons can and do pass the potential barrier represented by such a surface or contact, even when the kinetic energy of the electron is not apparently sufficient to overcome the change of potential energy involved in such a passage across the barrier. The theory involves a consideration of quantum mechanics, a definite probability being assigned to the escape of electrons. This probability is expressed in terms of the condition of the surfaces of the metal or semi-conductor, the electrostatic charge residing in the electron and the applied electrostatic field (voltage gradient) over and above the normal potential drop at the surface of the material under consideration. It is shown that electrons jump across gaps between two surfaces, the gaps being large as compared with atomic dimensions, i.e. of the order of 10^{-7} cm. The voltage gradient required to maintain such a cold discharge is of the order of 10^6 volts per cm. When the two surfaces are very close together in terms of atomic dimensions, and are both composed of the same material, the conduction of current obeys Ohm's Law; it is similar in mechanism to the conduction of current through a homogeneous conductor of the same material. As the distance between the surfaces increases, however, the conductance is reduced and is largely determined by the cold discharge of electrons from one surface to the other. Actually, electrons are emitted from both surfaces, but the predominating emission is in the direction of the potential gradient for a contact between surfaces of the same material. At these larger distances the number of electrons emitted from a unit area of surface increases as the applied electrostatic field, and hence the voltage gradient, is increased. The conductance of the contact thus depends on the applied electrostatic field. This effect is not very great for a contact between surfaces of the same metal, but may become considerable for a contact between surfaces of the same semi-conductor.

This theory of the conductance of contacts fits in very well with the observed effects of resistance of an Inset No. 10 if it is assumed that the granules become separated from one another with a relatively large applied sound pressure; for the resistance would be expected to increase as the applied alternating force is increased. The resistance for a given applied alternating force would also be expected to decrease as the polarising current is increased. This follows since an increase in polarising current always results in an increase in the direct potential difference across the transmitter (see Table III) and hence in an increase in the potential gradient between the granules. The change in conductance of a contact between approximately spherical granules will be greater for a given change of distance and/or of electrostatic field than will be experienced with a contact between plane surfaces, which is the condition usually treated by the physical theory. This will follow, since an increase in distance or a decrease in electrostatic field (in general, a decrease in potential gradient between the granules) will reduce the effective area over which electrons may be expected to escape and jump the gap. This reduction is due to the curvature of the surfaces bounding the gap, an increase in gap length resulting in a portion of the surfaces becoming separated by too great a distance to permit of cold discharge over this portion.

Consider now the transmitter in a " quiet " state. It is possible that the granules will settle into a condition of relatively intimate contact between a fairly large proportion of the separate particles due to the static pressure existing between the particles. In this condition one would expect the current through the transmitter to flow mainly through contacts which obey Ohm's Law. This may explain the constant " quiet " resistance of an Inset No. 10 with changing polarising current. When the granule filling is reduced to 1·2 grams the static pressure in the granules is considerably reduced, and it seems reasonable to suppose that, with this arrangement of granules, a much greater proportion of the polarising current is forced to flow through granules which are relatively far apart and whose contacts therefore exhibit non-linear current conduction. This would account for the fact that the " quiet " resistance of a transmitter filled with only 1·2 grams of granules decreases as the polarising current is increased.

It should be emphasised that this suggested explanation of the current conduction through a carbon-granule transmitter has not been in any way proved. It is pure speculation, but has the following points in its favour :—

(*a*) A consideration of the mechanical performance of an Inset No. 10 leads to the belief that the granules become separated from one another at sound pressures above a critical value. If the accepted physical theory of contacts is applied to these separated granules, the measured electrical performance of the transmitter can immediately be explained.

(*b*) The electrical performance is not easily explained in any other manner.

(*c*) The electrical performance of the transmitter exhibits unusual properties which require the postulation of separated granules for their explanation at values of sound pressure in excess of about that same critical pressure above which the postulation of granular separation is necessary to explain the mechanical performance of the transmitter.

In discussing in detail the causes of some of the distortions introduced by the transmitter, the reduction in transmitter sensitivity which occurs at the higher values of sound pressure has so far been neglected. The existence of the effect has already been noted and it is illustrated by the curves of Fig. **10**. These curves show that, with a normal granule filling, the sensitivity of an Inset No. 10 drops as the applied sound pressure is increased above about 30 dynes per sq. cm. At these higher values of sound pressure the effective mass and stiffness of the moving parts of the transmitter have become substantially independent of sound pressure (see Fig. **8**), and hence have little tendency to cause amplitude distortion. Further, reference to the curves of Fig. **12** shows that the electrical resistance of the transmitter is still rising rapidly with increasing sound pressure in the range 30 to 60 dynes per sq. cm., and this rising resistance might be expected to cause an increase in the sensitivity of the transmitter (in terms of open circuit E.M.F.).

No detailed investigation into the reasons for the saturation effect has as yet been made. It seems likely, however, that the efficiency of a granular contact will be greater for, say, the positive half-cycle of force than for the negative half-cycle. In fact, if the pair of granules separate for every alternate half-cycle of force, it is fairly certain that an asymmetrical wave-form of E.M.F. will be produced, i.e. all negative, say, half-cycles of E.M.F., will be relatively too small. The oscillograms of the output from a Tele. No. 164 transmitter given in the earlier article by the author illustrate this effect for a complete transmitter. Since the suppression of one-half of the wave will become relatively greater as the sound input to the transmitter increases, the sensitivity of the instrument would be expected to drop as the input is increased. In practice, with an Inset No. 10, the increase in sensitivity due to the progressively decreasing mechanical impedance of the granules with increasing sound input swamps the saturation effect due to the partial suppression of one-half of the wave until a value of sound input is reached where the mechanical impedance of the granules has become negligible. At higher values of sound pressure the suppression effect predominates and saturation is observed. The test results illustrated in Fig. **10** fit in quite well with this explanation, for the saturation effect occurs at a lower value of sound pressure as the amount of granules used in the inset is reduced and it has already been shown that the mechanical impedance of the granules becomes constant at a lower value of sound pressure when the quantity of granules is reduced. Further, the extent of the saturation is greater for the smaller quantities of granules and this is reasonable, since the granules then have an increased freedom of motion and are likely to separate for longer periods during each successive cycle.

This argument suggests that the increased agitation of the granules which is desirable in order to reduce amplitude distortion introduced by a transmitter may not necessarily result in a simultaneous reduction in the non-linear distortion. The longer period of separation of the granules is likely to cause considerable asymmetry of waveform and therefore to increase the harmonics and sum and difference tones generated by the carbon granules. On the other hand, the more constant values of effective mass and stiffness of the granules, brought about by the increased freedom of motion, should reduce the harmonics generated due to the non-linear motion of the moving electrode of the transmitter, i.e. due to purely mechanical effects. In particular, the sub-harmonics should be greatly reduced since these are almost certainly mechanical in origin.

Tests with model transmitters constructed with specially shaped electrodes and carbon chambers and exhibiting much less amplitude distortion than does the Inset No. 10 indicate that the higher order harmonics and the sum and difference tones are only slightly reduced with these special transmitters. The sub-harmonics, however, are almost completely eliminated. It seems unlikely that substantial reduction in the non-linear distortion can be obtained while high-sensitivity granular-contact transmitters are used.

Conclusion.

It is realised that the theory of operation suggested in the above summary of further experimental investigations into the performance of the Transmitter, Inset, No. 10 is not rigidly proved. Nevertheless it appears to form a satisfactory provisional explanation of the performance of the instrument and certainly does form a useful basis for design. This last contention is supported by recent work in the laboratory which the author hopes to describe in a future publication. It has been found possible to design and construct transmitters having a predicted amplitude characteristic and to make working model transmitters which exhibit very little amplitude distortion over a wide range of input sound pressures. These model transmitters are almost as sensitive as the present Post Office standard transmitter and have much improved frequency characteristics. The non-linear distortion also is less. It is too early to state that a new transmitter has been designed, since constructional and manufacturing difficulties may arise when mass production is attempted. Further, it is unfortunate that no information relating to the probable life of transmitters made to the new design can become available until these manufacturing difficulties are overcome. The author is of the opinion, however, that a new and greatly improved transmitter will be produced for general use within a comparatively short time, and that such a new transmitter, when combined with the new receiver now on field trial, will form a telephone instrument much in advance of any which have so far been used in this country.

In conclusion, the author wishes to tender his thanks to the Engineer-in-Chief of the Post Office for permission to publish these notes and to his colleagues in the Research Branch at Dollis Hill for valuable advice and assistance in connection with the research work carried out.

APPENDIX I

Calculation of the Horizontal Static Forces existing between the granules of an Inset No. 10.

Fig. **3** shows the more important dimensions of the granule chamber of an Inset No. 10. The total space enclosed in the chamber

$$= \frac{\pi}{4}\left[1{\cdot}15 \times 1{\cdot}75^2 - 0{\cdot}45 \times 1{\cdot}1^2 - 0{\cdot}5 \times 1{\cdot}1^2\right]$$
$$= 1{\cdot}82 \text{ cc.}$$

Let 1·5 grams of granules be introduced into this space and occupy the portion shaded in Fig. **3** (a) and (b).

The effective density of granules (normal packing) is about 0·95 grams per cc. and hence the 1·5 grams of granules will occupy 1·6 cc.

Let the area shaded in the cross-section (b) be 'a' sq. cm.

$$\text{Then} \quad 1{\cdot}15\,a - 0{\cdot}95 \cdot \frac{\pi}{4}(1{\cdot}1)^2 = 1{\cdot}6$$

$$\text{Hence} \quad a = 2{\cdot}17 \text{ sq. cm.}$$

$$\text{But} \quad a = r^2\left[\pi - \cos^{-1}k + k^2\sqrt{1-k^2}\right] \ldots\ldots (1)$$

where $k = h/r$ and h and r are as shown in the diagram.

Substituting the value of (a) and solving equation (1) gives $k = 0{\cdot}78$ approx.

Hence $h = 0{\cdot}68$ cm. and total depth of granules

$$= \frac{1{\cdot}75}{2} + 0{\cdot}68 = 1{\cdot}55 \text{ cm.}$$

Fig. **14** shows (to scale) the electrodes immersed in the granules. The line AB on this diagram corresponds to AB in Fig. **3** (a) and (b). Following the argument and lettering of the main text, we note

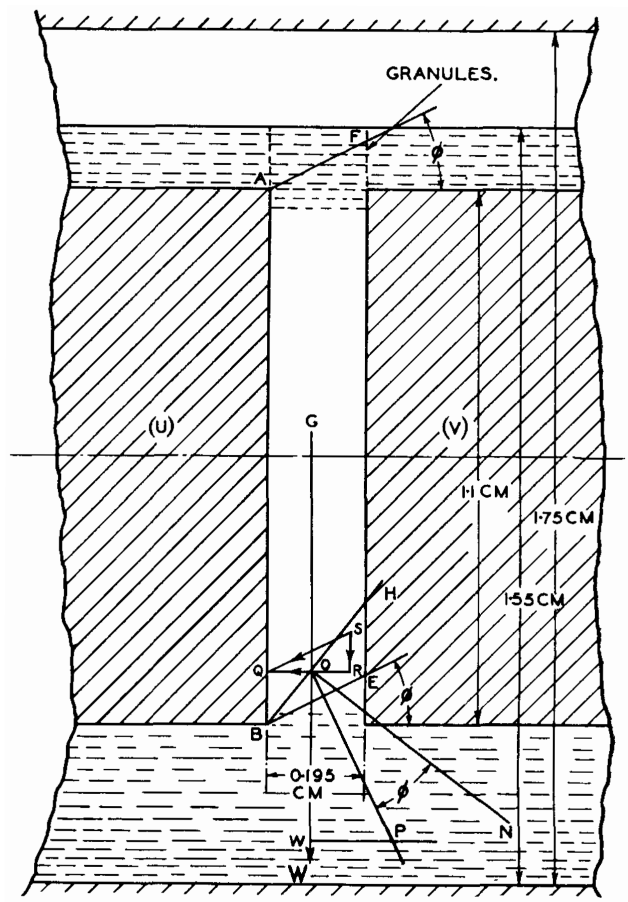


FIG. **14**.—VECTOR DIAGRAM OF STATIC FORCES ON THE ELECTRODES OF AN INSET NO. 10 (CALCULATION A).

that the force on the elementary strip AB of the electrode may be taken as being due to the parallelogram of granules ABEF (approx.).

Two alternative calculations have been made to determine the magnitude and position of the resultant horizontal force on AB.

(A) The ordinary "retaining wall" calculation has been adopted, and the force on AB is taken empirically to be due to the wedge of granules ABHF, where BH bisects $A\hat{B}E$. G is the centre of gravity of ABHF, and a vertical line through G intersects BH at O. OW represents the weight of the granules in ABHF. The reaction force on BH occurs at O and would be normal (ON) except for friction. Actually, it is represented by OP where $P\hat{O}N = \phi$.

A graphical calculation shows that

$$RQ = 0{\cdot}5 \times \text{weight of granules ABHF} = 0{\cdot}5\ W \text{ (say).}$$

(B) Since the conventional "retaining wall" calculation (A above) yields a position of Q which seems to be rather low, a second calculation, based on a different arbitrary assumption, was made. In this calculation the force on AB was taken as being due to the triangular wedge of granules ABF (see Fig. **15**). This assumption almost certainly represents an extreme condition which is not likely to apply in practice. Some line through B and situated between BH and BF probably represents the lower boundary of the area of granules operating in the practical case. Let G represent the centre of gravity of the triangle ABF. The weight of the triangle is obviously about W/2.

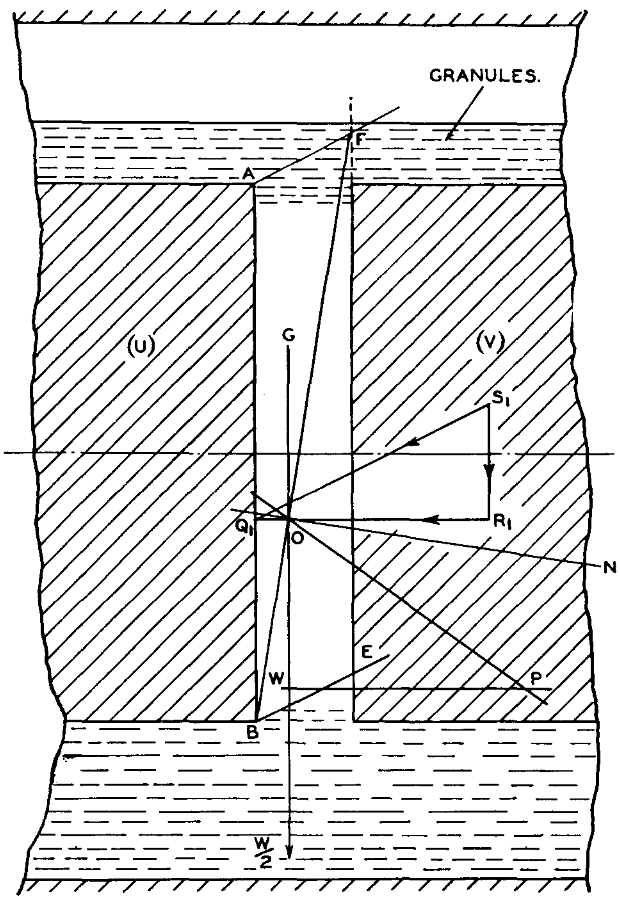


FIG. **15**.—VECTOR DIAGRAM OF STATIC FORCES ON THE ELECTRODES OF AN INSET NO. 10 (CALCULATION B).

Following a similar calculation to (A) above

$$R_1\,Q_1 = 0{\cdot}7\ W.$$

Some intermediate value between $0{\cdot}5$ W and $0{\cdot}7$ W and some intermediate position between Q and Q_1 for the reaction force probably represents the practical state of affairs.

Consider now the value of W :

250 average granules weigh $0{\cdot}005$ gram,
i.e. each granule weighs about $0{\cdot}00002$ gram (and $1{\cdot}5$ grams of granules contains 75,000 granules).

The volume of one granule

$$= \frac{0{\cdot}00002}{1{\cdot}6} = 0{\cdot}0000125 \text{ cc.}$$

Assuming that the granules are of spherical form of mean diameter d cm., we have

$$\frac{4}{3}\,\pi\left(\frac{d}{2}\right)^3 = 0{\cdot}0000125 \quad \text{whence}$$
$$d = 0{\cdot}0288 \text{ cm.}$$

If these spheres are loosely packed one against the other, arranged thus $\begin{smallmatrix}OOOOO\\OOOOO\end{smallmatrix}$, then it may easily be shown that 1 part in $1{\cdot}9$ of the total space occupied by the spheres is actually filled with solid matter. It is known, however, that the ratio of the actual density of the material to the effective density of a mass of granules is $1{\cdot}7$, i.e. 1 part in $1{\cdot}7$ is occupied by solid matter. This means that the granules are normally packed somewhat more tightly than the loose packing arrangement indicated above.

Thus there will be

$$\frac{1}{0{\cdot}0288}\left(\frac{1{\cdot}9}{1{\cdot}7}\right)^{\frac{1}{3}} \text{ granules per cm. along the line AB,}$$

$$\text{i.e. a total of } \frac{1{\cdot}1}{0{\cdot}0288}\left(\frac{1{\cdot}9}{1{\cdot}7}\right)^{\frac{1}{3}} = 38 \text{ granules.}$$

The number of granules in the area ABHF is approximately N

$$\text{where } N = \frac{\text{Area ABHF}}{\frac{\pi}{4}\,(0{\cdot}0288)^2} \times \left(\frac{1{\cdot}9}{1{\cdot}7}\right)^{\frac{2}{3}}$$
$$= 300 \text{ granules.}$$
$$\text{Hence } W = 300 \times 0{\cdot}0002$$
$$= 0{\cdot}006 \text{ gram.}$$

From (A)

$$\text{Force on AB (acting at Q)} = 0{\cdot}006 \times 0{\cdot}5 \times 981 = 2{\cdot}9 \text{ dynes}$$
$$\text{and } AQ : AB = 99 : 110.$$

And from (B)

$$\text{Force on AB (acting at } Q_1) = 0{\cdot}006 \times 0{\cdot}7 \times 981 = 4{\cdot}1 \text{ dynes}$$
$$\text{and } AQ_1 : AB = 68{\cdot}5 : 110.$$

The practical condition is probably represented by some intermediate value of force acting at some point intermediate between Q and Q_1

Calculations of the values of the individual forces concerned have been made using the data from (A) in one case and the data from (B) in the other. The results obtained are not very different so far as the majority of the 38 forces are concerned. For the purposes of this paper it will be sufficient to give the details of a single calculation, using data derived from both (A) and (B) above.

It appears reasonable to take a value of total force of $3{\cdot}5$ dynes and a ratio AQ : AB of 2 : 3. This choice of AQ : AB allows the assumption that the individual forces increase at a uniform rate from

A to B. Thus there will be 25 reaction forces (totalling 1·75 dynes) above Q and 13 reaction forces (again totalling 1·75 dynes) below Q.

Calculation shows that the minimum force (near A) is about 0.029 dyne and that successive forces below A increase by about 0·0034 dyne until a value of $0{\cdot}029 + 37 \times {\cdot}0034 = 0{\cdot}155$ dyne is reached at B.

The average force will be about 0·085 dyne, and 21 of the 38 reaction forces will have a value of less than 0·1 dyne.

(NOTE : If the calculation is based on the data given by calculation (A) above, it is impossible to assume a uniform increment of force for each successive force from A to B. A much larger value of force at B (about 0·5 dyne) is obtained, but above Q there are 33 forces which together total only 1·45 dynes, i.e. an average of 0·44 dyne. At least 30 of the 38 forces have a value of less than 0·1 dyne.)

From the above calculations, and from the considerations set forth earlier in this article, it seems reasonable to conclude that the average horizontal force (static) on any one granule will not greatly exceed 0·1 dyne.

APPENDIX II

The Measurement of Effective Mass and Stiffness of the Moving Parts of a Transmitter Inset.

For this purpose the inset was set up to operate in the normal way and a family of frequency characteristics for a constant value of polarising current was recorded over a range of sound pressures extending from 60 dynes per sq. cm. downwards. A second family of characteristics was then obtained with the diaphragm of the inset loaded with a known, small mass (k grams).

On the assumption that the effective mass, stiffness and resistance (mechanical) of the inset at resonance are independent of frequency over a small range of frequencies for any one applied sound pressure it is then possible to calculate the effective mass and stiffness from an observation of the frequencies of resonance with and without the mass k grams.

For, if m grams is the effective mass of the inset
s dynes/cm. is the effective stiffness of the inset
f_o c.p.s. is the frequency of resonance without the mass k
and f_k c.p.s. is the frequency of resonance with mass k added,

$$f_o = \frac{1}{2\pi}\sqrt{\frac{s}{m}}$$

and

$$f_k = \frac{1}{2\pi}\sqrt{\frac{s}{m+k}}$$

Hence

$$m = k \cdot \frac{(f_k)^2}{(f_o)^2 - (f_k)^2} \text{ grams}$$

and

$$s = 4\pi^2 (f_o)^2 m \text{ dynes/cm.}$$

The assumption that the mechanical constants of the inset are independent of frequency is not strictly justified, but Dr. Sutton has shown that the diaphragm of an Inset No. 10 acts as a piston, at least up to 2,500 c.p.s. This result has been confirmed by the author and was discussed in the main text. The test results probably indicate orders of magnitude and relative magnitudes quite fairly, although no account has been taken of possible variations of mechanical resistance and its consequent effect upon the frequency of resonance. There is some evidence, moreover, that this effect is small. Comparison of a pair of resonance curves at any one sound pressure, one curve for the inset alone and the other for the inset with added mass k, shows that the addition of the mass k reduces the decay factor (Δ) of the resonance curve by a small amount. Accurate measurement of Δ is impossible, but the amount of reduction may be reasonably well explained by assuming that the mechanical resistance (r) remains unaltered upon the application of k.

$$\text{Thus } \Delta_o = \frac{r}{2m} \text{ and } \Delta_k \simeq \frac{r}{2\,(m+k)} \cdot$$

Electrical Services in Large Buildings

C. G. A. McDONALD and
F. C. CARTER, B.Sc.(Eng.), A.M.I.E.E.

In order that a flexible system for the provision of telecommunication and other services may be available in a building it is necessary to consider the requirements at the building design stage. The authors describe how they would co-operate with architects in this respect and give details of the various methods adopted to serve different types of building.

Introduction.

THE ever-increasing part that the science of engineering plays in all phases of life, suggests that electrical and telecommunication engineers should take a more prominent part in the development of buildings.

Site values, together with the modern tendency of centralising big businesses, have led to the erection of large blocks of buildings, and the efficient functioning of the work carried on in these buildings is dependent largely upon the efficacy of the engineering services. It is, therefore, a reasonable deduction that engineering services should be planned simultaneously with the planning of the fabric, and the physical construction of the building should be of such a character that these services can be accommodated to meet not only immediate needs but also future demands.

It would not be possible in a single article to deal with all types of modern buildings, so it is proposed to make special reference to official buildings used for administrative purposes and commercial buildings used for office purposes. The electrical services in these buildings may be divided under two sub-heads: power and communications. The former comprises the electric lighting, lifts, conveyors, heating, office aids, etc., and the latter the telephones, dictaphones, electric clocks, messenger bells, heat control, television, fire alarm, etc.

It is important to remember that the majority of the communication services are controlled by, or fed to, desk positions, whereas only a limited proportion of the lighting needs to be controlled from such positions.

It is generally agreed that the unsightly method of running wiring on the surface of walls and ceilings, also the feeding of desk positions by flexible connections led from walls, or dropped from ceilings, is not sound engineering practice, but merely " a means to an end." Therefore, all these services should be concealed within the fabric of the buildings and, in addition, facilities should be provided for extensions and alterations.

It must be remembered that a modern building is designed to last a considerable number of years, and any disturbance of the structure to permit the extension of electrical services, or to provide additional services, is in the nature of a major operation and very costly. It is, therefore, essential in the very early stages of the design of a projected building that all interested parties should carefully consider all possible demands for services and prepare preliminary schemes. These schemes can, however, have only a limited value unless they can be co-ordinated, and this co-ordination can be assured only if the architect, the mechanical and electrical engineer, and representatives of other professions associated with the structure constitute a Designs Board to determine how best their individual schemes can be welded together with due regard to efficiency and economy. Nowadays, it is customary for architects in preparing plans for large buildings to divide the work into two distinct stages: (1) the preliminary or sketch plan stage and (2) the final or drawing stage, and the closest co-operation with the architect can be obtained if the electrical engineer follows a similar course in the preparation of his designs for the electrical services.

Preliminary or Sketch Plan Stage

Control Room and Riser Shaft.

Whatever may be the final layout of the building, it is evident that certain services, i.e. lighting, power, communications and access to lifts, must be given to all floors of the building, and the most convenient means of providing these facilities is by the generous provision of vertical shafts or rising mains (Fig. 1)

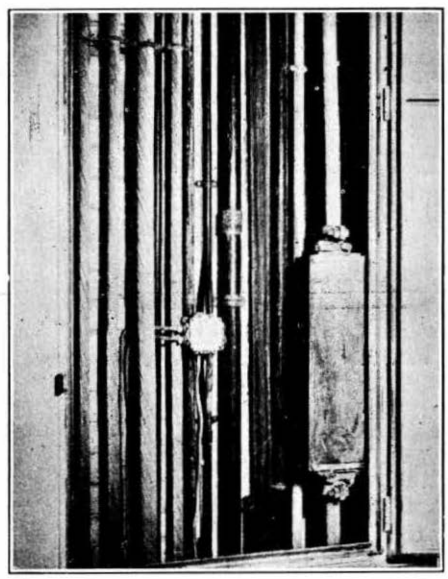


FIG. 1.—RISER SHAFT SHOWING E.L. & P. CABLES.

running from the bottom to the top of the building. The design of the shafts has to be such that access is readily obtainable at all floors for connection to the horizontal distribution network.

The risers should all be connected to a common control room, and if this room is in the basement of the building it can be used also for the termination of the incoming street cables. The risers would carry all main feeders for power services and multi-core cables for communication services. At each landing level would be fixed fuse boards for lighting, and distribution cases for the communication services, and, if the building were to be let off in suites of offices, the tenants' meters. Thus the risers at landing levels would feed the sub-distribution centres which in turn would be built around the risers to control all services on the relative floors. It is important that the riser shafts should be located in as central position as possible of the area which they are intended to serve so that lengthy cable routes may be avoided. Positions in proximity to main staircases or lift wells are usually the most convenient. These positions have the additional advantage that provision is more readily arranged for uninterrupted vertical runs (Fig. **2**).

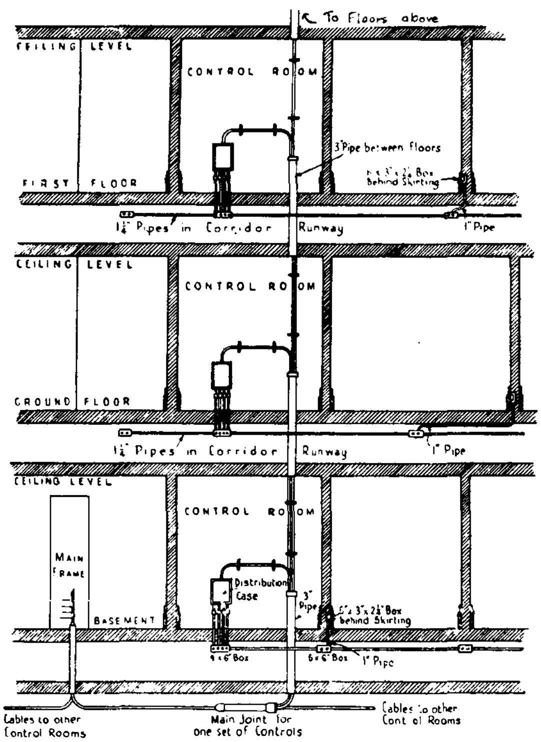


FIG. **2**.—LOCATION OF CONTROL ROOMS.

Although to some extent the number of riser shafts required will depend upon the shape of the building, as a result of extensive investigation the authors have found that the average superficial floor area per storey of the building can be used as a reliable guide to the determination of the number of risers required, and that for conventional forms of building construction one riser shaft should be provided for every 5,000 square feet of such floor area, e.g. for a building six storeys high having a total superficial floor area of 60,000 sq. ft. the average floor area is $60{,}000/6 = 10{,}000$ sq. ft. and $10{,}000/5{,}000 = 2$, i.e. two riser shafts should be provided.

The figure of 5,000 sq. ft. has been arrived at since it provides the most convenient and economical layout of cables. If it is materially exceeded lengthy horizontal runs will occur and conduit and duct systems will become congested near the riser shafts. On the other hand, if more generous provision is made excessive vertical routes will become necessary.

The physical dimensions of a riser shaft are small and its actual shape is immaterial, although a rectangular form is preferable. All cables required for electrical services in the highest building in this country can be accommodated in riser shafts **2** ft. wide by **9** ins. deep, provided the number of shafts is in accordance with the above-mentioned conditions. A slightly larger riser shaft will easily accommodate all the distribution boards in addition to the cables.

Size and Capacity of Control Room.

It is evident that at this stage every effort should be made to obtain as much information as possible regarding the ultimate requirements of electrical services in the building, and with this object the Post Office find it convenient as regards their own buildings to forward a questionnaire to the prospective occupier or occupiers. The form details the services likely to be required and the occupier is requested to indicate his requirements. Where this information is not available provision must still be made for the essential services previously referred to and a rough approximation of these requirements can be obtained by the following means.

Lighting.

For the preliminary survey the " watts per sq. foot " method might be adopted, but difficulty may arise in fixing the ideal factor. It has recently been advocated that electrical engineers should base their design of lighting on an ultimate factor of **4** watts per square foot of floor surface, but this appears to be unduly extravagant. A factor of **1** watt per sq. foot for office lighting giving approximately 6-7 foot candles, and **1·6** watts per sq. foot for drawing offices and the like, giving **10** foot candles, seems to be a sound basis for calculations.

Having obtained the approximate disposition of the lighting load throughout the building, it is possible to design the points for sub and main distribution.

Power.

In all buildings a certain number of power points must be provided for vacuum cleaners, auxiliary heating, fans, etc., and in the absence of any other information the Post Office find it convenient to make provision for a minimum of one power point per room. The disposition of the power load can, therefore, be roughly estimated by these means and the points for sub and main distribution can be designed.

Lifts.

Lifts should be provided at traffic centres, and should be of sufficient numbers and capacity to deal with peak traffic, with a margin to provide for periodic overhauls. In high buildings, through working by means of high speed lifts should be advocated. Floor-to-floor traffic should be catered for by lifts of a lower speed.

It would be an advantage if some degree of standardisation could be applied to lift design, such as depth of pit, method of fixing guides, bolt centres, landing cills and all parts which materially affect the structure. The builder could then mould into the structure of a concrete building, or leave out half bricks in a brick structure, to permit the fixing of attachments without having to resort to the costly method of cutting away and making good. As an example: to fit a lift in one new brick building it was necessary to cut **194** holes, each **3** ins. square by **6** ins. deep, for fixing guides alone.

Communications.

There can be no question that the most important communication service in the average commercial office building both from the point of view of the facilities provided and the capital cost of the plant involved is the telephone service, and the methods whereby flexibility of this service can be provided with a minimum of disturbance and delay will be described as being typical of other communication services.

Nowadays all large buildings requiring telephone facilities are wired in a manner known as " Block Wiring " or " Development Cabling." In this arrangement every circuit in the incoming street cable is terminated upon a main frame in the basement of the building and feeder cables also connected to this frame are led *via* the riser shafts to each of the floors of the building and terminated upon distribution cases.

The cabling and equipment comprising the block wiring or development cabling is installed before the completion of building operations so that it can be concealed as much as possible when the building is completed. A typical plan is shown in Fig. **3** and Table I. It is provided in advance of any order for telephone service, as distinct from the distribution wiring to instruments, which is provided only when a definite order is received. The capacity of the cables and apparatus is based upon the estimated telephone requirements in the building, and equipment is provided initially to cater for the requirements forecast for 20 years ahead. This forecast is prepared by the Sales Department and is based wherever possible upon the requirements of the subscriber who is going to occupy the premises. In the absence of this information the estimate is based upon the class and type of premises and their probable usage.

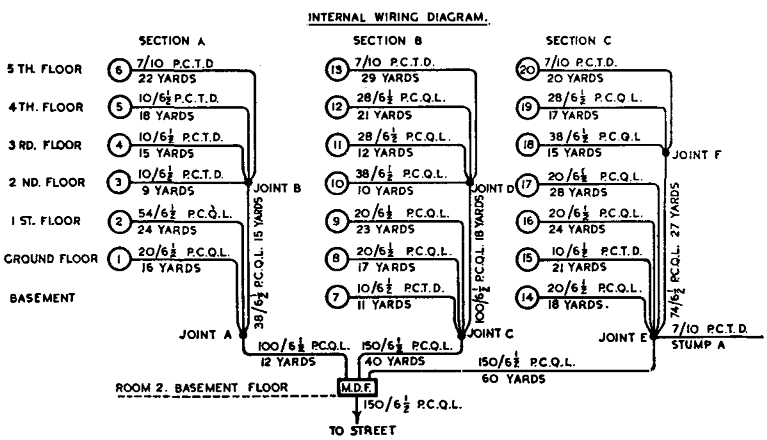


FIG. 3. TYPICAL BLOCK WIRING SCHEMATIC.

Flexibility of service is provided for by means of facilities for cross connection between all circuits at the distribution positions.

Having fixed the approximate disposition of the load for all services, it is possible to fix the position of risers for vertical distribution, and from the position of the risers the position of the main control room or sub-station can be determined.

FINAL PLAN STAGE

Permanent and Flexible Services.

The foregoing deals in a broad manner with preliminary surveys mainly for the purpose of fixing distributing centres, risers, and the main control centre. In determining final plans, it is essential to make a closer study of the building, and at this stage it is probable that information will be available upon which the ultimate layout may be developed.

It is now important to view the position from two aspects, namely, permanent services and flexible services. Under the former may be grouped the general lighting of offices, corridors, block wiring, and, in fact, all services which can reasonably be considered permanent. Under the latter may be grouped all services which are controlled from, or fed to locations which are from time to time subject to rearrangements, such as desks, etc.

Permanent services should, as far as practicable, be treated as a whole, and run in screwed tube laid in the fabric of the building. During the life of a building partition walls may be pulled down to make one large room out of several smaller rooms, or vice-versa ; and it is desirable,

TABLE I

CIRCUIT NUMBERING

Dis. Point		Jointed to		Dis. Point		Jointed to	
No.	Pairs at	Main	M.D.F.	No.	Pairs at	Main	M.D.F.
		1–150	1–150	12	1–28		397–424
				13	1–6		425–430
		Dead	151–180		7	Dead at Joint D	
1	1–20		181–200	13	1–20		431–450
2	1–43		201–243				
	44–54	Dead at Joint A		15	1–10		451–460
3	1–10		244–253	16	1–20		461–480
4	1–10		254–263	17	1–20		481–500
5	1–10		264–273	18	1–38		501–538
6	1–7		274–280	19	1–28		539–566
7	1–10		281–290	20	1–7		567–573
8	1–20		291–310	Stump A	1–7		574–580
9	1–20		311–330		1–150	1–150	
10	1–38		331–368	M.D.F.	151–180	Dead	
11	1–28		369–396		181–580	Various	

whenever possible, to lay out initial schemes of general lighting as if partition walls did not exist, that is, to arrange that the light points over the whole floor area are equi-distant. For the same reason switch points should not be fitted to partition walls.

Modern trend of lighting appears to point to an increase in the general standards of illumination on the working plane, but not wholly throughout the room or office. This development means that a general illumination of from 5 to 6 foot candles should be provided, accompanied by a "topping up" on the working plane by the aid of correctly designed desk or table standards. The general lighting would be designed by the lumen method and the "topping up" would be considered a flexible service and dealt with as described later.

It is important that all conduit runs should be shown on drawings, prior to the erection of the building, so that chasing is reduced to a minimum. There is generally no difficulty with horizontal runs laid in the floor filling, but vertical runs are often omitted and cutting away has to be resorted to.

The average cost of running one yard of ¾-in. conduit on the surface is 10d. to 1s., if it has to be chased into the wall the cost is from 3s. to 3s. 6d. If in the course of the construction of the building vertical runs are known, the builder could provide grooved bricks or chases to accommodate these conduits at no extra cost.

Means of Concealment of Services with Flexibility.

The Post Office have been fully alive to the desirability of the concealment of services together with some measure of flexibility of distribution, and with the object of attaining these features a brochure entitled "Facilities for Telephones in New Buildings" was compiled and issued to all members of the Institute of British Architects and other interested parties in 1931.

In the light of further experience, however, it has been decided to revise the publication, and to facilitate this revision and to ensure that all lines of approach were fully considered, a Departmental Committee was set up, and representatives of H.M. Office of Works, the Electrical Development Association and the Society of Consulting Engineers were co-opted. The terms of reference to the Committee were "To investigate the best means of providing concealed ducts or conduits in P.O. buildings and the like." The problem was discussed with architects, builders and contractors, and a number of commercial buildings were inspected.

It was found that although to some extent the means adopted for concealment of services depended upon the individual building construction, the majority of the methods in use could be classified under one of the following five categories. It should be emphasised, however, that these categories are considered primarily from the point of view of flexibility and concealment of final distribution services as distinct from the provision of main riser shafts and fixed lighting services already discussed. The five categories are as follows :—

(1) Pipes or ducts in floors.
(2) Trenches or chases in floors.

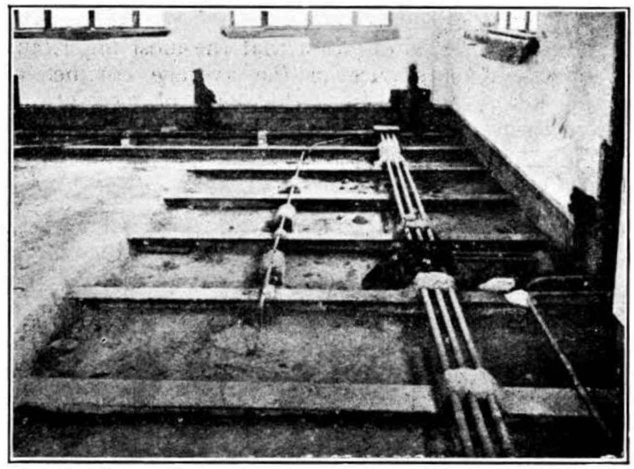


FIG. 4.—3-WAY STEEL CONDUIT IN COURSE OF INSTALLATION.

(3) Hollow skirtings.
(4) Suspended ceilings.
(5) Hollow ducts or cavities in main walls.

The relative advantages of these systems may be summarised as follows :—

(1) (*a*) Conduits are comparatively cheap to provide (Fig. 4), but have the inherent disadvantage that outlets for cabling are limited to points where special boxes are provided. Such points are generally few in number, and this is a serious drawback where flexibility of service is required. It is invariably found that lengthy runs of service wiring are unavoidable.

(*b*) Duct systems (Fig. 5) are more expensive than conduits but provide greater flexibility of services without surface wiring. They must be very completely planned, bearing in mind the requirements of all other services before the final floor surfacing is laid, and must be provided initially on a generous scale to allow for the ultimate requirements in perhaps 50 years' time.

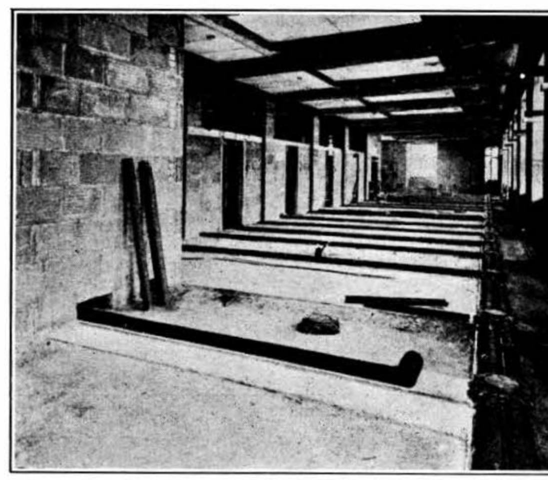


FIG. 5.—LAYOUT OF UNDERFLOOR FIBRE DUCTS.

(2) Trenches or chases in floors are comparatively cheap to provide (Fig. 6), but are not easy to finish off in a satisfactory manner. They usually require to be augmented with conduits or ducts for wiring to service positions. . It is difficult to arrange for all the

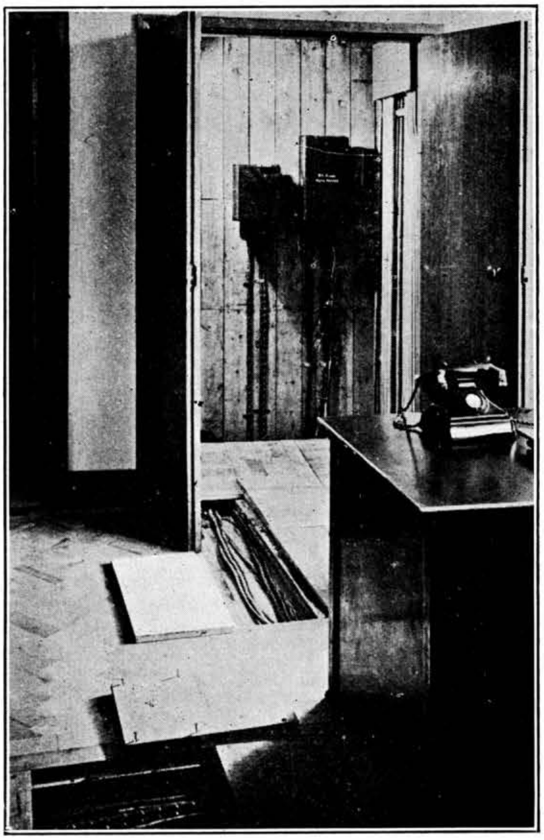


FIG. 6.—FLOOR TRENCHING.

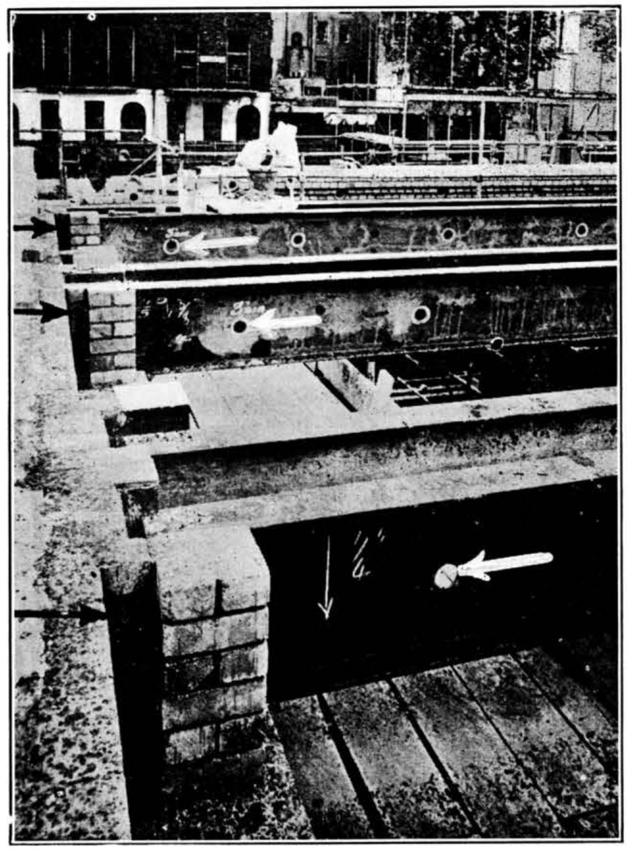


FIG. 8.—UNIVERSITY OF LONDON BUILDING SHOWING CAVITY RISERS AND HOLES FOR CONDUITS.

fittings to be just flush with the floor, and frequently covers get loose and rattle under passing traffic. Many architects object to them on the grounds that their appearance spoils an otherwise artistic floor finish.

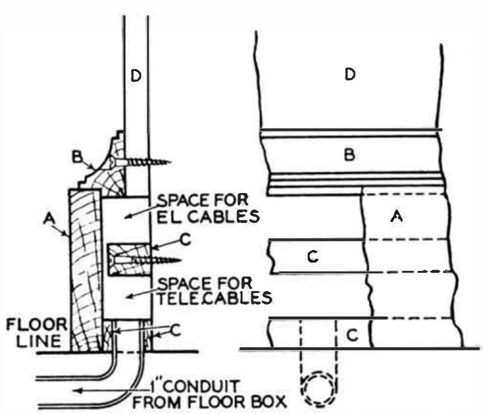


FIG. 7.—ACCOMMODATION OF CABLING IN HOLLOW SKIRTINGS.

(3) Hollow skirtings (Fig. 7) can conveniently be used only to accommodate cabling round the main walls of a building. They will not provide for the requirements of island positions. Their use is generally restricted to smaller buildings where they provide a convenient means of concealment at a nominal cost.

(4) Suspended ceilings are generally suitable only for corridors on account of the loss in effective room height. In these positions, however, they frequently clash with ventilation ducts. They can, however, be used with advantage in rooms which have to be specially treated acoustically. Their utility is limited to main lateral runs and they require to be augmented by conduits or ducts to the actual service positions.

(5) Cavity walls are employed in the new University of London buildings. The system does not cater for island positions and would not be very suitable for a commercial office building where service is required primarily between adjacent rooms upon the same floor, rather than immediately above one another (Fig. 8).

It will be evident that combinations of the above systems can be arranged in a variety of ways to provide for the appropriate separation between E.L. & P. and communication services. For instance :—

(1) Communication services may be buried under the surface of the floor and E.L. & P. services suspended from the ceiling underneath.
(2) All services may be buried under the surface of the floor, but the communication services arranged around, say, the outer walls of the building and the E.L. & P. services around the inner walls and interlaced with the communication service (Fig. 9).
(3) A twin or triple system of ducts and pipes may be provided running side by side with a complete mechanical separation between those used for different services.

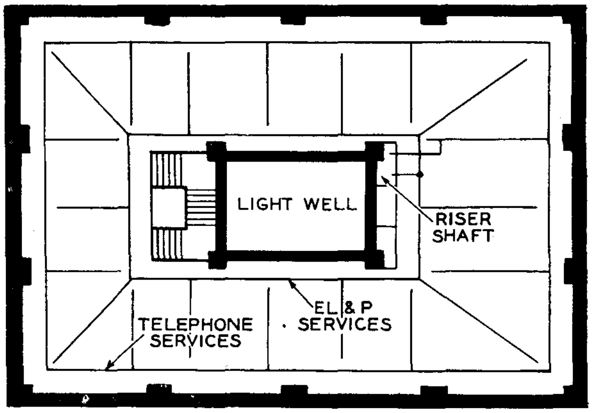


FIG. 9.—TELEPHONE SERVICES INTERLACED WITH THOSE FOR E.L. & P.

As a result of their investigations the Committee came to the conclusion that the requirements not only of Post Office buildings but of the majority of commercial office buildings could be met most conveniently by the provision of a twin or triple system of underfloor steel ducts concealed in the floor screening, the system to include complete mechanical separation between E.L. & P. and communication services and with ample facilities for bringing the service above floor level. The construction of the system should be such that building costs were not materially increased, which in turn meant that the duct system should be accommodated in a floor fill $2\frac{3}{4}$ ins. deep. At the same time space should be provided for the permanent services previously referred to.

The British Standards Institution were approached with a view to preparation of a standard specification to cover the manufacture of such a duct system, and in collaboration with various conduit manufacturers B.S. Specification No. 774 has now been issued. Subsequently it was felt that there was scope for a specification to cover ducts manufactured of material other than steel, and a specification for such materials is now in preparation.

BRITISH STANDARD UNDERFLOOR DUCT SYSTEM.

The following is a brief description of the underfloor steel duct system that has now been standardised.

Duct.—The duct is rectangular in section either $1\frac{1}{8}$ in. or $1\frac{1}{2}$ in. deep. Width is to purchasers' requirements, but the following sizes are recommended :— 2 ins., $2\frac{1}{8}$ ins., or $2\frac{1}{2}$ ins.

Duct Outlets.—Access to the duct is provided by means of duct outlets provided at intervals to purchasers' requirements. Outlets may be of two types :—

(*a*) Formed integral with the duct during manufacture ; or
(*b*) Fitted as required after the duct has been installed.

The first method of construction is rather more expensive in first cost, but provides a more ready means of access to the duct system when service is required.

The outlets are screwed internally $1\frac{1}{2}$ in. conduit thread and the top s flush with the finished floor surface. Outlets not in use are covered by a metal cap.

Couplings may be either :
(*a*) Through type ; or
(*b*) Outlet type with side entry for conduit.

Junction Boxes.—These are three or four way for the twin or triple duct system. All boxes include a divider so that complete mechanical separation is ensured between the cables for different services when passing through the box in any direction.

The boxes are provided with a recess trap to accommodate material to match the floor covering, together with means whereby the trap can be levelled flush with the finished floor surface.

Standpipes.—Services are fed to desk positions by means of standpipes which screw into the duct outlets in such a manner that a watertight joint is made and earth continuity maintained. Two types of standpipes are employed, one for communication services and the other for E.L. & P. services, and various shapes and designs are available to meet individual requirements.

The standard system requires normally $2\frac{3}{4}$ ins. depth of floor screeding with $\frac{1}{4}$-in. lino cover, and such a floor fill is sufficient to permit of 1-in. conduit passing either over or under the duct. If this facility is not required it is possible to accommodate the system in a 2-in. floor fill providing junction boxes can be recessed.

The system complies with the I.E.E. regulations governing earthing requirements, but an earth wire may be run if desired.

Layout of Underfloor Duct Installations.

Fundamentally there is little difference between the use of underfloor ducts and steel conduits for the distribution of electrical service. In fact, the most satisfactory arrangements can be made perhaps by the judicious use of both systems, conduits being provided for fixed services and ducts for flexible services.

Although it is not possible to lay down any hard and fast rule for the design of all installations, there should be no difficulty in designing a duct layout to suit any individual requirements, provided the following precautions are observed.

(1) Underfloor ducts are intended primarily for concealment of flexible services, and they should not be encumbered by cables for main or sub-distribution. These cables can be run more conveniently and economically in screwed conduit direct from the riser shaft to the distribution board concerned.

(2) In order to avoid any possibility of congestion in ducts where cables are fitted into them, i.e. at riser shafts or distribution boards, it is important that multiple feeds should be provided in such positions, also that the cross-sectional area of the duct should not be reduced at any point to form a bottleneck. To facilitate these requirements suitable bends, elbows and bellmouth fittings are now available.

(3) For ordinary commercial office buildings the

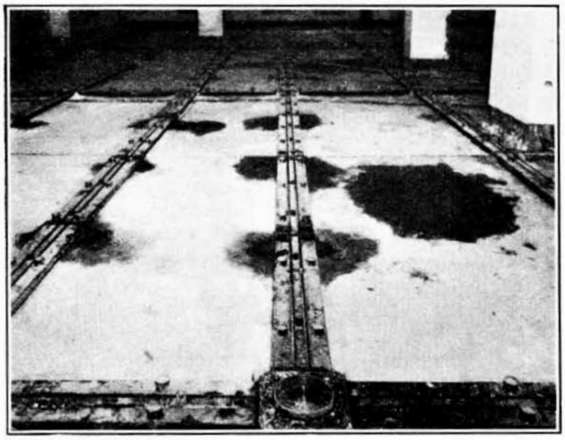


FIG. 10.—LAYOUT OF UNDERFLOOR STEEL DUCTS ON STRUCTURAL CONCRETE.

use of a triple duct system is recommended (Fig. 10). With this arrangement the ducts would be used for

(*a*) Flexible E.L. & P. services;
(*b*) G.P.O. services, such as telephones, etc.;
(*c*) Private house telephones, bells, clocks, etc.

This arrangement has the advantage of providing ample duct space for the communication services which in a normal building occupy from two to three times the space of the E.L. & P. services. It also provides independent duct runs for the G.P.O. telephones and privately owned telephones, thus avoiding any maintenance difficulties which occur with other systems of ducts where both services share a common run.

(4) Although ducts may be laid in any pattern to suit individual requirement the most convenient and economical arrangement is that in the form of a grid network comprising a number of rectangles 30 to 50 ft. long and 5 to 6 ft. wide with junction boxes at the intersection points. Such an arrangement ensures that outlets for E.L. & P. and communication services are available within 3 ft. of any required position.

(5) When the use of formed outlets is specified, it is desirable that the distance between centres of these outlets shall be the same throughout the entire building so that outlets can be conveniently located. The Post Office find that a convenient distance for this spacing is 3 ft., suitable datum positions being the centre points of junction boxes. The number of formed outlets required can be kept to a minimum by the judicious use of outlet couplings.

(6) It is also important to ensure in such installations that the centres of outlets in adjacent ducts are in line and at right angles to the main duct run. By these means the location of all outlets is greatly facilitated and a single line of markers can be used to indicate the position of a twin or triple-duct system.

(7) Formed outlets are unnecessary in short runs between junction boxes or in corridors. Generally speaking outlets are not provided in runs less than 6 ft. in length.

(8) Lighting and power services in ducts will be limited to low-pressure cables, i.e. not exceeding 250 volts. This cabling will be much facilitated if the occupier of the premises will agree to accept an all-in tariff for lighting and power supplies, especially as most supply companies offer favourable rates for such a service. When such a tariff cannot be arranged, it will be necessary to identify the lighting and power cables sharing a common run, and this can be conveniently arranged by the use of a twin-type cable for the power wiring, and a single looped-in cable for lighting circuits.

The actual layout of an underfloor duct installation in a large modern office building is shown in Fig. 11.

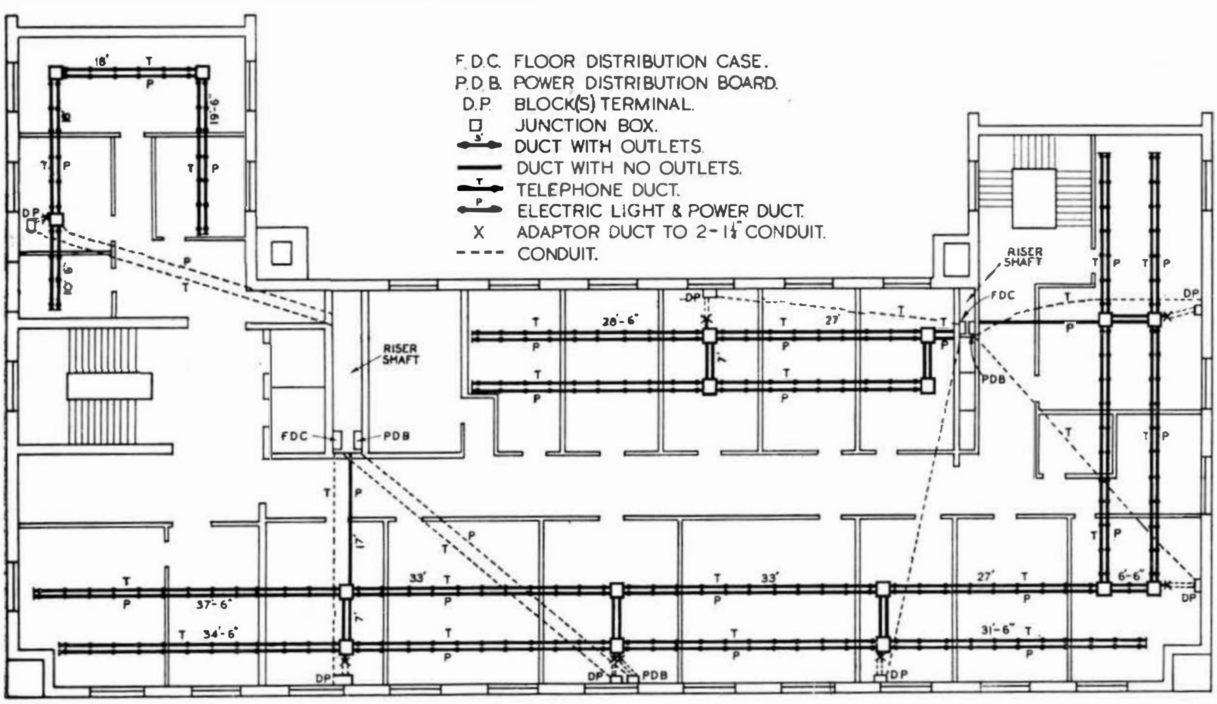


FIG. 11.—TYPICAL UNDER-FLOOR DUCTS LAYOUT IN A MODERN OFFICE.

Although the standard specification was only agreed in December last about twelve installations are now in the course of erection, and the following instances may be of interest :

Printing Works. — The standard scheme was employed to provide power for machines where the final position was not known during progress of building work. In this installation it was found to be cheaper to provide and install the duct system than an equivalent size screwed conduit owing to the quickness with which the duct could be laid, and the flexibility associated with the system.

Research Laboratory.—Here the scheme was used to provide for E.L. & P. and communication services at island sites and to augment a main cable trench running round the outer walls of the building.

Administrative Offices.—The scheme was adopted to provide for flexibility of service and concealment of wiring for E.L. & P., P.O. and house telephones when the final desk position and communication requirements were not known.

Telephone Manager's Office.—Concealment of the whole of wiring of communication services and small mains-operated machines was arranged as shown in Fig. **12**.

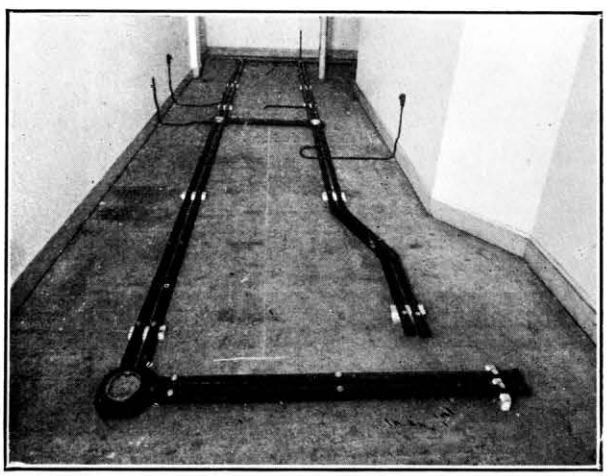


FIG. 12.—UNDER-FLOOR DUCT SCHEME IN TELEPHONE MANAGER'S OFFICE.

Large Stores.—Flexibility and concealment of E.L. & P. and communication services was provided when the ultimate use of the premises was unknown. In this installation a twin duct system was used, one duct for E.L. & P. services and the other for communication services, but alternate runs of the E.L. & P. duct were served from different sources of supply so that partial illumination would be obtained in the event of the failure of one supply.

PROGRESS AND EXECUTION OF WORK.

When the designs of all the services required in the building are completed and specifications prepared, the placing of the contract follows.

It is then essential that the starting date and progress of each separate work should be considered not only with relation to the building, but with relation to all other works connected with the structure and its equipment. This is, perhaps, the most important responsibility of the engineer, who must keep a constant watch on each service to make certain that it is carried out in proper sequence so that building operations may be completed with the utmost expedition. These supervisory duties can be greatly facilitated if a progress sheet for the whole of the work is prepared in advance of the commencement of building operations and kept up to date throughout the progress of the work.

Conclusions.

In conclusion, the authors would like to bring to the attention of all interested parties the following extract from the B.S.S. for Under-floor Duct :—

"The object of the specification is to provide a standard under-floor duct system for electrical services such as heat, light, power and communications for incorporation in buildings during construction.

It is in the interests of both owners and tenants that building specifications and plans should not be regarded as complete unless they ensure that it will be possible to provide immediate electrical service at all points where such service is required.

In these days of steel and concrete building construction, and especially in view of the steady expansion of different types of electrical services, it is essential that careful forethought be exercised in planning for such development. The Committee has had evidence of the lack of systematic advance planning for these services in buildings where, in order to remedy the deficiency, it has been found necessary to adopt methods that are expensive, inconvenient and architecturally undesirable.

When no such provision has been made, damage to walls and floors, disfigurement of decorations and inconvenience results ; walls and floors may have to be cut through, leads may have to be taken through the offices of adjacent tenants, and disfigurement of walls results through the fixing of casing or tubing. All these difficulties may recur at intervals in the same building.

The matter is, therefore, one of particular concern to owners of buildings.

The extent to which such disadvantages can be avoided depends upon the adequacy of the standardised duct system incorporated in buildings during construction. In the specification it is provided for a comprehensive and flexible system of standardised ducts and fittings which makes it possible to carry out thoroughly and with minimum disturbance any new provision or re-arrangement of electrical services that may be necessary.

The co-operation of architects, owners, surveyors, consulting engineers, builders and others responsible for the planning and erection of buildings, in arranging for the layout of electrical services with a minimum of inconvenience and trouble to all concerned, is, therefore, earnestly solicited by the Committee which is fully representative of all interests concerned."

The Problems Associated with Impulsing in Non-Director Areas

H. WILLIAMS, A.C.G.I., A.M.I.E.E.
and S. RUDEFORTH

Previous articles have examined the conditions which limit the permissible dial speeds and junction resistances in Non-Director areas using non-ballast, pre-2,000 type selectors. This examination is continued in the present article for pre-2,000 type selectors fitted with ballast feeds.

Survey.

IN a previous article[1] bearing the above title various factors affecting both impulse distortion and pick-up under loop dialling conditions were discussed in some detail. It was shown how these factors limited the dial speed and junction lengths with which satisfactory impulsing was possible over a single junction and over two and three junctions in tandem, via relay-sets ("repeaters," or their equivalent) incorporating 200 + 200 ohms A relays. Finally, the impulsing limits, expressed in terms of maximum permissible dial speeds and junction resistances, were established for conditions involving a number of simultaneously applied adverse factors.

In the present article it is proposed to discuss impulsing using pre–2000 type selectors under conditions similar to those already dealt with, but using relay sets in which the shielded 200 + 200 ohms A relays are replaced by shielded 50 + 50 ohms relays with ballast feed resistors.

It should be understood that the impulsing elements of U.A.X.'s 13 and 14, discriminating selectors, and the ballast type auto-to-auto relay-set (hereinafter called an "impulse repeater") are similar and, as such, whatever modifications are applied to the one for the purpose of improving impulsing should apply equally to the others.

Use of Ballast Resistors in Transmission Bridges.

By virtue of the increased transmitter current, 50 + 50 ohms feeding bridges give an increased transmission sending efficiency compared with 200 + 200 ohms bridges. In order to prevent damage to the transmitter and relay windings due to excessive current with short subscribers' lines and yet maintain an increase of current with longer lines over that obtainable with 200 + 200 ohms bridges, the 50 + 50 ohms windings of the feeding coils are connected in series with a twin filament, 100 mA type, ballast resistor or barretter. The effect of the barretter is shown in Fig. 1 which compares the currents in subscribers' lines of various resistances for 200 + 200 ohms and 50 + 50 ohms bridges when the latter is associated with a 100 mA type barretter; the relationship between the resistance of the barretter and the subscriber's line resistance is also shown.

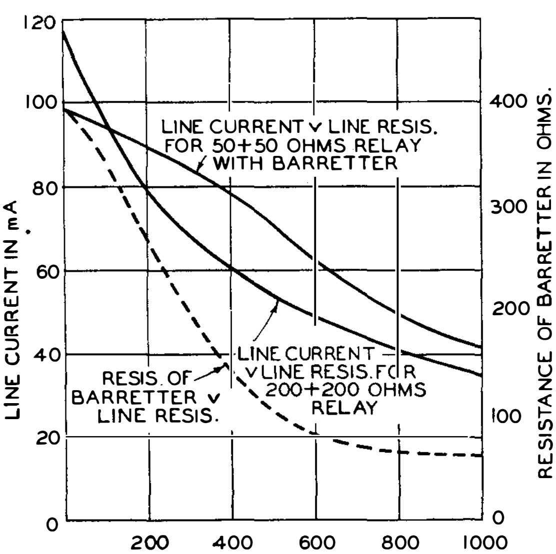


FIG. 1.—EFFECT OF BARRETTER ON LINE CURRENT.

Alternatively, for the same sending efficiency as that obtainable with 200 + 200 ohms bridges, the 50 + 50 ohms bridge with ballast resistor permits the resistance of the subscriber's line to be increased.

Ballast resistors are required on junction calls. It is therefore necessary that they be fitted on the local side of auto-to-auto relay sets and of discriminating selectors, and on the called subscribers' side of final selectors.

For further information on ballast resistors in feeding bridges, attention is drawn to a previous article in the JOURNAL[2] and to an article in the Engineering Supplement to *Siemens Magazine*, No. 117, February, 1935.

The Ballast Type Impulse Repeater A Relay.

This relay is of lower resistance than the equivalent non-ballast A relay and, because of the limited winding space available, has, in consequence, fewer turns (4,000 as against 8,000 for the 200 + 200 ohms relay), so that (*a*) its operate current, operate and release lags and hence the impulse distortion introduced by the relay, are all changed; (*b*) its inductance and effective resistance are reduced. In regard to (*a*), this has necessitated the use of a "special" isthmus—sometimes referred to as a "V" or "pear-shaped" isthmus—armature for the ballast type impulsing relay. An illustration of such a relay with the special isthmus armature is shown in Fig. **2** (*c*), p. 192, Vol. 30 of the JOURNAL.

As far as its effect on impulsing is concerned, the special isthmus armature is equivalent to an ordinary isthmus armature having a slightly wider neck; but the practical difficulty arising from having two similar armatures of slightly differing dimensions is obvious.

For reasons given later the 50 + 50 ohms A relay now has spring-sets comprising one ordinary change-over (C) and one make-before-break (K), compared with the K and M (make) spring-sets of the 200 + 200 ohms, non-ballast impulsing relay.

[1] *P.O.E.E.J.*, Vol. 30, pp. 191 and 320.

[2] *P.O.E.E.J.*, Vol. 26, p. 140.

Impedance of 50 + 50 *ohms A Relays.*

Effect of Nickel-iron Sleeves. Since these relays are bridged across the lines, for a low transmission loss it is essential that they offer a high impedance to speech currents ; and with a relay so low in resistance as 50 + 50 ohms, some means of increasing its impedance is necessary. Ekelöf[3] has shown that the impedance of an iron-cored coil is increased by having thin sleeves over the core of the same material, but that the increase in impedance is much more pronounced when the sleeves possess high permeability and electrical resistivity.

In the 3,000 type relay, the core has been standardised as an ordinary soft iron core which may be surrounded by three nickel-iron sleeves, 20 mils. thick. These sleeves are longitudinally slit and thus present an incomplete path for eddy currents and also permit ease of assembly.

In an article on nickel-iron sleeves for telephone relays appearing in the Engineering Supplement to *Siemens Magazine*, No. 75, August, 1931, it is shown that the A.C. flux, for frequencies above about 100 c.p.s., does not penetrate to a depth greater than 0.25 mm or so ; whereas the steady D.C. flux penetrates to the centre of the core. Thus, approximately, the solid core may be regarded as carrying the D.C. flux, while the A.C. flux is confined to the outer sleeves ; these, being of high electrical resistivity and of high permeability, cause the A.C. impedance to be large and sensibly independent of the D.C. flowing in the windings. Although the sleeves will carry some D.C. flux, it would appear from a study of the cross-section of the magnetic circuit that most of the flux will be carried by the solid core

The inductance, effective resistance and impedance of a shielded 50 + 50 ohms relay with and without the nickel-iron sleeves are shown in Figs. 2 and 3.

Although the inductance and effective resistance of 50 + 50 ohms relays are necessarily lower than for the 200 + 200 ohms relays, nevertheless, with a

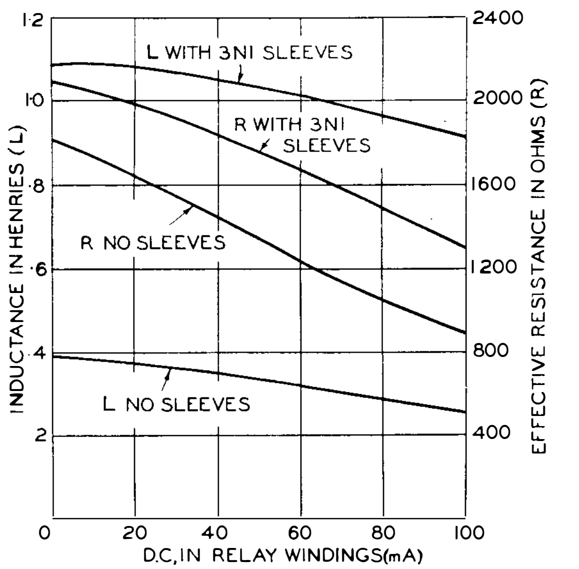


FIG. 2.—INDUCTANCE AND EFFECTIVE RESISTANCE OF A 50 + 50 OHMS RELAY, TESTED WITH 1 VOLT AT 800 C.P.S.

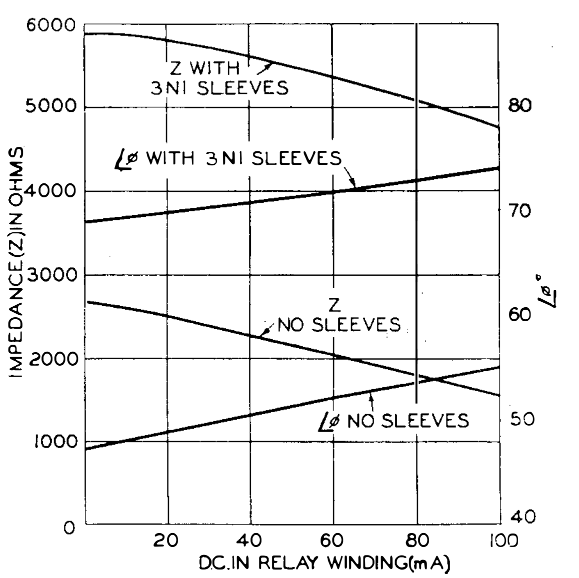


FIG. 3.—IMPEDANCE OF A 50 + 50 OHMS RELAY, TESTED WITH 1 VOLT AT 800 C.P.S.

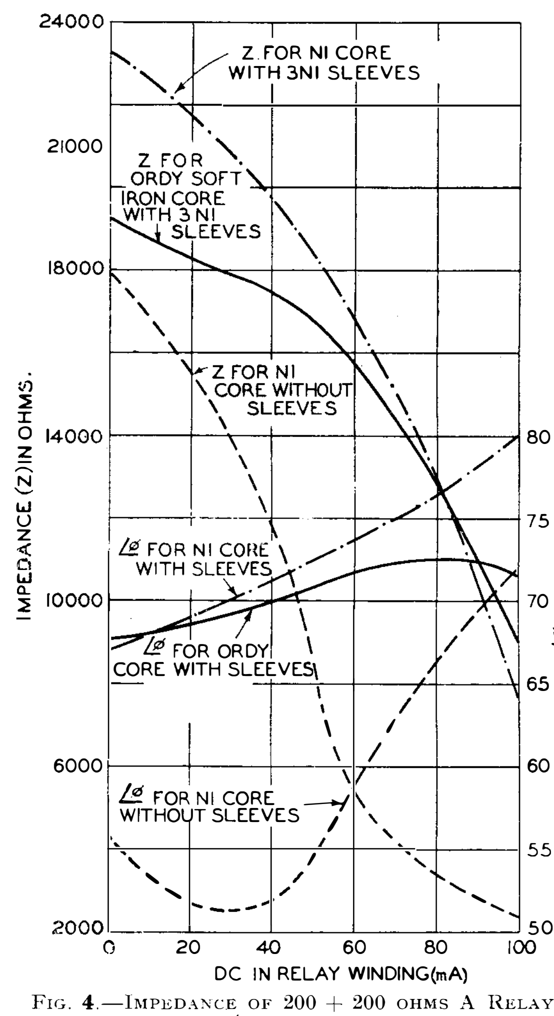


FIG. 4.—IMPEDANCE OF 200 + 200 OHMS A RELAY (800 C.P.S., 1 VOLT).

[3] " The Calculation of Magnetic Circuits Fed by Alternating Current," *Zeitschrift Fermeldetechnik*, March 22nd, 1935.

modulus of about 5,000, so long as the phase angle is not less than approximately $\underline{/50°}$, the transmission loss introduced by the relay is less than 0·1 db.

Impedance with Nickel-iron Cores. The impedance may be increased by the use of a core entirely composed of the nickel-iron alloy; but it is considerably affected by the amount of D.C. flowing in the relay winding, since such a core is more easily saturated. Fig. **4** will be of interest; it compares the impedance of a shielded 200 + 200 ohms A relay having (*a*) an ordinary soft-iron core with three nickel-iron sleeves, (*b*) a nickel-iron core with nickel-iron sleeves, and (*c*) a nickel-iron core without nickel-iron sleeves.

Characteristics of Nickel-iron Cores and Sleeves.

T. D. Yensen[4] has shown that a 30 per cent.—36 per cent. nickel-iron alloy possesses the highest specific resistance of the nickel-iron alloys, the value being about 80 microhms per cm. cube. With 30 per cent. nickel, however, the permeability is only about 250 (H=1 Gauss) compared with nearly 3,000 for the 36 per cent. nickel-iron alloy; the highest permeability is obtained with 50–60 per cent. nickel. The characteristics of nickel-iron alloys are, it appears, greatly affected by heat treatment and the presence of impurities. It is understood that the nickel-iron sleeves (and cores) used on telephone relays are composed of the 36 per cent. nickel alloy which possesses the following characteristics:

Permeability (H=1 Gauss)=1,600-1,700.
Maximum permeability = 5000.
Electrical resistivity = 80 microhms per cm. cube.

Effect of Short-circuited Turns on the Impedance of a Relay.

Short-circuited turns on the A relay affect:

(*a*) its impedance and therefore the transmission loss introduced by it;

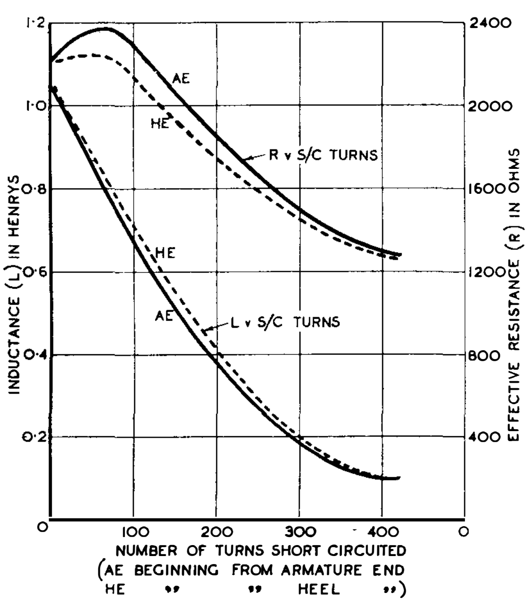


FIG. **5**.—EFFECT OF SHORT-CIRCUITED TURNS UPON RELAY INDUCTANCE AND EFFECTIVE RESISTANCE.

[4] *Journal of the Franklin Institute,* Vol. 199, pp. 333-342.

(*b*) its operate and release lag and, hence, the impulse distortion produced by the relay.

Since both (*a*) and (*b*) are important, it is proposed to demonstrate the effect of short-circuited turns by giving some quantitative results.

Fig. **5** shows how the impedance of a shielded 50 + 50 ohms A relay is affected by short-circuited turns. These curves were obtained by winding, side by side, six additional small coils over the top layer fo the relay and covering the whole of the winding length. Each small coil comprised **70** turns of the same gauge copper as the main winding in two equal layers. An equivalent of **420** short-circuited turns could thus be obtained. The very considerable reduction in the relay inductance with short-circuited turns will be noted as well as the ultimate reduction in effective resistance. For the sample tested the impedance with no short-circuited turns and with **420** short-circuited turns on the surface of the winding is, respectively, **5,777** $\underline{/67° 38'}$ and **1,380** $\underline{/22°}$. The effect of the short-circuited turns on the operate and release lags of the relay and hence on impulse distortion will be demonstrated later.

Effect of A Relay Shield on Impedance of 50 + 50 *ohms Relays.*

This is shown in Table 1, from which it will be noted that the shield increases the effective resistance and inductance by **10–20** per cent. and **6–13** per cent. respectively, the angle being slightly reduced. The effect on the transmission loss may be regarded as negligible.

TABLE 1.

D.C. in Relay Winding mA	Effect of " A " relay shield on impedance measured at 800 c.p.s., 1 volt P.D.)		
	Without shield		
	Effective Resistance in ohms	Inductance in henries	Impedance in ohms
0	1,750	0·968	5,200 /70·2°
20	1,678	0·974	5,170 /70·9°
50	1,550	0·957	5,040 /72·1°
80	1,350	0·915	4,800 /73·6°
	With shield		
0	2,090	1·089	5,860 /69·1°
20	1,992	1·085	5,800 /70°
50	1,758	1·037	5,490 /71·4°
80	1,480	0·964	5,070 /73°

Impulsing under Ballast Resistor Conditions.

General Considerations. Originally, the 50 + 50 ohms impulsing relay had, like the 200 + 200 ohms relay, 1K + 1M spring-sets, as shown in Fig. **6a**. In order to obtain satisfactory short and long line impulsing, however, it was found necessary to adopt the special isthmus armature. Later, the investigations on loop impulsing under non-ballast conditions showed the need for a rectifier across the

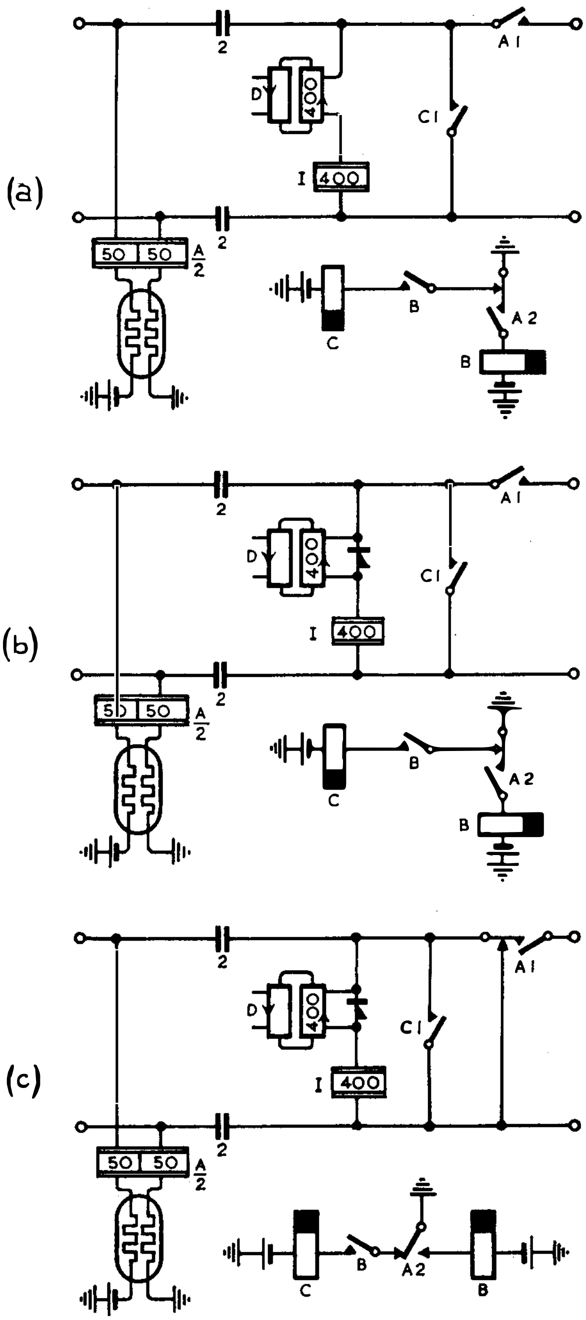


FIG. 6.—MODIFICATIONS TO IMPULSE REPEATER.

400 ohms winding of the impulse repeater D relay for the purpose of extending permissible junction resistances by minimising initial and subsequent pick-up troubles. When, however, the D relay rectifier was employed on the ballast type impulse repeater (Fig. **6** (b), the permissible dial speeds under short line conditions fell very considerably. The reason for this appears to be due to surge re-operation of the impulse repeater A relay during the first break of the dial impulsing contacts, a condition which is accentuated by the fact that during the first break the A relay current decays slowly, as shown in Fig. **7**. (Incidentally, another point of interest in Fig. **7** is

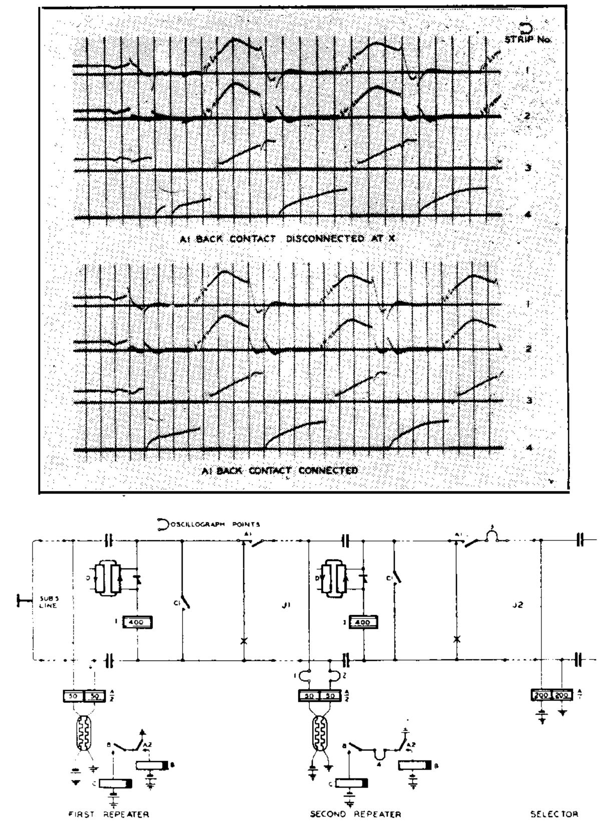


FIG. 7.—EFFECT OF A1 BACK CONTACT.

that it shows the gradual reduction in A relay current from impulse to impulse as the barretter warms up.) The net result of the re-operation of the A relay during the first break was the equivalent of a very short first impulse with consequent reduction in permissible dial speed.

During the first break of the dial impulsing contacts, the rate of decay of the A relay current has been accelerated and the tendency for the relay to re-operate has, for all practical purposes, been eliminated, as will be seen by comparing the oscillograms in Fig. **7**, by a device due to Messrs. Siemens Brothers. This consists of replacing the repetition contact, A1, by a K spring-set as shown in Fig. **6c** By this means, partial simulation of the conditions appertaining for the subsequent impulses of the train dialled (C1 contact short-circuiting the D and I relays) is obtained.

Under short line, low insulation conditions, the first impulse break period at the selector still remains shorter than the subsequent breaks, but only by about 3 mS ; but this difference is constant irrespective of whether the call is routed over a single junction or over two and three junctions in tandem. From Fig. **6c** it will be noted that the K spring-set formerly operating the B and C relays is now replaced by a change-over (C) spring-set which, incidentally, has a stiff back spring. This spring-set combination of 1 C + 1 K, in conjunction with the special isthmus armature, results in a satisfactory compromise between the short and long line impulsing requirements.

Surge Effects. With tandem junction working, i.e. when a call passes via more than one impulse repeater, surge effects are more evident with 50 + 50 ohms relays than with the non-ballast type. Certain difficulties arose due to these surges. For example, using two and three junctions in tandem, with onerous telephone instrument conditions comprising, say, a P.B.X. with two night extensions, and to a minor degree with Tele. 162 conditions on a 3-junction route, the 2nd and 3rd impulse repeater C relays (in heavy adjustment) chattered on operation. This chattering, however, occurred only under short line low insulation conditions when the dial speed was such that the impulsing limit was approached, i.e. 33 mS selector A relay B.C.C.P. (break contact closed period).

C relay chatter on operation was attributed to the partial re-operation of the A relays during the first break sufficient to interrupt the C relay current but not sufficient to re-establish the outgoing loop current via contact A1. During the 2nd break of the dial impulsing springs the C relay released, having not been sufficiently fluxed during the 1st break. In consequence, the 2nd break period of the impulse repeater A1 contacts was shortened, even more than the 1st. This trouble has been avoided by limiting the impulse repeater C relay release lag between 150 and 225 mS, whereas formerly it was permitted to follow that set by the mechanical tolerances on the relay, a lower release lag of 100 milliseconds being possible. With a minimum impulse repeater C relay static lag of 150 milliseconds, therefore, the permissible dial speed is made dependent only on the length of the 1st B.C.C.P. of the selector A relay.

Surges also accentuated subsequent pick-up troubles; these, however, have been eliminated by a device which will be described later.

A Relay K Spring-set Contact Clearances. As will be seen later, the impulsing limits have been decided upon with all factors adverse but with relaxed make-contact clearances which, for the short and long line impulsing conditions were 15 mils (for armature travel = 23 mils) and 18 mils (for armature travel = 27 mils) respectively. These contact clearances may be regarded as nominal values. In practice, if the contact clearances were set at random, the make-contact clearance would generally be not less than about 15 mils but tending to be larger than 18 mils, especially for armature travels greater than 25 or 26 mils.

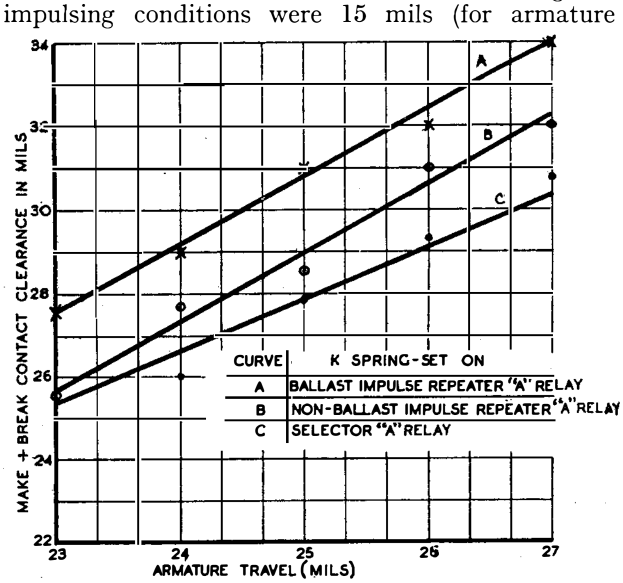


FIG. 8.—VARIATION OF MAKE + BREAK CONTACT CLEARANCES WITH ARMATURE TRAVEL.

The graphs shown in Fig. 8 will be of interest; they show how the average minimum K spring-set make + break contact clearance varies with armature travel for the relays and data given in Table 2, the spring tensions quoted being such as to produce the greatest flexing of the relay springs with the spring tensions permitted. The increased contact clearances obtainable with very stiff back springs will be remarked.

TABLE 2.

Selector " A " relay on	Spring thicknesses in mils		
	Lower	Lever	Upper
Ballast impulse repeater ..	24	12	12
Non-ballast impulse repeater	18	12	12
Selector	14	14	14
	Spring tension in grammes		
	Lower	Lever	Upper
Ballast impulse repeater ..	50	12	13
Non-ballast impulse repeater	35	13	17
Selector	30	16	20

The minimum make or break contact clearance for the impulsing relays considered, has now been fixed at 10 mils. It will be seen from Fig. 8, therefore, that for an armature travel of 23 mils, the minimum make = break contact clearance is about 14 mils for the ballast A relay, and 13 mils for the selector A relay. For an armature travel of 27 mils it will also be observed that, when the break-contact clearance of the ballast A relay is 10 mils, the make-contact clearance can be at least 24 mils.

Short, Leaky Line Impulsing.

Impulsing Tests. A series of tests was made to ascertain the maximum dial speeds, with a constant dial break ratio of 63 per cent., or the lowest dial break ratios at a constant dial speed of 12 i.p.s., with which it was possible to impulse over one junction or over two and three junctions in tandem when the following adverse factors were applied:

(*a*) Light A relays, i.e. just releasing on their minimum allowable release currents.

(*b*) Voltage: 52 V and 46 V on the impulse repeaters and selector respectively.

(*c*) Zero resistance, subscriber's line and junctions.

(*d*) Subscriber's line insulation resistance = 50,000 ohms and junction insulation resistance = 50,000 to 250,000 ohms, leg-to-leg.

(*e*) A relay K make-contact clearances = 15 mils throughout.

(*f*) Capacitance of subscriber's instrument condenser = 2 μF + 10 per cent.
(*g*) Telephone conditions : Tele. 162.

For reasons already given in the previous article the impulsing limit under the above conditions is reached when, if the impulse frequency is further increased, the selector A relay B.C.C.P. for the 1st impulse in a train of impulses becomes less than 33 milliseconds.

Three impulse repeaters and a selector of each of the five makes were tested and the impulse repeaters were selected and placed in that order along the route which gave the worst performance. It was found, however, that with accurate contact gauging the results for Tele. 162 conditions were remarkably consistent—a fact which is partly attributed to the practically bounceless break contacts of the A relays.

The results of the tests are summarised in Table 3.

TABLE 3
(TELE. 162 CONDITIONS)

Number of Junctions in tandem	Permissible dial speed in i.p.s. with subscriber's line = 50,000 ohms and with junction leaks of :		Limiting dial break ratio % with dial speed = 12 i.p.s. and with subscriber's line and junction leaks = 50,000 ohms
	250,000 ohms	50,000 ohms	
1	14·4	13·9	53
2	13·2	12·6	59
3	12·0	11·4	64

It is of interest to compare the figures given in Table 3 with similar figures for the non-ballast impulsing which are stated in Table 7, page 325 of Vol. 30 of the JOURNAL ; it will be noted that the permissible dial speeds for 50,000 ohm line leaks are almost identical.

Effect of Low Junction Insulation Resistance.—With Tele. 162 conditions and assuming 15 mil A relay make-contact clearances with other factors adverse, the lowest junction insulation resistances which would permit a maximum dial speed of 11 i.p.s. to be met, are given in Table 4.

TABLE 4.

Number of Junctions in tandem	Approximate junction insulation resistance for a permissible dial speed of 11 i.p.s. (Subscriber's line insulation resistance = 50,000 ohms)		
	J1	J2	J3
1	12,000	—	—
2	250,000 12,000 15,000	12,000 125,000 15,000	— — —
3	14,000 250,000 20,000	250,000 250,000 20,000	250,000 14,000 20,000

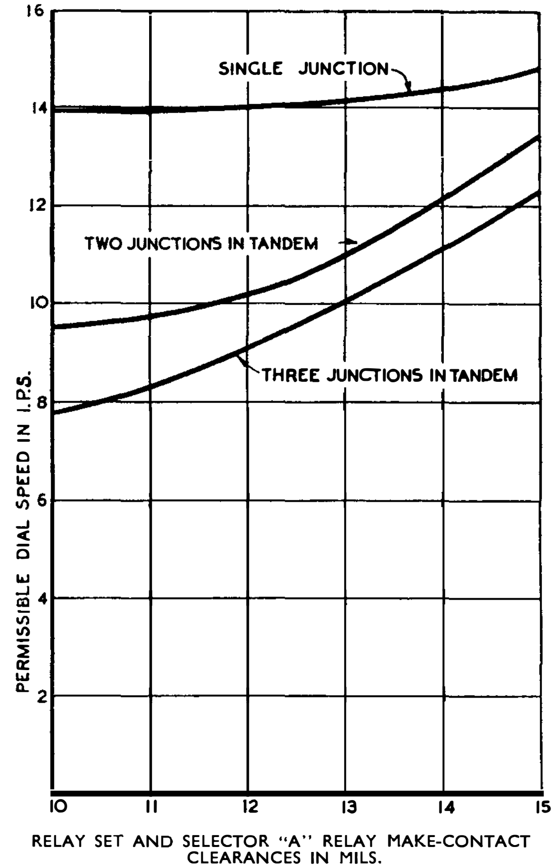


FIG. 9.—EFFECT OF SMALL A RELAY MAKE-CONTACT CLEARANCES.

Effect of Small A Relay Make-Contact Clearances. This is shown by the curve in Fig. 9. It will be remarked that the change in permissible dial speed is much more pronounced for the two and three junction routes. The reason for this lies in the fact that in the latter instances, with small make-contact clearances (incidentally, also for line insulation resistance of less than about 14,000 ohms) intermittent increase in impulse distortion occurs due to the effect of surges on the A relays. In Fig. 9 the worst results of about 8 i.p.s. and 9·5 i.p.s. are quoted for 10 mils contact clearances. Tests, show, however, that the higher dial speeds of 11 and 12 i.p.s. respectively can generally be met for the two and three junction routes respectively, under the conditions cited.

Effect of an Impulse Repeater A Relay having Short-circuited Turns. Fig. 10 shows how short-circuited turns of the relay described earlier affected the static operate and release lags, and the permissible dial speed for a single junction route. From the curves shown it is interesting to compare the armature-end and heel-end slug effects on the operate and release lags of the relay.

The importance of making impedance tests on A relays in order to ascertain the presence of short-circuited turns will be appreciated both from the transmission and impulsing aspects.

Effect of Centralised Service Observation (C.S.O.) Equipment.—With the present C.S.O. apparatus, on

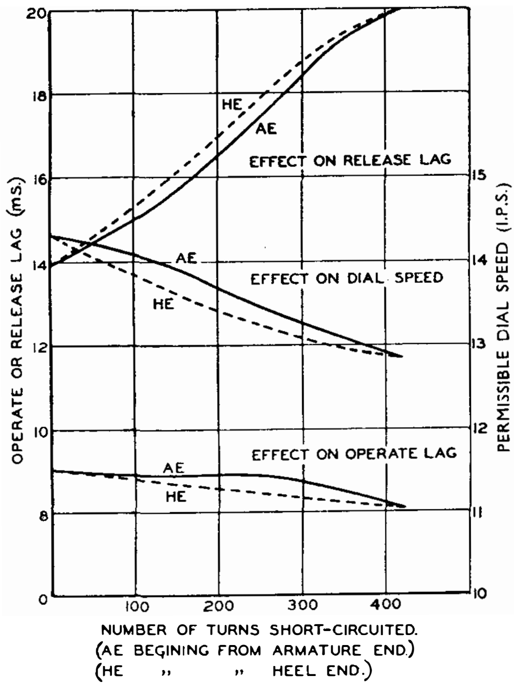


FIG. 10.—EFFECT OF SHORT-CIRCUITED TURNS ON THE OPERATE AND RELEASE LAGS AND ON PERMISSIBLE DIAL SPEED.

lines undergoing observation, the equivalent of another impulse repetition is introduced; this, of course, means added impulse distortion and further limitations in permissible dial speed and junction lengths. Although the C.S.O. A relay can be modified by fitting a special isthmus armature and a K spring-set for the A1 contact so that a considerably smaller impulse distortion results, nevertheless, under short leaky line conditions, a further reduction of 1·3 i.p.s. in permissible dial speed occurs when the C.S.O. equipment is inserted. The Post Office Research Branch, however, is developing a device for C.S.O. which will not produce additional impulse distortion on circuits undergoing observation.

Effect of Amplified Junctions.—As is well known, more and more heavy gauge overhead lines are being transferred to underground cables of the star-quad type; such cables will consist of light gauge conductors, e.g. 20 lbs., associated with amplifiers. The reasons for this are (*a*) improved transmission, (*b*) re-routing, (*c*) cheapness. In such instances, signalling and impulsing are effected over the two side circuits in parallel, the D.C. for this purpose being brought to the centre points of the transformers for bye-passing the amplifiers. Thus, the resistance of the lines excluding the terminations is halved, and the line capacitance is appreciably increased. This increase in the line capacitance causes a reduction in the dial speed for satisfactory impulsing.

The effect on the permissible dial speed using 4-wire, amplified, 20 lbs., star-quad cable for a single-junction route is shown in Fig. **11**. The subscriber's lines and junction leaks were 50,000 ohms and 250,000 ohms respectively. It is seen that for the ballast conditions, the amplifier terminations themselves cause a reduction, apart from the line capacitance; such, however, is not evident with non-ballast conditions.

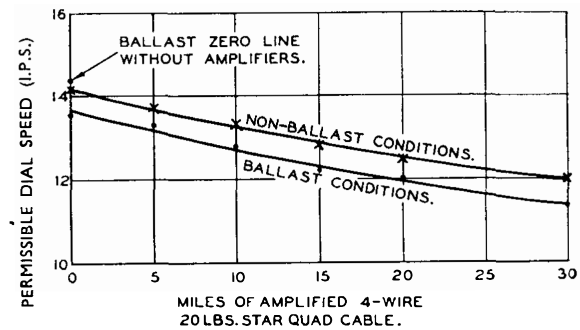


FIG. 11.—EFFECT OF AMPLIFIED CABLE ON PERMISSIBLE DIAL SPEED.

Formerly impulsing failure due to the selector A relay B.C.C.P. being less than 33 mS occurred with overhead lines when these were short and of low insulation, but with 4-wire amplified junctions this failure occurs over a long line because, as shown in the previous article, the greater capacitance offsets the effects of line resistance.

Again, with 4-wire amplified junctions, since the effect of the increased line capacitance is to increase the make ratio of the A relays, the margin for holding the B relays during impulsing over long lines is increased.

Long Line Impulsing.

Impulsing Tests. A large number of tests were made to determine the maximum allowable junction resistances for 1-, 2- and 3-junction routes applicable to overhead lines (adverse conditions). The following is a list of adverse factors which were ultimately applied and upon which the impulsing limits have been based:

(*a*) High dial speed; upper limit = 12 i.p.s.
(*b*) Low dial make ratio = 28 per cent.
(*c*) Low battery voltage throughout = 46 volts.
(*d*) All impulsing relays in heavy adjustment.
(*e*) Large impulsing relay make-contact clearances.
(*f*) Heavily adjusted B relays.
(*g*) Maximum subscriber's line resistance = 600 ohms.
(*h*) Capacitance of subscriber's instrument condenser = 2 μF—10 per cent.
(*i*) Junction and subscriber's line insulation resistance "infinite."
(*j*) Telephone conditions, Tele. 162.

These factors have already received detailed analysis in the previous article, and it is thought that further consideration here is unnecessary. It will be recalled, however, that with the above-stated conditions the impulsing limit (as distinct from the pick-up limit) is reached when failure to hold of the B relays occurs.

The first impulsing tests were made on 15 impulse repeaters and 5 selectors (3 impulse repeaters and a selector of each make) with the following conditions applying:

(1) Impulse repeater A relays not shielded but selector A relay shielded.

(2) A relay make-contact clearances = 18 mils.
(3) Subscriber's instrument condenser = 2 μF.
(4) A relays just operating on their maximum permissible operate figures.

The results obtained are summarised briefly in Table 5.

TABLE 5.

Number of Junctions in tandem	Junction limits in ohms		
	J1	J2	J3
1	1,640–2,200	—	—
2	820–1,360 0 1,120–1,400	820–1,360 1,700–2,220 0	— — —
3	780–1,020 0 0 1,180–1,460	780–1,020 0 1,140–1,500 0	780–1,020 2,000–2,340 0 0

The variable results obtained are mainly attributed to the bounce of the A relay make contacts, being particularly marked for the impulse repeater A relay.

Effect of Shielding Impulse Repeater A Relays. The effect on the impulsing limit was observed to be only slight for the single-junction route, an increase of about 10 ohms being noted, but for the two- and three-junction routes the increase was about 50 ohms per junction.

Effects of Telephone Condenser Capacitance. This is shown in Table 6 for a particular set-up of apparatus using shielded A relays having 18 mil make-contact clearances.

TABLE 6.

Number of junctions in tandem	Telephone Condenser capacitance (μF)	Junction limits in ohms		
		J1	J2	J3
1	1·8 2·0 2·2	1,650 1,700 1,800	— — —	— — —
2	1·8 2·0 2·2	890 925 990	890 925 990	— — —
3	1·8 2·0 2·2	770 800 835	770 800 835	770 800 835

It is seen that the change in junction resistance between the capacitance limits of 1·8–2·2 is quite appreciable.

Effect of Increasing A Relay Make-Contact Clearances. This is illustrated in Fig. **12**. The full line curves are for the selector A relay adjusted to maximum mechanical tolerances, and the dotted curve is for the single junction when the selector requires its maximum value of operate current just to actuate it. It will be noted that for a single-junction resistance limit of 1,500 ohms, changing the selector A relay adjustments from extreme heavy to maximum mechanical tolerances has the same effect as a change of about 2 mils on both the impulse repeater and selector A relay contact clearances.

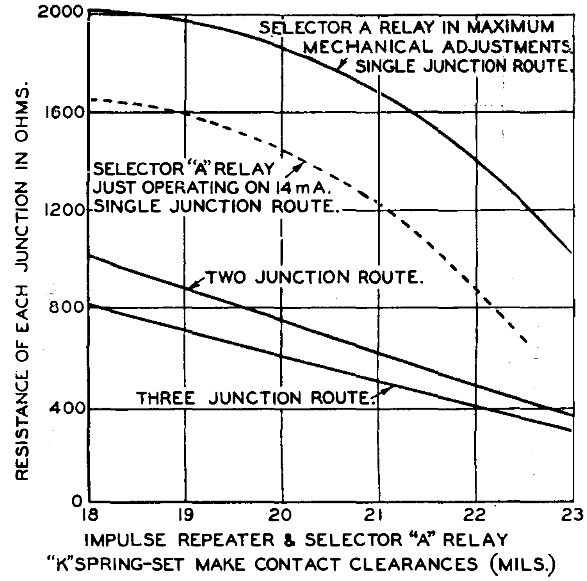


FIG. **12**.—EFFECT OF INCREASING "A" RELAY MAKE-CONTACT CLEARANCES.

The junction limits which have been established after a review of all the tests made, will be tabulated later.

Effect of the Present C.S.O. Equipment on Permissible Junction Resistances. Using the modified C.S.O. A relay mentioned earlier, the C.S.O. apparatus reduces permissible junction resistances by approximately 100 ohms for the single junction, and 30 ohms per junction for two and three junctions in tandem when these are of equal resistance.

Pick-up Limits.

The meaning of the terms initial and subsequent pick-up, as far as impulsing is concerned, has been given in detail in the previous article. Three aspects of pick-up are to be envisaged, viz.:

(*a*) Initial pick-up of impulse repeater and selector A relays.
(*b*) Pick-up of impulse repeater A relays under "called subscriber answers" conditions.
(*c*) Subsequent pick-up, i.e. when the A relays are again held operated and the impulse repeater C relays are de-energised at the end of each train of impulses.

In the following it is to be assumed that the impulse repeater D relays are "rectified" and that all impulsing relays are shielded.

(a) *Initial Pick-up of Selector and Impulse Repeater A Relays.*

With all factors adverse, for initial pick-up from an impulse repeater to a selector, no vertical magnet pawl flick occurs on the selector for a junction resistance of less than 2,100–2,300 ohms. Since the relay flux is reversed when the called subscriber answers a worse pick-up condition for the impulse repeater A relay is:

(b) *Pick-up of Impulse Repeater A Relays under "Called Subscriber Answers" Conditions.*

The inter-repeater junction limit for this was found to be 810-920 ohms. A value of 800 ohms may, therefore, be regarded as a sound limit.

(c) *Subsequent Pick-up.*

False impulses to the selector on subsequent pick-up occur more readily on ballast equipment than on non-ballast equipment ; so much so, in fact, that even with a rectifier across the 400 ohms winding of each impulse repeater D relay, the junction resistance may have to be reduced to about 400 ohms in order to prevent false stepping of the selector.

Although subsequent pick-up effects, depending as they do on the relative values of the impulse repeater and selector C relay release lags, as well as on critical values of subscriber's line resistance, are frequently somewhat fortuitous, nevertheless it was considered desirable to find some means, if possible, to eliminate such effects ; at least to such an extent that firm 800 ohms inter-repeater junction resistances could be met.

Elimination of Subsequent Pick-up Effects.

This has been done by the use of an auxiliary relay, CA, on relay C of each impulse repeater. Contact CA1 is connected in series with an 800 ohms resistor,

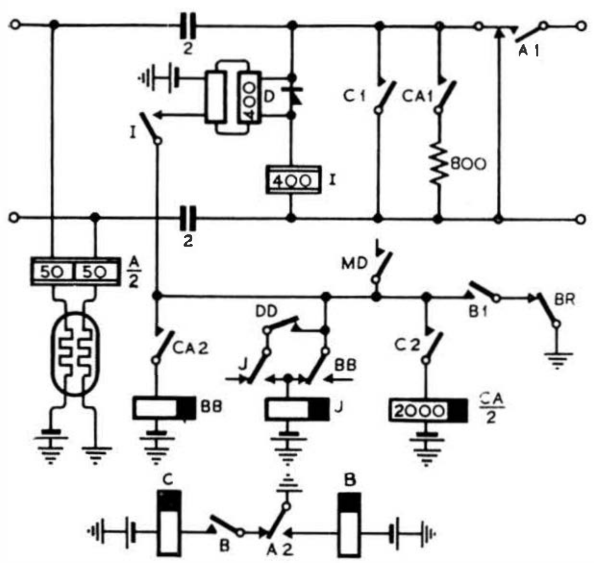


FIG. 13.—MODIFICATION TO IMPULSE REPEATER TO ELIMINATE SUBSEQUENT PICK-UP EFFECTS.

the whole being in parallel with contact C1 as shown in Fig. 13 which depicts the conditions as far as impulsing is concerned.

In Fig. 13, assume that contact CA1 is disconnected ; then, at the end of a train of impulses the A relays re-operate and contact C1 subsequently falls away. At this instant the current in the A relay ahead momentarily falls to zero because of the inductance of the D and I relay path. That A relay is, therefore, momentarily de-energised sufficiently, perhaps, to result in an extra impulse being given to the distant selector. With the CA1 contact connected, however, when C1 falls away the current is momentarily transferred to the 800 ohms path of the CA1 circuit, the current subsequently commencing to rise in the D and I relay path. By the time CA1 falls away (relay CA being slow-to-release) the inductive effects of the D and I relay circuit have been mainly

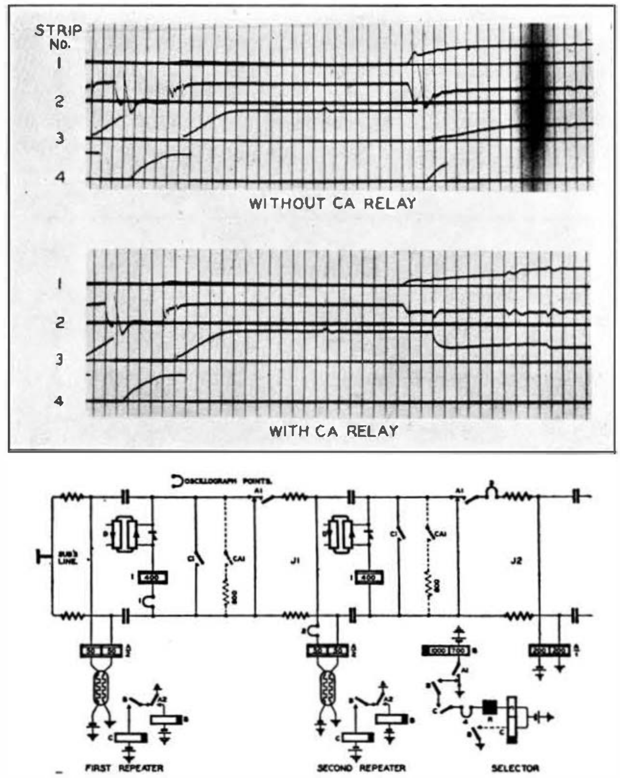


FIG. 14.—EFFECT OF CA RELAY.

overcome. The loop current during subsequent pick-up is therefore maintained, the A relays do not flick on subsequent pick-up for junction values up to at least 1,000 ohms, and false impulse troubles are eliminated. Fig. 14 illustrates the beneficial effect of the arrangement.

Referring again to Fig. 13 : during clear-down, relays C and CA start releasing together, since the CA relay is controlled via the B1 contact. This is so arranged in order to reduce the possibility of the impulse repeater being re-seized before full release of relay CA, otherwise relay BB would operate and subsequent operation of relay J would not occur. The release lag of relay CA is of the order of 100 milliseconds.

Summary of Changes Made to Impulse Repeaters or Equivalent.

These are :—

(*a*) Modification of the A relay including spring-sets (improvement of impulsing).

(*b*) Rectifier across the D relay (reduction of initial pick-up effects).

(*c*) Release lag of the C relay limited between 150 and 225 milliseconds (indirect improvement of impulsing).

(*d*) Addition of relay CA (elimination of subsequent pick-up effects.

Summary of Agreed Impulse Limits.

Table 7 gives the impulse limits, in terms of permissible dial speed and maximum allowable junction resistances for subscribers' lines of 0-600 ohms which have been agreed by the Contractors and the Post Office. These limits refer to Non-Director areas with pre-2,000 type selectors and (apart from the 200 + 200 ohms selector A relay) equipped with 50 + 50 ohms 3,000 type relays and ballast resistors. The figures given are for apparatus modified in accordance with the preceding paragraph.

TABLE 7.

(i) Single Junction—	
Dial speed using Tele. 162	12 i.p.s.
Junction resistance	1,500 ohms
(ii) Double Junctions—	
Dial speed using Tele. 162	12 i.p.s.
1st junction not to exceed	800 ohms
2nd junction not to exceed	1,600 ohms
The sum of the two junctions not to exceed	1,600 ohms
(iii) Triple Junctions—	
Dial speed using Tele. 162	11·4 i.p.s.
1st junction not to exceed	800 ohms
2nd junction not to exceed	800 ohms
3rd junction not to exceed	1,800 ohms
The sum of the three junctions not to exceed	1,800 ohms

Conclusions.

The investigation has shown how, by making certain modifications to the impulsing elements of the ballast type auto-auto relay sets and U.A.X. equipment, the impulsing limits for loop dialling may be extended. Impulsing limits using such modifications have been established, keeping in view reliable service to the subscriber and reduction in maintenance, as well as economic planning of junctions. It would appear, however, that dialling via more than one impulse repeater (of the type considered) or its equivalent, especially where 4-wire amplified junctions are concerned, is not wholly satisfactory. The Post Office is, therefore, reviewing certain methods, the application of which, it is hoped, will ultimately put the impulsing aspect of general automatisation on a sound basis.

It has been considered desirable (*a*) that a subscriber shall be able to dial directly to any other subscriber within a 4d. fee range ; (*b*) that toll and trunk calls shall be set up by the assistance of only one operator. Among the schemes under review for accomplishing this may be cited :

(i) Tandem loop dialling, using a series of single junctions, of 1,500 ohms maximum resistance, fitted with regenerators ;

and where the single-junction limit is exceeded, or for trunk calls, the application of two systems which have been developed by the Post Office. These are :

(ii) the differentiated impulse system[5] and

(iii) the 2 VF system of dialling over the trunk network.

A subsequent article will deal with impulsing using the 2,000 type selector.

[5] *P.O.E.E.J.*, Vol. 31, p. 108

First Installations of 1 + 4 Carrier Equipment

Equipment of the carrier system No. 4 type (audio + 4 carrier circuits) has recently been installed to provide circuits between London and Oxford and between Liverpool and Glasgow. Eight groups, i.e., 40 circuits, have been provided on each of these routes. The London-Oxford equipment operates on pairs in the London-Oxford-Gloucester 12-circuit type cable, whereas that providing Liverpool-Glasgow circuits works on specially loaded 25 lb. pairs in the Liverpool-Glasgow cable. The loading in this case is of 6 mH at 1,000 yard intervals, the specially loaded groups, each of 30 pairs being separated by the normally loaded pairs which carry audio circuits.

Mid-section distant-end crosstalk balancing networks have been provided as standard in connection with the London-Oxford-Gloucester 12-circuit type cable, but for the specially loaded pairs in the Liverpool-Glasgow cable, the positioning of the networks followed what is now the latest practice, and were placed at the receiving end of each section, i.e., at the terminal and intermediate stations instead of at the mid points of the repeater sections.

On the Liverpool-Glasgow cable, the position of loading pots on the reloaded pairs was governed by that of the normal loading on the remaining pairs in the cable. In addition, it was not possible to site the new intermediate repeater stations at such points that half coil or half section terminations were obtained ; for these reasons, it has been necessary in many instances to build-out the pairs artificially to obtain correct terminating conditions. Such conditions have been particularly desirable to avoid difficulties due to reflected near-end crosstalk and to make less complex the design of equalisers.

On the 1+4 type equipment equalisation is a more complex matter than in audio or high frequency carrier systems. This is due in the main to the fact that the frequency range 200 c.p.s. to 16,000 c.p.s. is transmitted, i.e., equalisation is necessary in the range over which the curvature of the attenuation—frequency characteristic of the cable pairs is the maximum. However, satisfactory equalisers have been designed for both of the systems concerned.

Both the London-Oxford and Liverpool-Glasgow equipments have most satisfactory performance characteristics and are now carrying traffic, in the main providing sections of longer audio or 1 + 1 circuits. F. J. D. T.

Slewing and Lowering Existing Ducts and Cables

A. T. SOONS

The author describes a practical method of slewing and lowering a cable route run in self-aligning earthenware ducts and stresses the precautionary measures necessary.

Introduction.

CONDUITS are laid to predetermined standards of depth, course and position, and in the past variation of any of these factors has seldom been required outside the larger cities or towns. Nowadays, however, in order to conform to road grading or widening operations, or to construct an additional manhole upon an existing conduit route, it is frequently necessary to lower and/or slew certain lengths of the track to meet the foregoing requirements.

It is a relatively simple matter to handle steel or cast iron pipes, and fairly easy to rearrange tracks comprised of self-aligning (S.A.) earthenware ducts. Octagonal duct routes, however, are not capable of rearrangement except by demolition and reconstruction. Due to the preponderance of the S.A. type the process of slewing and lowering usually concerns this type of duct, but there appears to be little recorded describing the working details, and a brief description of the method may be of interest not only to those directly concerned but also to those whose interests in telephone lines lie in different directions.

Preliminary Considerations.

Where conditions are favourable to rearrangement, i.e. where there is vertical and horizontal space available and providing that skill and patience be exercised, multiple-way ducts containing cables may be moved to new positions without risk of major damage to ducts or cables. Where conditions are unfavourable to removal, consideration should be given to protection *in situ* by means of a protective covering of concrete or boiler-plate if the ultimate depth of cover will be unduly shallow or if the track is likely to be steamrolled at a shallow intermediate depth during reconstruction.

Slewing and lowering can be carried out satisfactorily by utilising the slack cable available along the route, e.g. by reduction of existing radii, but it is sometimes necessary to interrupt and extend cables at jointing chambers in order to provide slack cable to meet overall extension of the track when laid in its new position. Exhaustive inspections should be made beforehand to ascertain what other obstacles exist (e.g. foreign plant) which may also require removal or diversion as a necessary preliminary to putting conduit rearrangement work in hand. Lead duct seals and anti-creepage devices should be released and all cables removed temporarily from bearers in at least two manholes on each side of the length to be moved. Cables should also be aligned so as to facilitate entry into their duct-mouths and thus prevent binding and consequent straining or fracture of the lead sheaths, also to allow for the general taking up of slack cable during the shifting.

Conduits containing cables have sometimes been shifted without proper attention being paid to preliminary work, with the result that certain of the cables were drawn so taut as to cause some of the conductors to snap and joints to be pulled apart, with consequent interruption of service.

Slewing and lowering of existing plant is inevitably an expensive operation due to the extensive excavation and the amount of " time work " which is involved. Where the distance between existing and new positions does not exceed, say, two or three feet, it is probably more economical to slew and lower than to lower only as consideration of Fig. **1** will indicate.

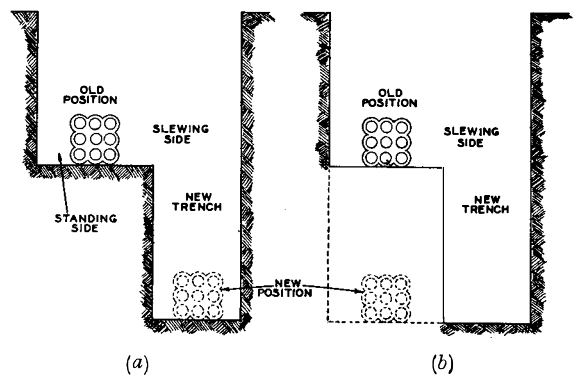


FIG. **1**.—(*a*) SLEWING AND LOWERING. (*b*) LOWERING ONLY

The choice is a matter of calculation with due regard to the existing cables and the cabling facilities afforded after rearrangement.

Approximately 1 ft. width of space is needed on the " standing " side for timbering and fixing bonds and slings in each case. Upon the " slewing " side the width of the excavation is determined by the distance of the " slew," and the depth on that side will be governed by the required depth to which the ducts are to be lowered.

Where lowering only is involved there is little, if any, saving of width and depth, as ample working space has to be allowed for excavation of the earth immediately beneath the ducts, and this is practically equivalent to a new trench (see Fig. **1**).

At times and perhaps as the outcome of inexperience, attempts have been made to slew and lower existing routes by excavating around and under the ducts, temporarily supporting them meanwhile on short lengths of timber or brick piers preparatory to sliding the track over and down a ramp formed of planks of wood. This method is wasteful of time and material, as the timber packing or brick piers must be extended downward as the trench is deepened. In addition, it is a hazardous operation, and considerable damage to ducts and cables, and perhaps injury to person may follow in the event of a slip, which once started is practically impossible to check.

A Practical Method of Slewing and Lowering S.A. Ducts.

The following method employed during a number of slewing and lowering operations, supervised by the author and carried out in conjunction with road alterations and other works, has invariably resulted in a substantial saving in contractors' charges and a negligible amount of damage to plant.

The trench having been excavated to the requisite width, i.e. sufficient to embrace both the old and the new positions (to the bottom of the ducts), this portion is timbered in the usual manner, viz., with poling boards, walings and struts. While the remaining part of the new trench, i.e. that part below the existing duct level, is being excavated, other men are employed in lashing the ducts to a " strongback," usually comprised of scaffold or fencing poles. Pairs of folding wedges (tapered pieces of wood) placed head and toe are driven between the top side of the ducts and the " strongback " for the two-fold purpose of tightening the bonds sufficiently to prevent the ducts from slipping while suspended, and providing a definite clearance between the duct sockets and the " strongback " to avoid damage to the sockets by chafing during shifting operations. The ducts in their splints remain on their original bed until all is in readiness for removal to their new position.

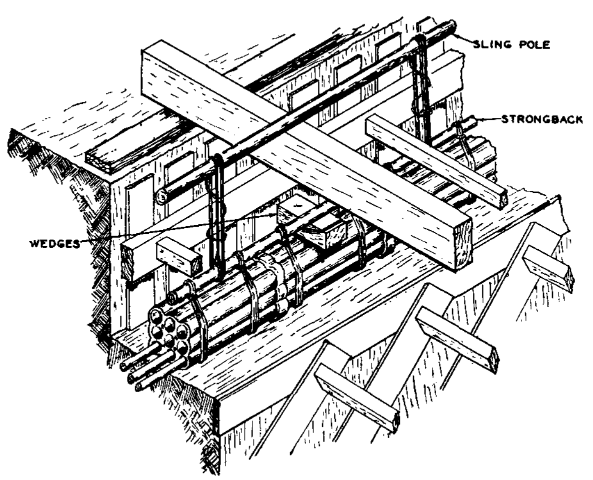


FIG. 2.—DUCTS LASHED TO STRONGBACK AND SLING POLE PRIOR TO REMOVAL.

Cross-members, consisting of baulks of timber, usually **12** in. by **6** in. and of a length sufficient to span the trench, are placed astride the trench at **6**-ft. or **8**-ft. intervals to form a bridge on which to slide the " sling-poles " aligned immediately above the " strongback." Sling ropes, at intervals of 8 ft. to **10** ft., are each passed two or three times around the sling poles and the " strongback " in the form of a running sling or strop (see Fig. **2**).

Whenever the subsoil is reasonably firm a considerable saving of time and material can be effected by timbering the lower trench as in Fig. **3**.

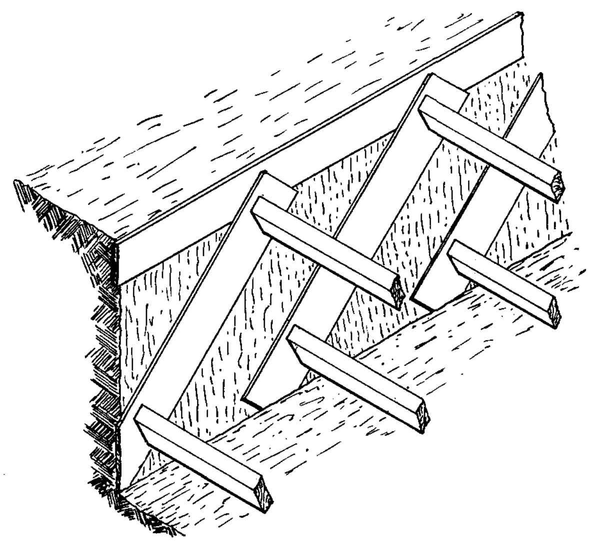


FIG. 3.—OBLIQUE TIMBERING IN STABLE SOIL.

Where, however, the subsoil is of a loose nature, additional boards placed horizontally may be necessary (see Fig. **4**).

It will be seen that in each example boards placed obliquely on the sides of the trench and kept in position by struts only are substituted for the normal method of timbering.

When all is in readiness for slewing and lowering the slings are shortened until the duct line swings just clear of its original bed. The sling ropes are then made fast at that level.

For ease in slewing the ducts, the upper surfaces of the cross-members are lubricated with a mixture of clay and water, and the sling poles carrying their load of ducts are gently and uniformly prised along the cross-members until immediately over the new trench.

The lowering is effected by gently and uniformly

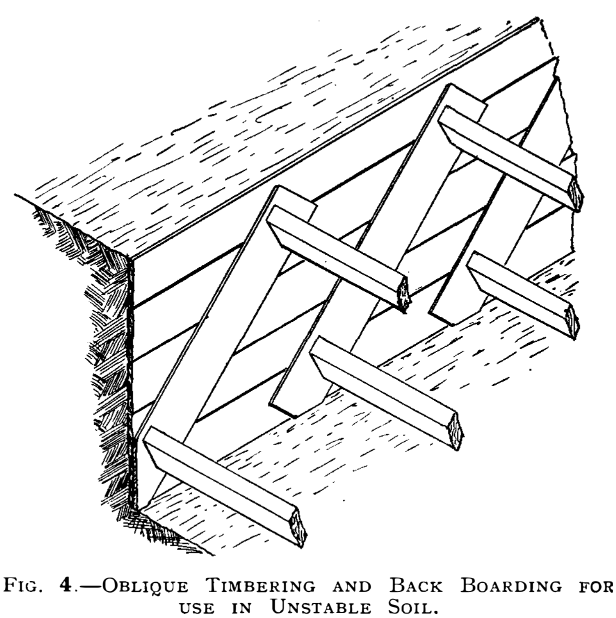


FIG. 4.—OBLIQUE TIMBERING AND BACK BOARDING FOR USE IN UNSTABLE SOIL.

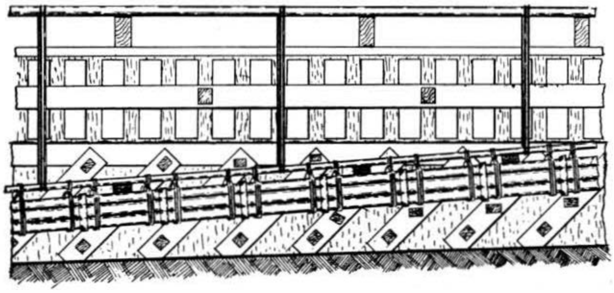


Fig. 5.—Removal of Struts as Ducts are Lowered.

slackening the rope slings until the ducts lie upon the newly prepared bed, collar holes having been prepared beforehand. As lowering progresses the cross struts are struck singly and replaced in suitable fresh positions along the obliquely placed boards without risk of other timbers slipping (see Fig. 5).

This method affords adequate support to the sides of the trench during the short time required for lowering the ducts.

It will readily be seen that a track could not be so easily lowered in a trench timbered in the usual manner as none of the struts could be struck for shifting until a complete replacing tier of temporary walings and struts was in position at the lower level. This would take a considerable time, and would add substantially to the labour costs.

The slings, wedges and " strongbacks " are next recovered, and the duct joints served externally with hot compound (No. 6) or pointed with cement mortar where any minor breakage of sockets has occurred.

Finally, before the trench is filled in, a test mandrel of the appropriate dimensions is drawn through each of the spare " ways " to check alignment over the length disturbed.

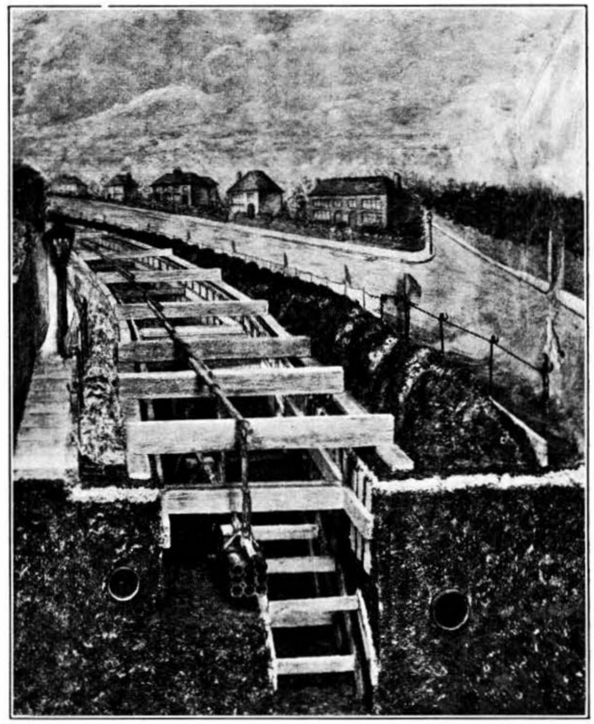


Fig. 6.—Model for Demonstrating Slewing and Lowering of Ducts.

In view of the widths of the trenches excavated, methodical and thorough filling in, following slewing and lowering operations, is of great importance, and particular attention should be directed to this part of the work.

Fig. 6 depicts a model constructed by the author for demonstrating the foregoing methods to Underground Works Supervisors at the Training School.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM
TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF, AND MAINTAINED BY, THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30th JUNE, 1938.

Number of Telephones	Overhead Wire Mileages					Engineering District	Underground Wire Mileages					
	Telegraph	Trunk	Junction	Exchange*	Spare		Telegraph	Trunk	Junction†	Exchange‡	Telephone Spares Trunk	Telephone Spares Junction†
1,137,847	320	912	1,872	56,130	5,650	London Reg	24,743	303,730	876,944	3,199,870	73,324	305,942
140,193	1,657	1,472	11,024	54,431	13,370	S. Eastern	5,631	132,892	22,394	381,277	60,822	23,412
166,703	1,903	10,604	25,893	106,584	10,973	S. Western	19,507	141,534	13,498	335,781	61,378	15,774
118,597	2,585	10,643	24,762	86,603	19,170	Eastern	8,047	149,040	14,266	241,552	80,946	10,496
137,021	3,364	11,664	18,155	69,787	26,403	N. Midland	8,822	213,730	20,470	278,328	94,272	19,118
153,926	1,822	6,006	19,622	79,154	19,219	S. Midland	10,484	188,302	31,994	397,878	67,982	30,531
80,777	1,132	5,568	16,796	57,201	12,628	S. Wales	5,571	80,350	15,678	153,471	42,990	12,762
202,930	1,548	9,594	22,666	87,929	19,959	N. Wales	12,510	199,640	102,046	428,038	123,696	40,170
240,709	971	1,622	3,245	35,947	6,744	S. Lancs.	10,386	119,510	106,931	675,608	57,364	56,585
100,978	706	2,014	5,074	36,794	16,558	N. Western	6,232	114,792	20,346	269,589	90,270	14,952
39,696	2,855	6,735	6,165	17,585	1,069	N. Ireland	1,317	13,110	8.214	87,475	27,842	4,262
286,455	4,731	13,758	22,521	95,769	26,659	N.E. Region	17,074	246,416	69,274	712,000	154,604	37,323
264,774	6,248	24,669	31,188	98,843	25,683	Scot. Region	9,989	212,824	30,915	511,763	128,304	22,851
3,070,606	29,842	105,241	208,983	882,757	204,085	Totals	140,313	2,115,870	1,332,970	7,672,630	1,063,794	594,178
3,026,079	30,572	111,981	211,646	865,675	203,529	Totals as at 30 June, 1938	146,734	2,067,096	1,355,094	7,495,160	1,034,082	657,521

* Includes low gauge spare wires, i.e. 40 lb. † Wholly Junction Cables. ‡ Includes all spare wires in local underground cables.

International Conferences

The International Telecommunications Conferences at Cairo, 1938

THE conferences at Cairo were the telegraph and telephone conference and the radio conference. Both conferences were opened on February 1st by His Majesty King Farouk and terminated on April 4th and April 8th respectively.

No fewer than 72 countries were represented at the conferences and the number of official delegates and representatives of operating companies and other bodies reached the total of 712. In addition there were present secretaries, typists, interpreters and observers.

The work of the telegraph and telephone conference was largely concerned with the question of tariffs. One of the important decisions was in connection with the unification of tariffs in the European region on the basis of 92 per cent. of the present full rates. A minimum charge of five words will also apply in this region with the exception of letter-telegrams and greetings-telegrams.

The radio-communication conference was chiefly concerned with modifications to the maritime regulations and with a revision of the table of allocations of frequencies (or wavelengths) to the various services. This latter problem was the " pièce de résistance " of the radio conference and was dealt with by a sub-committee under the chairmanship of Col. A. S. Angwin, Deputy Engineer-in-Chief of the Post Office. The need for the revision had arisen from the development of aeronautical and broadcasting services during the past five years. The difficulty in making any rearrangements arises from the fact that such alterations inevitably involve the shifting of the wavelength of stations working in the bands under consideration, and such problems frequently give rise to serious differences of opinion even among the various interests represented on individual delegations. That general agreement was eventually reached on this difficult question can only be ascribed to the spirit of compromise present in the various delegations and this in turn was largely due to the skilful and tactful handling of the sub-committee by the chairman, a feat which was generally admitted and deservedly and wholeheartedly applauded by leading delegates at the termination of the conference. The changes which have been made necessitated certain services losing wavelengths. These have been the fixed and marine services, and also the amateurs. The services entitled to most consideration were undoubtedly the aeronautical services as the security of life depends largely on the provision of efficient communication. The demands of the aeronautical interests have been largely met and this has enabled a world wide scheme of wavelengths to be worked out for the various main routes.

Broadcasting has also benefited appreciably. It was found impossible to give any extension to the long wave band but a slight extension of 60 kc.p.s. from 1,500 to 1,560 kc.p.s. has been arranged on the lower end of the medium wave band at the expense of marine mobile services. Another important step has been the provision of special bands of 2,300 to 2,500 kc.p.s., 3,300-3,500 kc.p.s. and 4,770 to 4,965 kc.p.s. to broadcasting in tropical and semi-tropical regions. This will be a valuable concession, as such areas are afflicted with severe atmospherics on the long and medium wave bands and there has been a tendency for stations working on short ranges in these regions to use the short wave bands intended for long distance, thus increasing the congestion in these bands. Addition has also been made, to the extent of 500 kc.p.s., to the short wave bands chiefly by widening the existing bands, thus providing space for 150 to 200 new allocations throughout the world.

An interesting development has been, as far as the European region is concerned, the detailed allocation of the ultra-short wave band from 30 Mc.p.s. to 200 Mc.p.s. (10 metres down to $1\frac{1}{2}$ metres). This will tend to encourage the orderly development of services in this band by putting high powered television stations in defined bands and leaving the remaining wavelengths free for other services which will normally be able to operate on appreciably lower power. An interesting feature has been the allocation of bands of waves reserved for unmanned meteorological balloons carrying extremely low power transmitters which send signals indicating the meteorological conditions in the upper atmosphere.

The general result of the conference and particularly of wavelength position can be regarded as very satisfactory in all the circumstances. The modifications introduced should go far towards assisting the orderly developmentof radio-communication from September 1st, 1939, when the new order takes effect, until the next conference which takes place in Rome in 1943.

The language question has always been an important one at these conferences. Although French has in the past been the recognised language for diplomatic purposes there has been a growing demand outside the British Empire for the use of English. This has been recognised at the League of Nations where French and English enjoy equal status. At Cairo, following previous practice, French and English were used, speeches in one language being translated into the other by an official interpreter. All official documents, however, were produced in French only although the United States delegation issued unofficial translations of documents to all who desired copies, but intimated that they would be unable to do this in the future. An important decision has now been taken that in future the Secretariat will issue unofficial English texts of all documents at Conferences and also at C.C.I.T. and C.C.I.R. meetings. The costs of these English texts will be borne by the administrations and bodies making use of the service.

A. J. G.

C.C.I.F. Rapporteurs' Meeting at Oslo

A MEETING was held at Oslo last June attended by delegates to all the Engineering Commissions, in order to prepare answers to questions put before them by the Assemblée Plénière at Copenhagen in 1936.

The meeting opened under the shadow caused by the sudden death of Herr Ministerial direcktor Höpfner, the German Chief Rapporteur of Commission 3, and whose obituary notice will be found elsewhere in this issue.

Commission 1 completed the work of revising the Directives regarding measures to be taken to prevent interference from power circuits. The groundwork for this revision had been prepared by a small committee which met in Rome in October, 1937, and on which the Post Office Engineering Department was represented. The new Directives have been prepared with the collaboration of representatives of the electrical power industries and incorporate the new knowledge resulting from experimental work carried out under the direction of the C.M.I. during the past few years. Commission 2, which is concerned with the protection of underground plant against corrosion and electrolysis, also completed the work of preparing a series of Recommendations for the guidance of telephone administrations and traction companies.

Commissions 3 and 4 study transmission and line plant questions, together with telephone instruments, measuring apparatus and the co-ordination of signalling operations both manual and automatic.

Commission 5 studies all problems concerned with the linking up of radio links and land lines.

The three most important matters concerning which decisions were desired at an early date were :—

(1) Standardisation of technique of cables for wide-band transmission.
(2) The application of the idea of "effective transmission" to replace the older "volume" basis in assessing the grade of transmission.
(3) The design of a co-ordinated European switching plan.

The first of these problems concerned with wide-band transmission was considered as extremely important in view of the fact that several countries are now doing intensive development work both on carrier cables and cables of co-axial type.

In order to prevent countries developing on different lines, attempts had already been made to standardise the carrier frequencies together with the spacing of these frequencies within the total band transmitted. A preliminary meeting held in Paris in September, 1937, had revealed the fact that whereas this country and the United States were considering for 12-channel work a carrier spacing of 4 kc.p.s., Germany was considering the possibility of using a spacing of 3 kc.p.s.

It was felt by the British delegates that, with the information now available, showing the need for the maximum intelligibility on telephone lines, together with the general trend which has been observed for many years towards widening the frequency band, it would be a fatal step to organise research and development on the more restricted spacing of 3 kc.p.s. It is admitted that this would allow the retention of the then existing C.C.I.F. regulation that the upper frequency to be transmitted should be 2,600 c.p.s.

The German Administration, together with the American Telegraph & Telephone Company, gave demonstrations in order to show the effect of various band widths on transmission with ordinary instruments and under various other conditions. Both demonstrations were somewhat striking considering the relatively small effect which one would consider to be apparent. The German Administration, in addition, showed that considerable additional faithfulness was given when lower frequencies were transmitted than is the present practice. The debate on the matter after the demonstrations, together with the data produced by the administrations as a result of tests which they had carried out, revealed the fact that all nationalities were agreed that a wider frequency band is not only desirable but is inevitable in the view of the present trend in the design of telephone instruments.

Agreement was reached that on all transmission systems involving carrier and co-axial cables for international purposes, the spacing of 4 kc.p.s. should be envisaged.

The only further difficulty that arose was the decision as to which side-band should be transmitted on 12-channel carrier cables. The British delegates advocated the lower side-band, as this is the practice in Great Britain. It was then found, however, by a special Commission appointed to study the question, that every other country working on carrier transmission was developing the upper side-band system.

It must be admitted that neither one nor the other shows any very great advantage in cost or on any other grounds, and in order to obtain uniformity of practice on long European connections, the British delegates agreed that for international purposes the upper side-band should be used.

Great Britain has only one International Exchange, where apparatus to the international standard must be used. For the inland trunk network apparatus of a non-standard type can continue in service.

The second point dealing with effective transmission showed that although many countries were in agreement concerning the principles involved, yet they found it difficult to agree on any application of the principle without considerable further study. It was agreed that with the improvement in quality brought about by the increased band width and the improved telephone now being introduced the old volume method of assessing the grade of transmission was inadequate. It is necessary to take into account the effect of differing degrees of distortion, side tone and noise. Several methods by which this may be done have been suggested and a Sub-commission has been set up to study this question further with expert assistance. This Sub-commission, together with another one concerned with the development of co-axial work, will meet in London next December.

In connection with the study of noise measurements members of the C.I.A. attended some of the meetings and co-operated in the decisions reached.

The third important question, the European Switching Plan, has also progressed as a result of the Oslo meeting. A Sub-commission is studying the problems involved in agreeing the main centres for collection and distribution of traffic in Europe. When this matter has been decided the technical details concerning the lines by which these centres are connected and the lines for distribution can proceed in the normal manner. At a further stage the sixth commission, dealing with traffic in special relation to the demand service and allied problems, will take part in the European Switching Plan so that the question can be tackled from all points of view.

Among other questions, that of signalling and the signalling tones of automatic telephony as applied to the international system was seriously studied. In order that an approach to the problems of standardisation could be made a permanent Sub-committee was formed and will hold its first meeting during 1939.

The British delegates on their return felt that this meeting was one of the most successful and important of the whole series considering the problems that were before it and the degree of solution which was reached.

The short space of time left free from the extensive labours were made especially happy by the very hospitable way in which our Norwegian colleagues entertained the delegates and enabled them to see, as far as could be done in the time, the beauties of their lovely city.

R. M. C.

The International Electro-technical Commission (I.E.C.)

FURTHER steps towards the international standardisation of electrical nomenclature, specifications, materials, testing methods, etc., were taken at the Torquay meeting of the I.E.C. held in June, 1938. Twenty-two countries were represented, the largest delegations being from Great Britain (92), Germany (70), Italy (36), France (27) and the United States (22). The P.O. Engineering Department was represented on many of the committees, and the following is a brief record of the work with which this Department is most concerned.

Advisory Committee No. 1. *International Electro-technical Vocabulary.*

The first edition of this vocabulary, which has been in preparation for over a quarter of a century, was approved for publication. It includes nearly 2,000 scientific and technical terms divided into 14 groups, each definition being drafted originally in French and translated into English. In addition to the definitions in French and English, the translation of the terms is given in German, Italian, Spanish and Esperanto. It was appreciated that the vocabulary could be perfected only by its constant use for reference and the notification of any errors to a central body. Comments from Great Britain should be sent to the British Standards Institution which will co-ordinate and transmit them to Advisory Committee No. 1 with a view to final revision of the vocabulary. Copies of this Vocabulary can be obtained from the General Secretary of the I.E.C., 28 Victoria Street, Westminster, London, S.W.1, at a price of 10s. each.

Advisory Committee No. 3. *Graphical Symbols.*

Proposals for the revision and extension of I.E.C. Publication 35, Graphical Symbols for Heavy Current Systems, were discussed and the National Committees were invited to submit proposals for further sections dealing respectively with electronic devices (rectifiers), time switches and clocks. A committee of the British Standards Institution is discussing the revision of B.S.S.108, British Standard Graphical Symbols for General Electrical Purposes, and the new edition will include the symbols agreed by the British representatives at Torquay.

Advisory Committee No. 7. *Aluminium.*

The definitions of annealed and hard drawn aluminium were agreed. Agreement was also reached regarding standards of resistivity for aluminium as used for insulated cables and bus-bars, as well as regarding certain standards for aluminium alloys for overhead lines and for the strength of joints in aluminium wires.

Advisory Committee No. 24. *Electric and Magnetic Magnitudes and Units.*

At the previous meeting in 1935 the Giorgi (MKS) system of units was adopted, and the question of the choice of the fourth unit was referred to the National Committees for consideration. The committee agreed at Torquay to recommend that the connecting link between the electrical and mechanical units should be the permeability of free space (μ_0) with the value of 10^{-7} in the unrationalised system or $4\pi\ 10^{-7}$ in the rationalised system. It was further agreed to recommend that the name of this fourth unit should be the " Newton."

Advisory Committee No. 25. *Letter Symbols and Signs.*

This Committee was concerned with the revision of I.E.C. Publication No. 27, and a revised edition will be circulated to the National Committees for approval.

A number of social functions were held during the week at Torquay, and concluded with a banquet given at the Guildhall (London) on July 1st, at which nearly 600 were present. The Duke of Kent proposing the toast of the " International Electro-Technical Commission " referred to its work as the co-ordination of the electrical requirements of industry throughout the world. By powerful penetration its recommendations were gradually influencing the electrical standards of all nations which were free to adopt them if and when they found it desirable to do so.

J. R.

The Photographic Recording of Subscribers' Meter Readings

L. L. TOLLEY, B.Sc., A.M.I.E.E
and W. A. J. PAUL, F.R.P.S.

The authors describe the experimental apparatus developed by the Post Office Research Branch for the photographic recording of subscribers' meter readings.

Introduction.

AT present, subscribers' meters are read visually by the operating staff, the readings being written into a meter book, but investigations have been pursued for some time with a view to providing a photographic method of recording. Several advantages can be claimed for photographic recording, viz :—In the first place there is a considerable saving of the time of the exchange staff, an advantage which becomes increasingly important as these staffs are reduced with the development of automatic working ; secondly, all the readings are recorded in a short space of time instead of being spread over two or three days as may occur with visual reading ; thirdly, the existence of the permanent photographic record of the meter reading should be of value in cases of dispute ; and in the fourth place, possibilities of error are considerably reduced. Mistakes are liable to occur under the present system when one operator reads and calls to her colleague, who in turn notes in a book the number heard.

In Paris, photographic recording has been employed since 1927[1] ; 380,000 meters installed in 32 exchanges are photographed each month by a staff of two photographers. It is stated that 5,200 meters are recorded per hour with the apparatus used. The records are taken on 35 mm. cinematograph film from which enlarged prints are made for reading purposes.

Photographic recording has been in use since 1929 in Amsterdam where a Zeiss equipment is installed. The camera, which will photograph 100 meters at each exposure, is carried, together with the lamps for illuminating the meters, on a stout steel pillar. As in the Paris system, 35 mm. film is used for recording, but after processing, the negative film is not printed but is optically projected and enlarged on to a translucent screen. A double projection apparatus is used so that the current set of readings, together with that of the previous quarter, are projected simultaneously. Only one pair of readings appear on the screen at a time. The equipment also incorporates a comptometer to facilitate the accounting.

In the Bell Laboratories Record, April, 1937, an account appears of a method of photographic recording which is being used in the U.S.A. A description is given of a camera for photographing 25 meters directly on to a sensitised paper. The camera, lights, etc., are suitably housed so that the complete unit is portable and may be held in position and operated by hand against the appropriate block of meters.

Early Method of Photographing 12 Type Meters.

During recent years experiments have been carried out at the P.O. Research Station at Dollis Hill to develop an economical photographic method applicable to meter racks used in British exchanges. Fig. 1 illustrates the use of a hand camera, of an early design, to photograph 25 meters of the 12 type at each exposure. The camera box consists of a duralumin frame covered with fabric. Enclosed at the top and bottom of the back plate are two strip-type lamps adjusted to illuminate evenly the meters to be photographed. The camera itself is mounted in the centre of the back plate and is at the correct focal distance for a photographic image of 25 meters to fill

FIG. 1.—EARLY TYPE OF HAND CAMERA.

the width between sprocket perforations of standard 35 mm. ciné film. Preliminary experiments indicated that cinematograph film would be the best medium for these records. It is cheap, reliable, light and compact, and is very suitable for subsequent projection. The film advance mechanism is operated by giving a quarter turn to the left-hand grip. As this operation also resets the camera shutter it is impossible to make a second exposure without first advancing the film. In this design it was also arranged to overrun the lamps during the exposure period of one second. This was done by short-circuiting the resistance which can be seen in Fig. 1.

A simple projector was constructed to view the negative records obtained after processing. A novel feature of this apparatus was the optical arrangement which permitted two films to be projected, using

[1] Annales des Postes, Télégraphes et Téléphones, 1927.

only a single light source, condenser and projection lens. The optical arrangement is so arranged that corresponding rows of five meter readings finally focus one above the other on a ground glass viewing screen.

Later Method of Photographing 12 Type Meters.

No. 12 type meters are usually mounted in bays of 10 by 60 and are numbered from left to right in consecutive horizontal rows starting from the bottom left-hand corner of the bay and reading upwards. In order to preserve on the record the proper numerical sequence it is desirable to record at each exposure the full width of ten meters accommodated in each bay of the rack. The latest apparatus shown in Fig. 2 was therefore constructed and installed at National exchange to photograph 100 meters at each exposure. A Leica camera is mounted on the camera box which is constructed of duralumin angle covered with aluminium sheet. The box is carried on two tubular vertical guides which are connected to form a rectangular frame with wheels and rollers mounted at the upper and lower ends of the frame respectively; the wheels run in horizontal channels fixed to the meter rack. Stops are provided in the channel to locate the frame opposite each bay of the rack, and further stops on the vertical guides locate the camera box at each block of 100 meters. One loading of the camera will accommodate 33 feet of film and is sufficient for 250 exposures. National exchange, with approximately 10,300 meters, requires 103 exposures. The camera shutter is set to operate for one second, the total time required for recording all the National meters, including positioning the camera, being about 30 minutes.

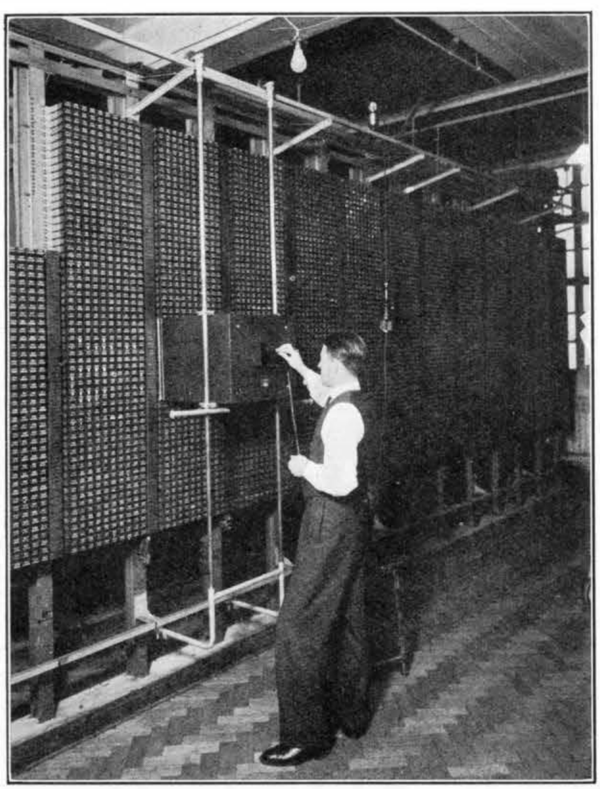


FIG. 2.—APPARATUS INSTALLED AT NATIONAL EXCHANGE.

Lighting of the Meters.

One of the principal difficulties experienced during the preliminary experiments was to avoid reflections from the meter glasses and at the same time to keep the overall spacing dimensions of the lighting units within reasonable limits. The difficulty was again aggravated by the fact that unless the photography could be carried out at night, or the meter room artificially darkened, an impractical bulky housing for the camera and lamps would be required to screen off all extraneous light from the meters. The problem was solved by arranging the lighting in a manner shown in Fig. 3. It will be seen that the light from the right-hand lamps is screened so that it falls only on the left-hand side of the block of meters, and similarly the left-hand lamps illuminate the right-hand side of the field. The size of the box, however, is now little more than the area occupied by 100 meters, and reflection troubles are eliminated.

Unfortunately, the effective cure of one trouble introduced another. For meters situated near the sides of the bay, the obliquity of the lighting caused shadows of the meter covers to be cast across the end digits of the recessed number wheels. To overcome this it was necessary to increase the length of the slot in the meter cover from 1 inch to $1\frac{3}{16}$ inch. A simple punch has been made with which to do this and the meter covers at National have been punched out.

Because the film in use is not sensitive to red, another necessary but simple modification is to replace the red identification discs at present indicating call boxes, by white shapes, say squares or triangles. Meters associated with service lines are characterised by white discs, which photograph well.

The exposed film is developed in the usual way. For the short length required a convenient method is to wind the film on to a drum which can then be slowly rotated in the processing solutions. It is obviously uneconomical to process each film separately and the normal procedure would be to establish a central studio to process the films from a number of exchanges. In Paris thirty-two exchanges are served in this way. Non-inflammable film is used, and since

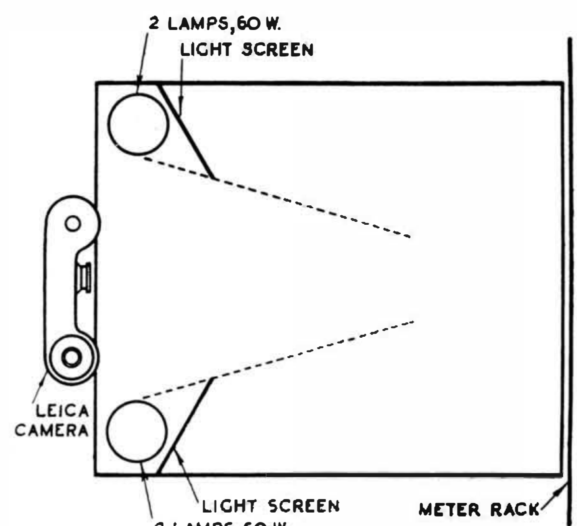


FIG. 3.—PLAN VIEW OF LIGHTING ARRANGEMENT.

the film magazines of the Leica camera are only about 2 inches by 2 inches diameter there is no difficulty in transmitting them by post if required.

Reproduction of the Readings.

Each photograph of 100 meters occupies a space of 1·2 inch by 0·9 inch, the four figures comprising a meter reading occupying a length of only 0·07 inch on the film. It is essential therefore that the record be considerably enlarged to make it readable for accounting purposes. Two methods are available for doing this. In one, the negative film is optically projected on to a viewing screen, and in the other enlarged photographic prints are prepared. Fig. **4** illustrates the experimental projector constructed at Dollis Hill for viewing the two films simultaneously. The optical arrangements are shown in Fig. **5**. Readings are displayed one above the other in order to facilitate subtraction, and only one pair of readings appear at a time. It will be seen in Figs. **4** and **5** that the subscriber's number on the lower reading is obscured. The two films are fed over sprockets mounted on a carriage that may be moved in two directions by the operation of the controls. The fixed projector lamps concentrate light upon one

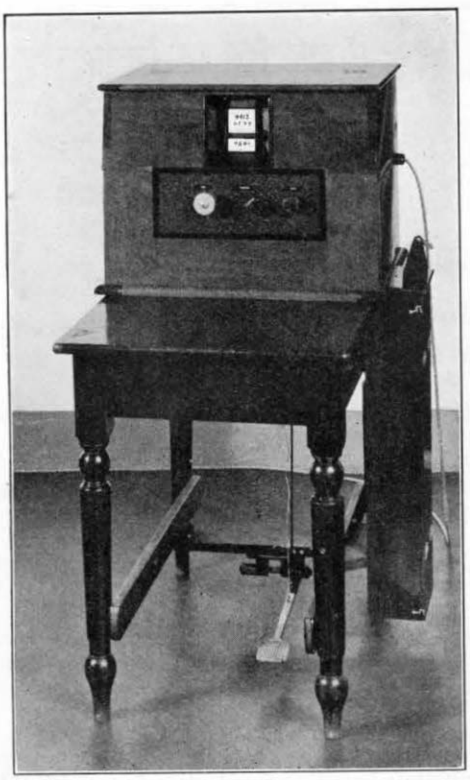


FIG. 4.—EXPERIMENTAL PROJECTION PANEL.

meter reading in each film. The central control seen on the front panel comprises two knobs, each of which operates a sprocket for advancing the film ; when the film readings are synchronised the knobs may be coupled and used as one. A foot pedal is depressed to step over the (ten) readings in one row, which are the photographs of a horizontal row of ten meters, then the two controls seen to the right and left of the panel are operated to bring the next row into position, and in this way the complete record may be scanned.

Alternatively, satisfactory enlarged prints can easily be obtained from the film record. These may be of any size, but an enlargement about 12 inches by 9 inches is considered suitable. One advantage of this method is that a number of readers may be employed simultaneously on the record of one exchange, since each bank of 100 meters forms a separate print. A further advantage is that the separate prints are more convenient when it is necessary to refer back to a particular reading at some later date.

Conclusions.

The apparatus described has been designed for the photography of meters of the 12 type. The new (100 type) meter presents photographic difficulties, because the number wheels are recessed further behind the cover, making it difficult to illuminate them obliquely. It is probable that a camera could be designed to photograph these meters in blocks of 25, but since the mountings for pre-2,000 type exchanges differ from those used more recently, it

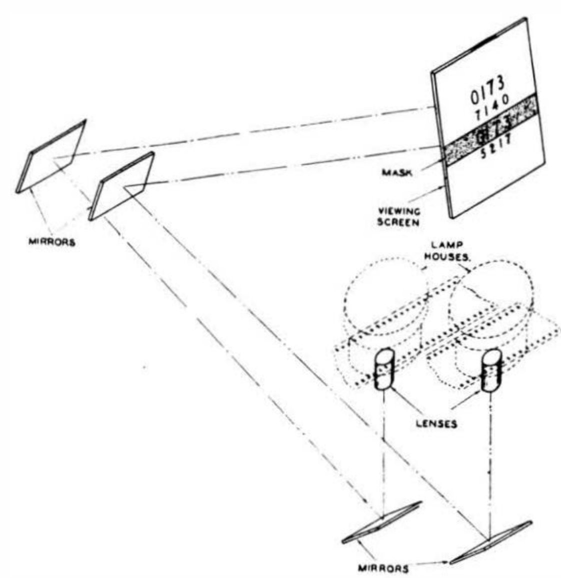


FIG. 5.—OPTICAL PROJECTION ARRANGEMENT.

would presumably be necessary to prepare more than one design of camera. On the Continent, the advantages of the photographic system appear to be sufficiently valuable for modifications of meter racks to be made with a view to facilitating photographic work. Possibly, therefore, further experience with photography of the 12 type meter may establish grounds for modification of the arrangements for 100 type meters. Meanwhile, experiments are being pursued with a view to providing a camera design suitable for recording the new meters.

Simple Transmission Theory Relating to the Matching of Radio Feeder Lines

F. A. LYNES

This article provides a useful summary of the formulae and derivations thereof dealing with the problem of matching radio transmission feeding lines.

OCCASIONALLY, in the radio technical press, in worked examples of the City and Guilds radio examinations given in supplements to the JOURNAL and elsewhere, references are made to radio transmission feeder matching lines. To some students, more especially those posted at outlying stations, not having the text book or technical class facilities, the origin and qualifications of the equations introduced in these references may not always be apparent.

The problem, generally, is to insert a matching line of impedance Z_m between a load of impedance Z_R and feeders of impedance Z_0 (or Z_K), so that the impedance at the end of the matching line remote from load, to which point the feeders are to be connected, is Z_0. The feeders will then be terminated in their characteristic impedance, thus ensuring absence of reflection and complete transfer of energy from feeder to load.

Actually, the formulæ used are straightforward applications of the sending end impedance,

$$Z_S = Z_0 \left\{ \frac{Z_0 \sinh \gamma l + Z_R \cosh \gamma l}{Z_R \sinh \gamma l + Z_0 \cosh \gamma l} \right\}$$

developed and found in text books such as J. G. Hill's "Telephonic Transmission."

γl is the complex angle of the form $\alpha l + j\beta l$ where α and β are the attenuation and wavelength constants respectively.

As the attenuation for the short lengths of feeder used is negligible in comparison with the other factors, it is accordingly assumed to be zero, so that $\sinh \gamma l = \sinh (0 + j\beta l)$ and $\cosh \gamma l = \cosh (0 + j\beta l)$.

Also, if the lengths of feeder used are an odd number of quarter-wavelengths, or in general $(2n-1)\lambda/4$, βl can be written $(2n-1)\pi/2$. Putting this value into the expressions for $\sinh \gamma l$ and $\cosh \gamma l$ and expanding,

$$\sinh \gamma l = \sinh \left\{ 0 + j\left(2n-1\right)\pi/2 \right\}$$

$$= \sinh 0 \cos \left(2n-1\right)\pi/2 + j \cosh 0 \sin \left(2n-1\right)\pi/2$$

$$= 0 + j \sin \left(2n-1\right)\pi/2 = \pm j$$

$$\cosh \gamma l = \left\{ 0 + j\left(2n-1\right)\pi/2 \right.$$

$$= \cosh 0 \cos \left(2n-1\right)\pi/2 + j \sinh 0 \sin \left(2n-1\right)\pi/2$$

$$= 0.$$

With this odd quarter-wavelength condition, the equation for Z_S loses its complex and hyperbolic appearance, and becomes

$$Z_S = Z_0 \left\{ \frac{(Z_0 \times 1) + 0}{(Z_R \times 1) + 0} \right\} = \frac{Z_0^2}{Z_R}$$

This shows that if a line of characteristic loss impedance Z_0 and length $(2n-1)\lambda/4$ connects two impedances Z_S and Z_R, then for zero energy loss, Z_0 must be the geometric mean of the terminal impedance. It is obvious also that if $Z_R = Z_0$ then $Z_S = Z_0$.

The term Z_0 is used in a general way for the characteristic impedance of a transmission line. For distinguishing the surge impedance of a matching line, Z_m is usually employed. The sending end impedance of a $(2n-1)\lambda/4$ length of matching line closed by impedance Z_R, then $= Z_m^2/Z_R$.

Z_R also is a general term for a terminating impedance, and may be a single impedance such as Z_A, the impedance of aerial radiators, or the resultant impedance of a combination of impedances.

A good example of a resultant impedance for Z_R is provided where an aerial load Z_A is fed via a $(2n-1)\lambda/4$ length of feeder of characteristic impedance Z_0, and a matching line of impedance Z_m, from main transmission lines of impedance Z_0 (Fig. 1).

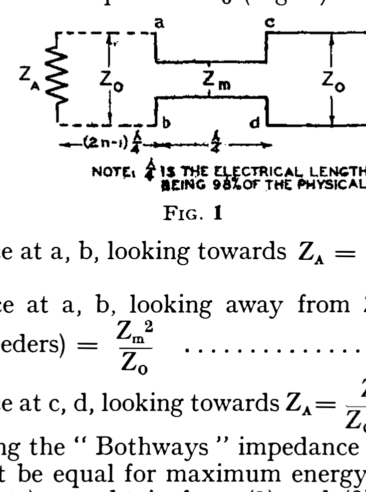


FIG. 1

Impedance at a, b, looking towards $Z_A = \frac{Z_0^2}{Z_A}$ ....(1)

Impedance at a, b, looking away from Z_A (towards main feeders) $= \frac{Z_m^2}{Z_0}$ ....(2)

Impedance at c, d, looking towards $Z_A = \frac{Z_m^2}{Z_0^2/Z_A}$ ... (3)

Equating the "Bothways" impedance at a, b (i.e., they must be equal for maximum energy transfer at these points), we obtain from (1) and (2)

$$\frac{Z_m^2}{Z_0} = \frac{Z_0^2}{Z_A}$$

$$\therefore Z_m^2 = \frac{Z_0^2}{Z_A} \times Z_0$$

$$\text{or } Z_m = \sqrt{\frac{Z_0^2}{Z_A} \times Z_0} = Z_0 \sqrt{\frac{Z_0}{Z_A}}$$

or the matching impedance (Z_m) should be equal to the geometric mean of those impedances (Z_0^2/Z_A and $Z)_0$ presented at its two ends.

To show that with the above value for Z_m a match results, from (3).

Impedance at c, d, looking towards $Z_A = Z_m^2/Z_0^2 \times Z_A$ and inserting the value found for Z_m^2, this becomes

$$Z = \frac{Z_0^2 \times Z_0 \times Z_A}{Z_A \times Z_0^2} = Z_0$$

which is the same as the impedance of the transmission line.

Where more than one matching line is necessary, similar treatment for the equivalent Z_R at each observation point would be used. Taking a two-matching

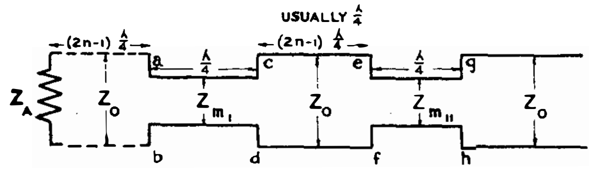


FIG. 2.

line system. Z_{m1} has been found to be insufficient, so another point Z_{m11} is inserted $(2n-1)\lambda/4$ (usually $\lambda/4$) behind Z_{m1} and away from the load (Fig. **2**).

Impedance at a, b, looking towards Z_A

$$= \frac{Z_0^2}{Z_A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Impedance at c, d, looking towards Z_A

$$= \frac{Z_{\ 1}^2}{Z_0^2/Z_A} = \frac{Z_{m1}^2 \times Z_A}{Z_0^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

Impedance at e, f, looking towards Z_A

$$= \frac{Z_0^2 \times Z_0^2}{Z_{m1}^2 \times Z_A} - \frac{Z_0^4}{Z_{m1}^2 \times Z_A} \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

Impedance at g, h, looking towards Z_A

$$= \frac{Z_{m11}^2 \times Z_{m1}^2 \times Z_A}{Z_0^4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

The equivalent Z_R in (4) being Z_A

The equivalent Z_R in (5) being $\frac{Z_0^2}{Z_A}$

The equivalent Z_R in (6) being $\frac{Z_{m1}^2 \times Z_A}{Z_0^2}$

The equivalent Z_R in (7) being $\frac{Z_0^4}{Z_{m1}^2 \times Z_A}$

If Z_{m1} is known, then Z_{m11} can be computed.

Equating the "bothways" impedances at g, h.

$$\frac{Z_{m11}^2 \times Z_{m1}^2 \times Z_A}{Z_0^4} = Z_0$$

$$\therefore \quad Z_{m11}^2 = \frac{Z_0^5}{Z_{m1}^2 \times Z_A}$$

from which $\log Z_{m11}$

$$= \tfrac{1}{2}\left\{5 \log Z_0 - \left(\log Z_A + 2 \log Z_{m1}\right)\right\}$$

Similar treatment would be applicable where the matching is commenced at the aerial junctions (Fig. **3**).

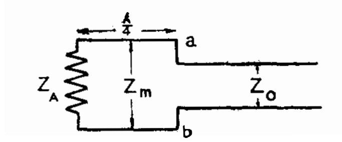


FIG. 3.

Impedance at a, b, looking towards $Z_A = Z_m^2/Z_A$ and looking the other way, Z_0.

For a match, these must be equal $\therefore\ Z_m^2 = Z_A \times Z_0$ or $Z_m = \sqrt{Z_A \times Z_0}$.

Where a single point is insufficient due to a high ratio Z_A/Z_0, when this would entail too wide spacing or too small gauge wires, the computation of a second point follows similar reasoning as in the previous example. An intermediate value (i.e. from that which would give a full match) for Z_{m1} would be assumed, due consideration being given to a suitable spacing for Z_{m11}. (Fig **4**).

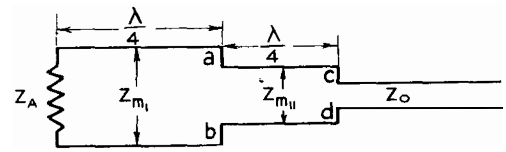


FIG. 4.

The two points are joined together in this case.

Impedance at a, b, looking towards $Z_A = Z_m^2/Z_A$

Impedance at a, b, looking away from $Z_A = Z_{m11}^2/Z_0$

Equating, $Z_{m11}^2 = Z_{m1}^2 \times Z_0/Z_A$ or Z_{m11}

$$= Z_{m1}\sqrt{\frac{Z_0}{Z_A}}$$

The impedance at c, d towards $Z_A = Z_{m11}^2 \times Z_A/Z_{m1}^2$ and substituting the value for Z_{m11}^2 found above, this is $\frac{Z_{m1} \times Z_0}{Z_A} \times \frac{Z_A}{Z_{m1}^2} = Z_0$ and a match results.

A worked example of the above was given recently in a JOURNAL supplement.

In passing, it is thought that the approximate proof for the formula for the surge impedance Z_0 or Z_m will not be found out of place.

By the general equation we have

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \text{ ohms}$$

In the high frequency case this becomes

$$Z_0 = \sqrt{L/C} \text{ ohms}$$

From the dimensions of the feeders this can be put equal to $120 \log_e D/r$ ohms or $276 \log_{10} D/r$ ohms, where D is the distance apart of the wire centres and r is the wire radius, both being in the same units.

To find L.

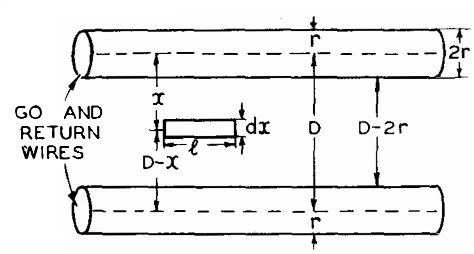


FIG. 5.

Fig. **5** represents a length of transmission system comparatively high above ground, and comprising a "go" and a "return" wire, the medium being air. The dimensions are in centimetres.

Considering the small elemental area ldx between the wires. The flux from one wire is additive to that from the other, being H_1ldx and H_2ldx respectively. H_1 is $2I/x$ and H_2 is $2I/(D-x)$, I being the current in electromagnetic units. The mathematical derivation for H in terms of I and x can be found in magnetism and electricity textbooks, and is an application of the law of Laplace.

The distances x and D−x are as shown in the figure. The total flux is the sum Hldx between the centres of the wires—i.e. for the purpose of this problem it will be assumed the flux circles commence from the centres. L, on the other hand, must be representative of the distance between the wires or D−2r, as when D−2r=0 then L=0.

Bearing these points in mind, we have for the total flux

$$H=l\int_r^{D-r}\left(\frac{2I}{x}+\frac{2I}{D-x}\right)dx$$

$$=2Il\int_r^{D-r}\left(\frac{1}{x}+\frac{1}{D-x}\right)dx$$

$$=2Il\Big[\log_e x+\big(-\log_e(D-x)\big)\Big]_r^{D-r}$$

$$=2Il\left[\log_e\frac{x}{D-x}\right]_r^{D-r}$$

$$=2Il\left\{\left(\log_e\frac{D-r}{D-(D-r)}\right)-\left(\log_e\frac{r}{D-r}\right)\right\}$$

$$=2Il\log_e\left(\frac{D-r}{r}\times\frac{D-r}{r}\right)=2Il\log_e\left(\frac{D-r}{r}\right)^2$$

$=4Il\log_e(D-r)/r$ or neglecting r compared with D

$=4Il\log_e D/r$.

Now L=flux per unit current, so putting L=H, and for unit length

$L=4\log_e D/r$ cms. of inductance.

To find C.

Each wire of radius r and length l will have charge of Ql units of electricity. The charge densities will be p and − p respectively.

$$\text{Density } p=\frac{\text{Quantity}}{\text{Surface area}}=\frac{Ql}{2\pi rl}.\quad\text{Hence } Q=2\pi rp.$$

Over an imaginary closed cylindrical surface of length l (Fig. **6**), through point x coaxial with the wire and enclosing length l of same, the force (F dynes) is uniform at all points of distance x.

The total normal induction over the closed cylin-

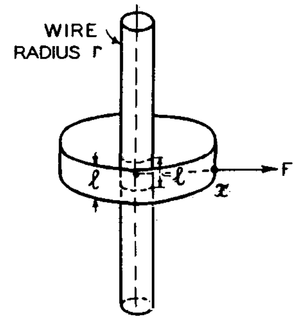


FIG. **6**.

drical surface is $2\pi xlF$ and over the wire, $4\pi Ql$. By Gauss's theorem these must be equal.

Equating, we obtain $F=2Q/x$ and substituting for Q.

$F=4\pi rp/x$ E.S.M. of intensity.

The intensity or force at distance x from one of the wires is $2Q/x=4\pi rp/x$, and at the same point due to the other is $4\pi rp/D-x$. x and D−x are the same distances as for the inductance proof. The intensity at point x is also numerically equal to the potential gradient at that point or $F=-dv/dx$, the minus sign denoting that the voltage between the charged wire and the like charge decreases with increasing distance between them. For the opposite direction dv/dx can be written as positive.

Then $dv=Fdx$.

With the same diagram as for the inductance, but with point x and no elemental area, and with the assumptions above, summing up the voltage between the wires

$$V=\int_r^{D-r}\left(\frac{4\pi rp}{x}+\frac{4\pi rp}{D-x}\right)dx$$

$$=4\pi rp\int_r^{D-r}\left(\frac{1}{x}+\frac{1}{D-x}\right)dx.$$

Putting in the limits as for the inductance working $V=4\pi rp\log_e\left[(D-r)/r\right]^2=8\pi rp\log_e D/r$ C.G.S. E.S. units approx.

As $C=Q/V$

$$\text{Then } C=\frac{2\pi rp}{8\pi rp\log_e D/r}=\frac{1}{4\log_e D/r}\text{ cms. of capacity}$$

Combining L/C and converting to practical units,

$$L/C=\frac{4\log_e D/r}{10^9}\times 4\log_e D/r\times 9\times 10^{11}$$

$$=16\left(\log_e D/r\right)^2\times 900$$

Finally $\sqrt{L/C}=4\times 30\log_e D/r=120\log_e D/r$

or $276\log_{10} D/r$ ohms.

Wire Broadcasting

T. WALMSLEY, Ph.D., M.Inst.C.E.

A Review is given of the systems of Wire Broadcasting at present in use, or proposed, with particular reference to audio-frequency systems.

Introduction.

THE idea of conveying sound from a distant point to a listener by means of electrical currents passing along wires is by no means new, its inception in England dating from 1877 when Graham Bell introduced his telephone into this country. As early as 1883 music was transmitted from a theatre to listeners in an hotel. The Electrophone Company in 1895, working over the National Company's telephone lines, provided service from theatres, music halls and churches to subscribers.

Since the inception of radio broadcasting, development in wire distribution of programmes has proceeded to a varying degree in different countries, the extent of its penetration being probably greatest in Holland, where over 50 per cent. of the total number of broadcast listeners use wired systems. In Great Britain only 3 per cent. of the total number of listeners receive their programmes by wire distribution. In certain populous districts in England, however, the extent of the penetration of wire broadcasting is such that over 40 per cent. of the total licencees use this method of receiving their programmes.

There are several possible systems of distribution of programmes by wire, but all can be grouped under two main classes—(1) carrier frequency, (2) audio frequency.

Carrier Distribution.

The chief attraction of carrier systems of distribution lies in the fact that existing power or telephone networks can be utilised with a consequent saving in line plant costs. Mr. P. P. Eckersley and his associates have already carried out a considerable amount of experimental work in England on carrier distribution over power networks. One obvious disadvantage of this system is the fact that to provide service in any area, the whole of the area feeders must be energised regardless of the number of listeners taking the service, with a consequent wastage of energy; furthermore, suppression of noise is a formidable task. In this respect, carrier over telephone lines, though at present more limited in the range of its potential application, offers appreciable advantages, since only the lines of those subscribers requiring service need be energised, and noise, already usually less than that present on power circuits, can be reduced to small limits by terminal filters inserted at the exchange and at the subscribers' premises.

When designing filters to reduce noise in the carrier frequency spectrum, it is important to ensure that no appreciable attenuation in the audio band, needed for ordinary telephone conversation, is produced. At the same time the dimensions of the filters of the exchange end of the subscribers' lines must be very small to enable them to be fixed in the limited space available on the main distribution frames. The filters as finally designed by the Post Office are contained in cases, $4\frac{7}{8}$in. by $1\frac{5}{16}$ in. by $\frac{7}{16}$ in. The exchange filter reduces the noise in the telephone pair by 25-30 db. at frequencies round about 200 kc.p.s.

The carrier system, whether applied to power or telephone lines, requires a receiver at the listener's premises. From the cost aspect this constitutes a disadvantage. To many listeners, however, the fact that a suitably designed receiver can be used both for radio and carrier reception, combining the advantages of both types of reception, constitutes a definite advantage. The receiver employing narrow selectivity enables distant radio stations to be selected; the same receiver using broad selectivity can be used for carrier reception, giving better quality of reproduction. From the manufacturer's point of view such a type of receiver offers a potential new market.

A carrier broadcasting service has been in use in Germany for a considerable period and large extensions are contemplated.

Audio Distribution.

The audio system of distribution can make use of existing telephone pairs, and by means of a suitable selecting device can enable the listener to choose one of several programmes available at the exchange. In general, however, the electrical energy cannot be sent over the lines at sufficient volume to work loud-speakers direct without causing considerable interference with telephone circuits in the same cable. Thus an amplifier is needed at each listener's premises, which fact increases the cost considerably. Obviously a broadcasting programme and a telephone conversation cannot both be received simultaneously.

The system has been in operation in Switzerland for a few years. It is interesting therefore to notice that in a recent article on "High Frequency Telephone Broadcasting in Switzerland"[1] Dr. Keller has enumerated the disadvantages of this method of broadcasting and appears to be turning towards a carrier system as a means of providing a more satisfactory service.

A more suitable audio system is one in which a separate wire network is used to distribute programmes at loud-speaker strength from a central amplifying station. Two variants are possible; one provides for several pairs, one for each programme, direct from the distribution station to the selector switch in the listener's premises; the other provides for pairs to suitable points at which electrically operated switches are fixed so that the listener, by sending switching currents along the single pair extending from his house to the switching position, can select one of several programmes. Which of the two variants is employed depends upon local circumstances. In sparsely populated districts, for example, the cost of providing several pairs over the whole distance between the amplifying station and listeners' premises might be greater than the cost of providing several pairs part of the way to a switching position, switching equipment and a single pair from this position to the listeners' premises. In general, however, the capital and maintenance costs of the switching equipments are greater than the saving in wire connections. On the technical side the remote switching system has many interesting features, and

[1] *E.T.Z.*, February 10th, 1938.

a considerable amount of ingenuity has been displayed in devising systems and equipment that combines low capital and maintenance costs with freedom from undesirable disturbances to other circuits during switching operations.

One system utilises two relays for each listener's circuit to enable one of four programmes to be selected. With a single pair leading from the listener's premises to the distribution position, four switching combinations are possible, the A or B line can be separately earthed, the two lines can be earthed simultaneously or rendered unearthed simultaneously. The obvious technical disadvantage of this system is the unbalancing of the lines with the consequent disturbance to circuits of other listeners, particularly those connected to the same distribution position. The effects can be mitigated to a considerable extent by suppression devices, but it is an unsound engineering principle to use appliances that have inherent defects and mitigate their disadvantages by the aid of palliatives. A diagram of this system is shown in Fig. 1 (*a*). A second system employs pulses to actuate a uniselector or a stepping relay at the distribution position, a simple push-button type of switch being all that is needed at the listener's premises. This system, being balanced, is free from the disturbance effects of the first. These variants of the system are shown in Fig. **1** (*b*) and (*c*).

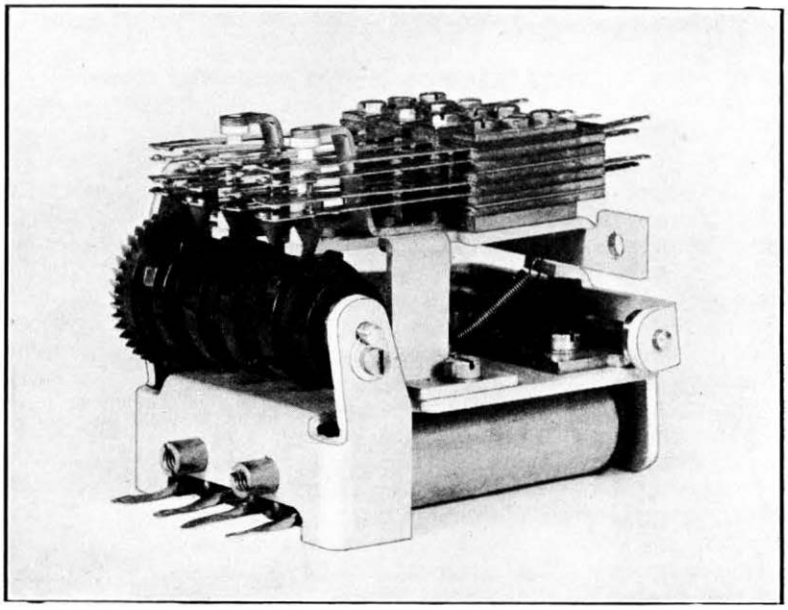


Fig. 2.—Stepping Relay.

A photograph of a stepping relay made by the Standard Telephone & Cables Ltd., is given in Fig. **2**.

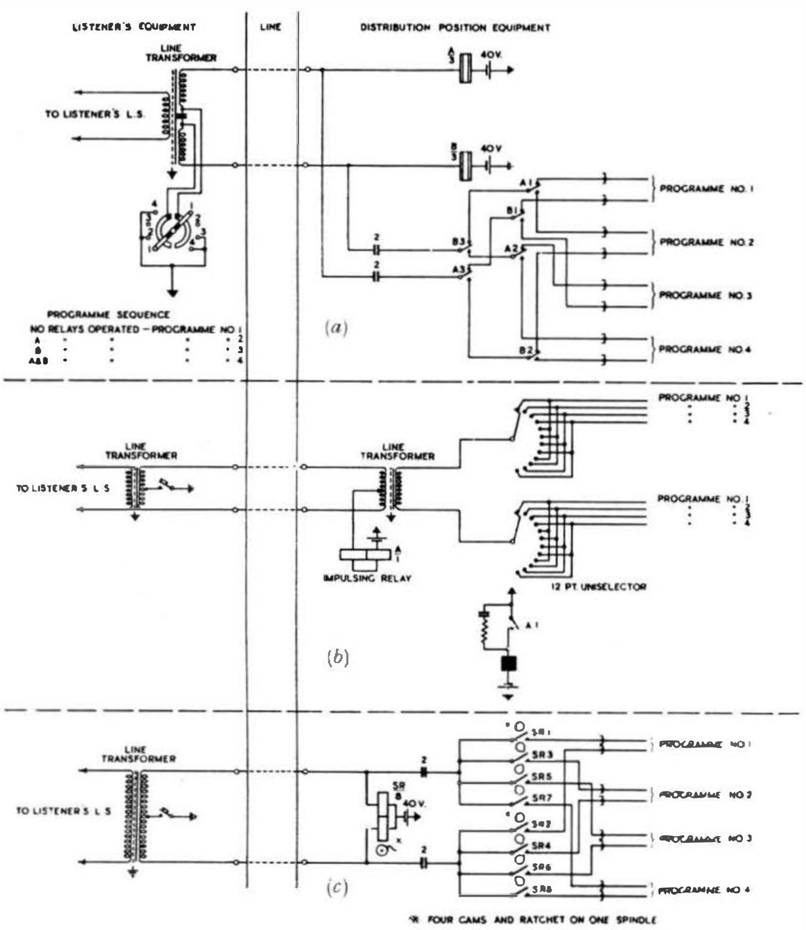


Fig. 1.—Methods of Selecting any one of Four Programmes.

Wire Broadcasting in Great Britain.

At the present time in Great Britain there are 227 companies providing a wire broadcasting service to over a quarter of a million listeners. The system in general use employs an overhead wire distributing network with teed connections from common feeders to the individual listener's loud-speaker selecting switch. Usually two programmes are provided.

The chief advantages of the overhead wire distribution over an underground cable system are the relatively low capital costs and the ease with which subscribers can be connected. Apart from æsthetic considerations the advantage of the underground system is longer life and greater freedom from fault liability. Cables laid directly in the ground or running in ducts may be used. When ducts can be shared with other services, e.g. the telephone, the mutual economic advantage might be very appreciable. In fact, in such a case the difference between the annual charges of the overhead and underground wire broadcasting installations might be negligible.

The selection of suitable underground cables for distribution purposes requires careful consideration. The problem of distribution has features common both to telephone and to electric power work. On the one hand it is required to transmit a broad band of frequencies, up to at least 7,500 c.p.s., with reasonably level response ; on the other hand it is necessary to have a cable that can readily withstand a peak voltage of over 200 volts and in certain cases twice that amount. The frequency requirements place a limit upon the permissible capacitance of the cable ; the voltage stipulation necessitates the use of dielectrics that unfortunately have a dielectric constant (permittivity) considerably greater than unity. Happily the individual lengths of line required in a local wire broadcasting distributing network are not great. It is thus possible to use cables having capacitances of 0·1 to 0·2 μF per mile, according to the degree of impregnation. A paper cable impregnated with petroleum jelly or a suitable oil has several advantages and tests made on such cables have shown that their resistance to moisture penetration is very high.

The employment of a comparatively high voltage is due to economic considerations ; the higher the voltage the less the size of copper conductor required for a given energy loss. Since, however, the impedance of the moving coil of the listener's loud-speaker is only a few ohms, a large step down in voltage is needed before connection is made to the loud-speaker. Furthermore, to maintain a uniform voltage over the required frequency band, equalisation is needed. The extent to which this uniformity can be achieved is shown in Fig. **3**. To obtain these

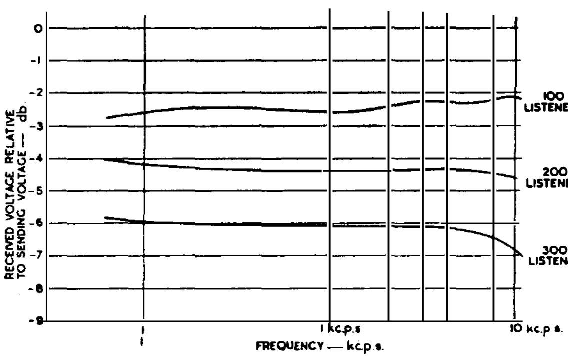


FIG. **3**.—VOLTAGE/FREQUENCY CHARACTERISTICS.

curves the voltage at the input end of the pair in a four-pair screened cable comprising 40 lb. per mile wires was maintained constant, and the voltage measured at the output end terminated in loads equivalent to varying numbers of loud-speakers.

It will be observed that the loss with 200 listeners simultaneously connected is about 4·4 db. This,

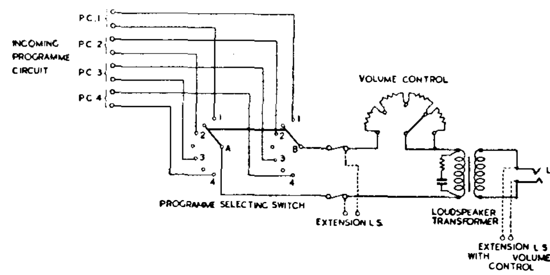


FIG. **4**.—LISTENER'S CONTROL UNIT.

from economic considerations, is high, a desirable upper limit being 3 db. Two considerations operate to reduce this loss in practice ; first, since volume controls are provided with the loud-speakers, the full load conditions on each listener's circuit assumed in the computation will seldom if ever be experienced ; and secondly, when four programmes are provided, it is unlikely that more than 60 per cent. of the listeners will select the same circuit simultaneously. Thus any four-pair cable having (say) 200 listeners connected to it will rarely have a load on one pair greater than that equivalent to 100 listeners taking full volume.

Two facilities are required in the listener's premises —selection of programmes and adjustment of volume. Control of volume can conveniently be obtained by the use of resistances, preferably placed in the high voltage side of the loud-speaker transformer, since in this position variation in rheostat contact resistance has little effect. It is convenient to the listener to have the two controls close together. Furthermore, there is some advantage in having the loud-speaker transformer housed in the same case as the selector and volume control switches, since by so doing dangerous voltages are removed from the loud-speaker. A circuit diagram showing a convenient arrangement of the listener's selector and control unit is shown in Fig. **4**.

Conclusion.

The foregoing outline briefly deals with some features of wire broadcasting but leaves untouched the many inter-related economic and technical problems. It is true to say that the major task in the design of wire broadcasting systems is to obtain a nice balance between performance and cost. The standards to be observed are intimately related to costs, but by careful design of apparatus—receivers, cables, line and main amplifiers, transformers, equalisers, loud-speakers and other equipment—a high quality of reproduction, a low value of noise, cross-talk and distortion, and a high degree of voltage regulation of the main amplifiers under widely varying conditions, can be achieved at a cost not too great for the pocket of the man in the street.

Automatic Exchange Developments in South Africa: Automatic Repeat Metering

C. E. BEALE, Automatic Telephone & Electric Co., Ltd.

The use of 50 c.p.s. alternating current to dial over the 36-mile trunk route between Johannesburg and Pretoria and to give time-metering facilities on calls over this route is explained. The scheme is arranged so that the repeat metering feature can be applied also to other routes from these exchanges.

Introduction.

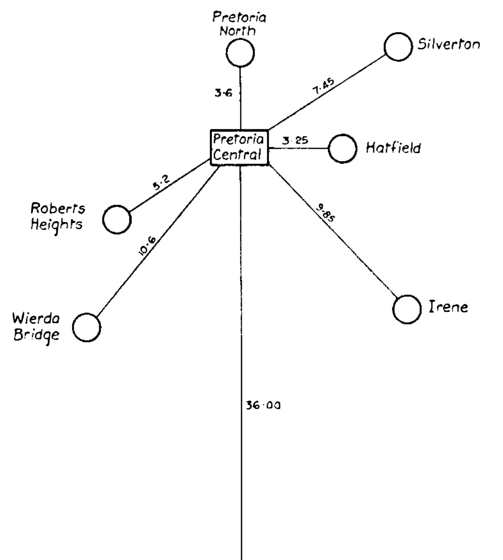
WITHIN the past few years two articles have been published in this JOURNAL dealing with the South African telephone system. The first[1] entitled "The Witwatersrand Automatic Telephone System" explained the conversion to automatic working of the Johannesburg network, and the second[2] described the automatic trunk exchanges and the Corlett call office scheme employed in the Union.

The present article describes a novel method of time and zone metering at present being installed for calls between the cities of Johannesburg and Pretoria, but which is capable of serving east to west Rand calls which will be set up automatically over a distance of some 60 miles when the automatisation of the West Rand exchanges is completed. The Johannesburg area employs two digit directors and contains, apart from Tandem, three types of automatic exchange; namely, main exchanges, satellite exchanges and sub-satellite exchanges. The Pretoria area is a 5-digit non-director system containing one main and six satellite exchanges, and will shortly be put into service.

The two areas are linked by a 36-mile route of 20-lb. multiple twin cable with terminal amplifiers, worked on a 2-wire basis so far as terminating traffic between the two areas is concerned. Access to the line side of the amplifiers is obtained for signalling over the trunk. In connection with the conversion of Pretoria to automatic working, the Union authorities desired that calls between ordinary subscribers on the two areas should be completed automatically and that the appropriate number of registrations should be recorded on the meter when the call was set up and at the expiration of each subsequent three-minute period. As the resistance of the trunk line was too great to permit ordinary dialling methods to be employed, a 50 c.p.s. scheme was decided upon. Such a scheme was in existence for dialling from the existing Pretoria manual exchange into the Johannesburg network and its extension to serve under automatic conditions offered a simple and inexpensive solution of the problem.

The repeat-metering facility was not so easy to provide, but again, experiments with a 50 c.p.s. scheme indicated that the require-

[1] *P.O.E.E.J.*, Vol. 26, p. 116.
[2] *P.O.E.E.J.*, Vol. 28, p. 12.



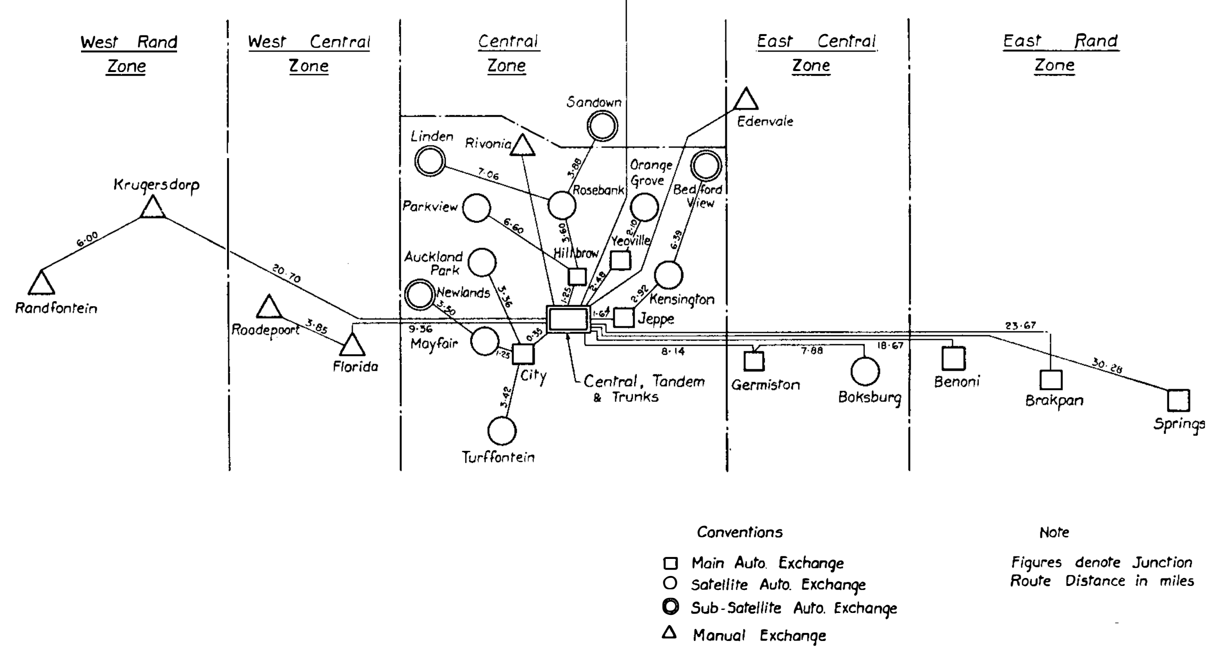


FIG. 1.—THE JOHANNESBURG-PRETORIA NETWORK.

ments could be provided by a relatively simple arrangement requiring the minimum of modification to the existing equipment in the Johannesburg area.

Fig. **1** shows the disposition of exchanges in the two cities, and the distances between exchanges have been included to give an idea of the area served and of the problem set in designing an automatic repeat-metering scheme.

Setting up a Connection.

If a subscriber connected to a sub-satellite exchange in Johannesburg requires a subscriber connected to a satellite exchange in Pretoria the routing will be as shown in Fig. **2**. It will be noticed that this connection involves the use of four junction lines and one trunk line between the two cities. When the receiver

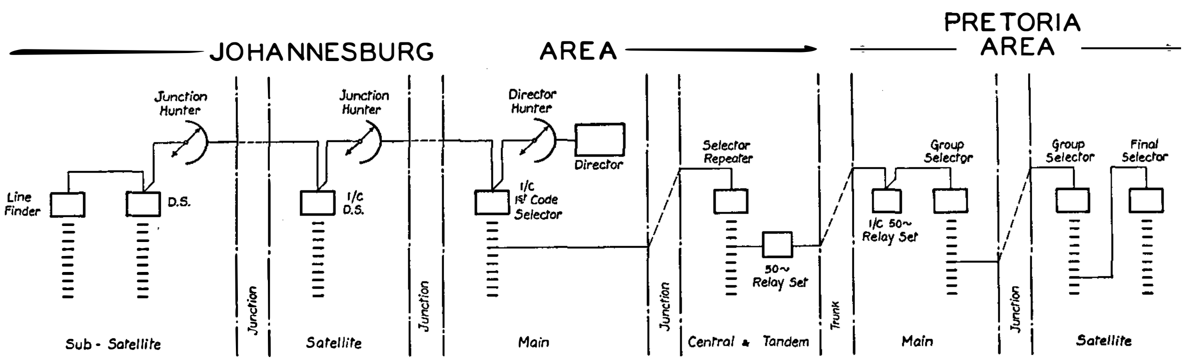


FIG. **2**.—ROUTING OF A CALL FROM A SUB-SATELLITE EXCHANGE IN JOHANNESBURG TO A SATELLITE EXCHANGE IN PRETORIA.

is lifted the discriminating selectors and junction hunters at the sub-satellite and satellite exchanges find an incoming 1st code selector in the main exchange, which finds a free director. Dialling tone is given from the director and the impulses from the calling party's dial are recorded in the director. Machine-made impulses from the director now operate the incoming 1st code at the main exchange and the selector repeater in Tandem exchange. In the outgoing 50 c.p.s. relay set the subsequent trains of director loop impulses are converted to 50 c.p.s. impulses and at the remote end of the trunk line the impulses are converted back to loop impulses for operating the selectors within the Pretoria network. The next four trains of impulses operate the group selector in Pretoria Central exchange and the group and final selectors in the satellite.

Fig. **3** shows the routing of a call from a Pretoria satellite exchange to a Johannesburg sub-satellite, which is very similar to Fig. **2**, the only point of special interest being that after the Pretoria subscriber has dialled the routing digit **7** he must wait for a second dial tone before completing his dialling.

Bank and Level Controlled Zone Metering.

Before describing the operations involved when the called party answers, it is desirable to explain briefly the manner in which the number of registrations to be applied to the calling party's meter is determined.

When dialling from a satellite exchange to a main exchange, the first two digits position the discriminating selector wipers on the bank. In addition to the usual negative, positive and private wipers, an additional wiper—P1—is provided, and the associated P1 bank is utilised to determine the metering zone. The bank contact on which the P1 wiper is resting is connected to the meter pulse wire appropriate to the zone dialled, and since six different meter pulse leads are provided, the 100 wires from the P1 bank must be multipled and each connected to one of the six conditions. When the called party answers, the requisite number of pulses from the meter pulse lead is given to the calling party's meter. The repeat-metering scheme is designed to cause this set of registrations to be repeated on the calling party's meter every three minutes of conversational time.

On calls originated from main exchange 1st code selectors, the level to which the 1st code is impulsed by the director decides the zone and consequently the number of meter registrations. Since the number of different levels is 10, these must be commoned as required and connected to the six meter pulse leads.

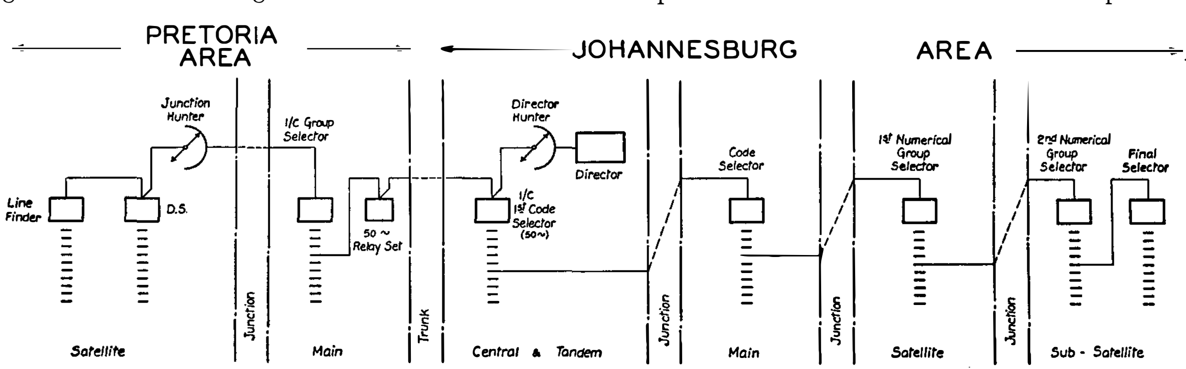


FIG. **3**.—ROUTING OF A CALL FROM A SATELLITE EXCHANGE IN PRETORIA TO A SUB-SATELLITE EXCHANGE IN JOHANNESBURG.

"Called Party Answers" Conditions.

Considering the call illustrated in Fig. **2** from Johannesburg to Pretoria, when the called party answers, the D relay in the final selector of the terminating satellite exchange reverses the battery to Pretoria Central. This reversal is converted to an A.C. signal and then transmitted to Tandem, where it is reconverted in the 50 c.p.s. relay set to reverse battery and transmitted to the incoming 1st code. From this point it is sent to the discriminating selector and repeated to the discriminating selector in the originating sub-satellite exchange.

Relay D in this selector closes a circuit to operate relay DA from the S pulse, which allows DB to operate from the next Z pulse. Fig. **4** shows a similar circuit for a 1st code selector. During the Z pulse, relay J is operated four times from the meter pulse lead, and J applies positive battery to the private wire. The calling party's meter is therefore operated four times, and when the Z pulse is finished relay DB locks and relay DA releases. At the same time this signal starts a timing switch in the outgoing 50 c.p.s. relay set, stepping from a six-second clock pulse, and after a period of three minutes a pulse of 50 c.p.s. is applied to the speaking wires towards the calling exchange. Associated with the selector at the calling sub-satellite exchange, there is equipment (relays AC and Q, Fig. **4**) arranged to receive this 50 c.p.s. impulse, and to release relay DB, which allows a further set of four registrations to be repeated on the calling party's meter. This 50 c.p.s. pulse is applied every three minutes thoughout the conversation with, of course, the usual warning signal of three pips of 800 c.p.s. tone applied to the line twelve seconds before the termination of each three-minute period.

Once the called party has answered, the calling party takes full control of the connection and the timing equipment continues to send repeat metering impulses once every three minutes while his receiver is off the hook even although the called party has replaced his receiver. If this procedure were not adopted it would be possible for the called party to replace his receiver while he made an enquiry and the trunk would be occupied but not earning revenue. In addition, if the reversal and repeat-metering signal were dependent upon one another the called party could replace his receiver at the instant the repeat metering signal was being transmitted and the additional registrations on the calling party's meter would be avoided.

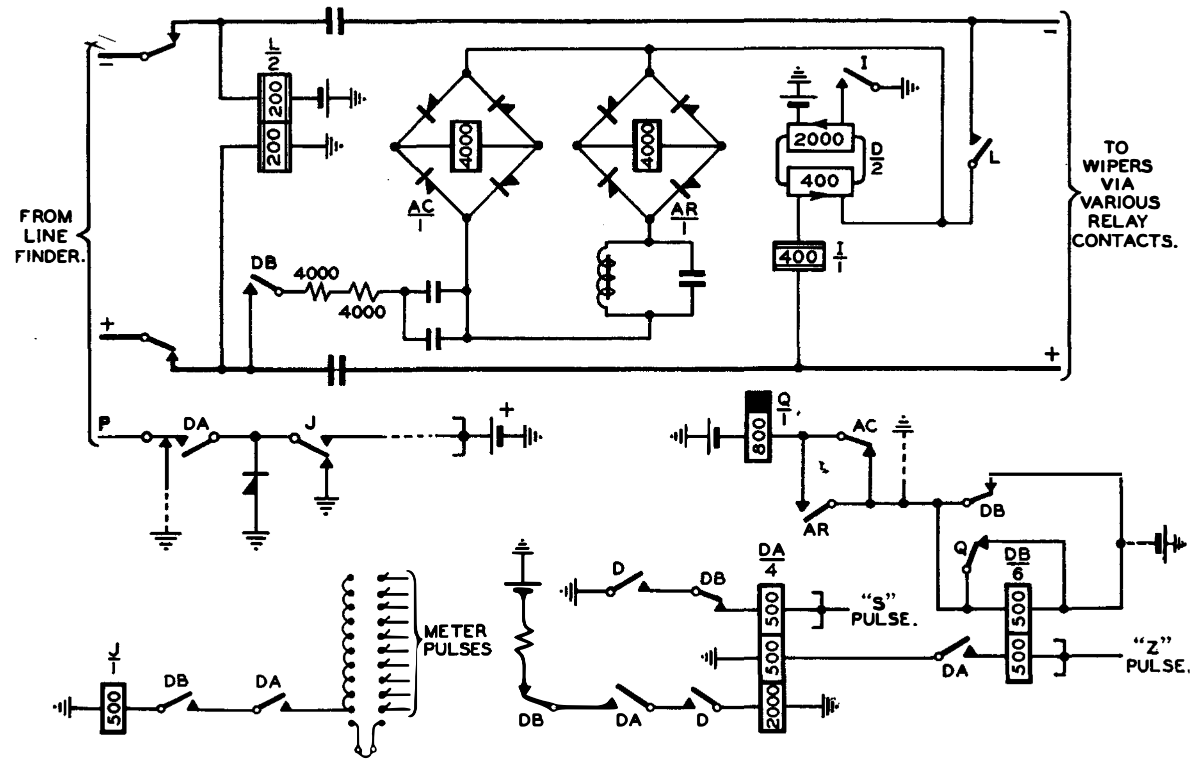


Fig. **4**.—Part of 1st Code Selector.

The advantage of placing the timing and 50 c.p.s. pulse equipment at the Tandem exchange is, firstly, that the number of such equipments is reduced to a minimum, and, secondly, it is an easy matter subsequently to introduce the repeat-metering equipment on any desired junction route.

It was decided to use a frequency of 50 c.p.s. for the pulse applied during conversation because a low frequency signal gives less noise in the receiver than one of high frequency, remembering that sufficient power must be transmitted to operate a relay without resorting to valves. In addition a 50 c.p.s. supply with standby arrangements in the event of mains failure already existed in the Tandem office.

The use of this low frequency, however, has the defect that if either the calling or called party dials during conversation, or if the called party flashes his switch-hook while the connection is established, condenser surges are produced which cause a relay in series with a 50 c.p.s. tuned circuit to operate. During development it was found impracticable to design a 50 c.p.s. tuned circuit which would reject these condenser surges. The circuit shown in Fig. **4** was therefore finally decided upon. This is part of a 1st code selector designed for two new exchanges, Brakpan and Benoni. Relay AR is joined in series with a 50 c.p.s. rejector, such that AR does not operate when 50 c.p.s. is applied to the lines. On condenser surges AC and AR both operate, and consequently relay Q which short-circuits relay DB and causes the re-metering does not release. When, however, the 50 c.p.s. pulse is applied, AC operates, Q releases and short-circuits DB which releases and starts the usual metering cycle involving DA, DB and J over again.

In order that the rejector circuit should not be swamped by an excess of current when the exchange concerned was near the point of application of the 50 c.p.s. pulse, the limiting resistance scheme was introduced. In sub-satellite exchanges where bridging and junction line losses occur before the pulse is received, the limiting resistance is short-circuited. In satellite exchanges where the loss due to two junctions and one bridge precedes the equipment, the resistance is 4,000 ohms, and in main exchanges where no bridging loss precedes the equipment the resistance is 8,000 ohms. This scheme has the advantage of maintaining standard equipment in all types of exchange. All relays used are standard and of the 3,000 type.

The equipment shown in Fig. **4** functions over the limits given below :—

Number of Junctions	Each Junction Resistance	Each Junction Insulation Resistance
1	1,800	20,000
2	1,200	20,000
3	1,200	Infinity
3	1,000	50,000
3	750	20,000

The extra transmission loss caused by introducing the equipment, measured at 800 c.p.s., is :—

Main exchange ..	0·2 db.
Satellite exchange ..	0·25 db.
Sub-satellite exchange	0·5 db.

The rectifiers connected across relays AC and AR respectively are of the standard copper-oxide type, being 24 elements on a common spindle, tapped at each six elements, and the rejector coil is mounted in a repeating coil type pot wound on an air-spaced laminated core and having an impedance at 800 c.p.s. of 27,000 ohms. It will be noticed that the repeat-metering equipment is not connected across the speaking pair until after a battery reversal has been received. No distortion is therefore introduced during dialling, and since no battery reversal is received from the trunk exchange the equipment does not introduce a transmission loss on trunk calls.

Outgoing 50 *c.p.s. Relay Set.*

When the 50 c.p.s. pulse is applied at the end of each three-minute period from Tandem exchange towards the calling sub-satellite, the AC must be applied without removing the DC. If the DC is removed, a chatter involving all the D and I relays commences, and if an excess of AC is applied a similar chatter commences. It is therefore essential to adjust the AC supply resistance such that no chatter occurs on the longest connection, that is when the excitation of D and I is weakest. Reference to Fig. **5**, which is a skeleton diagram of the 50 c.p.s. relay set, will show that the value chosen is 2,400 ohms. This high resistance has the added advantage that the click in the receiver is small when the pulse is applied during conversation.

It will be noticed from Fig. **1** that Tandem and Johannesburg Central exchanges are in the same building, and consequently there is no need to adopt the AC scheme for re-setting and repeating the metering pulses for Central subscribers. Dual access has therefore been provided, one access from selector repeater levels where the AC pulse is required, and the other from Central 1st code levels where the repeat-metering can be given on the private wire.

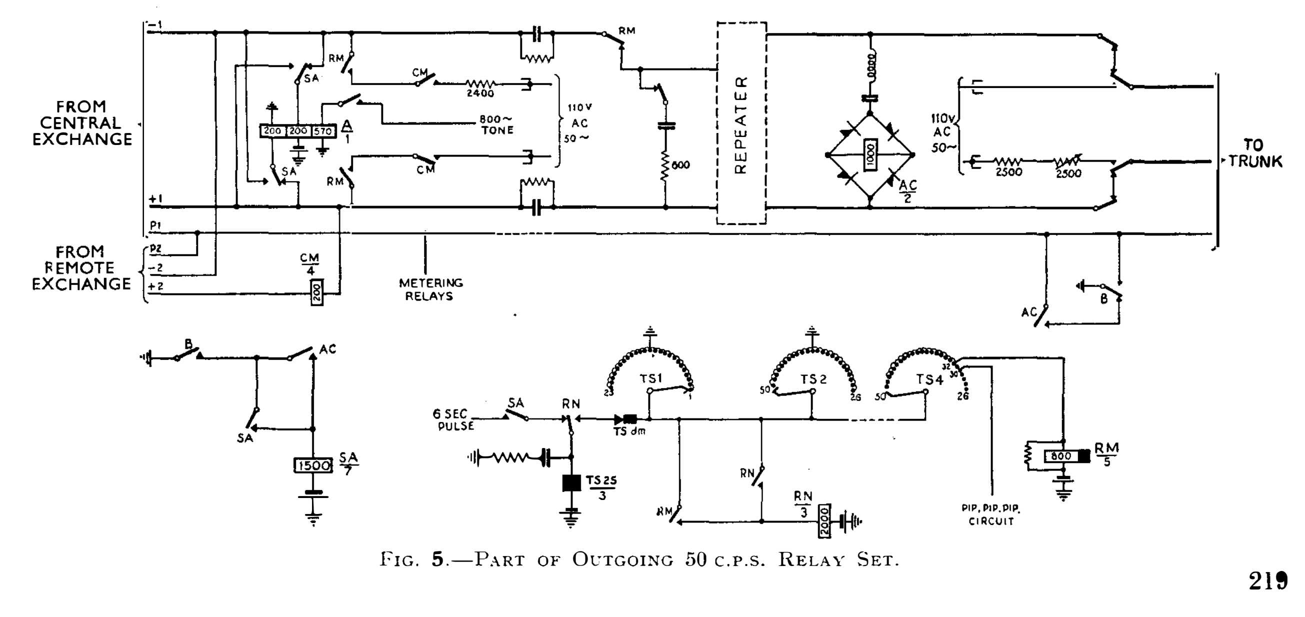


FIG. **5**.—PART OF OUTGOING 50 C.P.S. RELAY SET.

In practice, it may be found necessary to add a note in the directory instructing subscribers to disregard the metering click, but before this can be arranged it is essential that Central as well as all other subscribers in the area should receive the click. It is therefore arranged that by short-circuiting the two make contacts on relay CM (shown in Fig. **5**), the metering click can be given to all subscribers.

The circuit is associated with a 2-wire valve repeater, and whenever 50 c.p.s. current is being connected to the trunk line for either dialling or supervision the repeater bridge points are short-circuited, and when the repeater is idle it is terminated by the usual $1\mu F$ condenser + 600 ohm resistance.

The AC relay which receives supervisory signals from the remote end of the trunk is in series with a 50 c.p.s. filter designed to have a resistance of 300 ohms at 50 c.p.s., and a high impedance at speech frequency. In order that the 50 c.p.s. current applied to the trunk line is a minimum, consistent with reliable operation, a variable resistance is included in the supply to each relay set, and this resistance is adjusted to give reliable impulsing at the remote end, and then the sliding arm is soldered to prevent accidental alteration.

By inserting a link in the relay group at the remote end of the trunk, 50 c.p.s. can be applied continuously to line and relay AC, in operating, busies the private to prevent the relay group being seized again.

Incoming 50 c.p.s. Relay Set.

This relay set shown in Fig. **6** terminates the trunk and precedes the incoming group selector. Its main function is to convert the incoming AC pulses to loop pulses for operating standard selectors and to convert the called party answer signal to an AC pulse. It will be noticed that if the automatic selectors fail to restore to normal, the earth connected to the private by the selector operates relay E which sends continuous AC to the trunk and results in the private being busied at the outgoing end, as already explained in connection with Fig. **5**.

When relay D operates from the battery reversal, a pulse of AC is sent to line, and subsequent movements of the switch-hook by the called party, although operating and releasing D, do not send further AC pulses to line. It will, therefore, be understood that the called party has no further control of the D and I relays in the originating sub-satellite exchange.

Conclusion.

In order to introduce this scheme into the area, it has been necessary to modify every 1st code selector and every discriminating selector in the Johannesburg area. The existing bases were not large enough to accommodate the additional equipment, and consequently a new relay set was designed and cabled direct to its associated selector. In new exchanges, however, the equipment is being mounted on the selector base.

It may have occurred to the reader that if the AC metering pulse had been applied to both lines in parallel to earth at the remote end, all difficulties of clicks and condenser surges would have disappeared. This is true and the problem would have been solved in this manner provided no difference of earth potential existed between exchanges, but in the Johannesburg area, differences of potential as high as **24 V** can be expected over a distance of **30** miles.

Calls in the reverse direction—Pretoria–Johannesburg—operate in a manner similar to that described, but as Pretoria is a new automatic area it was possible to build the repeat-metering equipment into the circuits concerned.

Although 50 c.p.s. AC has not a very wide-spread application in telephony, this article illustrates that it can be used with advantage to solve a difficult problem in an economical manner.

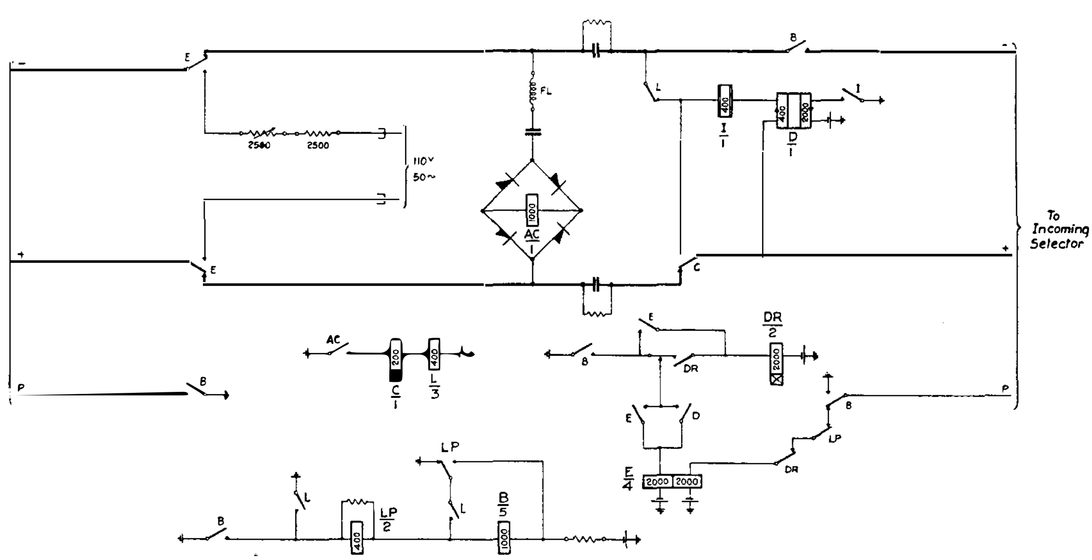


FIG. **6**.—INCOMING 50 C.P.S. RELAY SET.

The Treatment of Displaced Plant in Engineering Economic Cost Comparisons

F. C. HALIBURTON, A.M.I.E.E.

The economic considerations which arise when the displacement of plant is compared with its retention are explained with particular reference to the line plant aspect, and details of the treatment of such problems in engineering cost comparisons are given.

Introduction.

THE increased demand for telephone service and the consequent growing expenditure on plant provision, coupled with a rise in the cost of materials and contractors' charges for conduit work, combine to emphasise the paramount importance of controlling capital expenditure by economic considerations. It is impossible to cover all phases of telephone economics in a few short notes and the present article is intended to indicate the methods of accounting, from an economic viewpoint, for the monetary losses incurred when plant is taken out of service before the end of its useful life, with particular reference to the line plant aspect.

Before dealing with the methods of assessing the loss due to the displacement of plant for reasons such as obsolescence, inadequacy, or at the request of a third party, it will be advisable to give an explanation of what is meant by the terms capital cost, annual charges and the present value of annual charges.

General Terms and Principles Involved

Capital Cost. Generally, before additional plant may be provided, money must be borrowed to enable the work to be carried out and this expenditure involves an increase in assets and is called the "Capital Cost." In the Post Office Engineering Department the capital or prime cost is composed of direct charges, namely, the cost of materials, contractors' charges and the labour cost, plus the indirect charges which cover such costs as freight and handling of stores, salaries, travelling and subsistence, small stores, etc.

Annual Charges. After the prime cost has been incurred certain payments must be made each year to cover :

(*a*) The interest due on the borrowed money,
(*b*) The maintenance of the plant to keep it in good condition, and
(*c*) A credit to the depreciation account for the purpose of renewing or retiring the plant when this becomes necessary.

The interest and maintenance charges are self-explanatory, but the credits to the depreciation account require some explanation which is given later.

Present Value of Annual Charges. The provision of plant initially, sufficient to meet ultimate requirements, is not generally economical. Alternatively, the requirements may be met by the provision of several instalments of plant at pre-determined periods, with the result that the total annual charges are not constant during the period under review. Some reference datum is necessary, therefore, to enable a comparison to be made between the costs of alternative schemes. This reference datum is obtained by assessing the equivalent value, as at a common date, of the annual charges incurred over the period of years under review, which is called the "Costing Period." The common date is the beginning of the costing period and for the majority of telephone economic studies, a costing period of 20 years is used, this being the longest period over which telephone growth can be forecast with reasonable accuracy. The equivalent value referred to is called the "Present Value of Annual Charges" and represents the sum of money which, invested at the beginning of the costing period and accumulating at the current rate of compound interest, would enable the annual charges to be paid during the costing period.

If, for example, plant bearing an annual charge of £10 is provided six years hence and remains in situ until the end of the 15th year, the annual charge will be payable each year for 10 years. Now a sum of £83·17* invested at 3½ per cent. compound interest will provide an annuity of £10 for 10 years, after which time the original sum and interest will be exhausted. The amount of £83·17 is the equivalent value of the annual charges to be incurred from the 6th to the 15th year at *the beginning of the 6th* year, and should be brought back five years to obtain its present value. A sum £0·842* invested now at 3½ per cent compound interest will amount to £1 by *the end of the 5th* year, so that the present value of the annual charge of £10 from the 6th to the 15th year is :

$$0{\cdot}842 \times £83{\cdot}17 = £70{\cdot}0$$

In other words, if a sum of £70 is invested now at 3½ per cent. compound interest, withdrawals of £10 per annum can be made each year from the 6th to the 15th year, after which date the investment is reduced to zero.

Depreciation Account. Telephone plant, like other types of plant, decreases in value with use and should be considered as a "wasting asset." It is good financial practice to counter-balance this depreciation in value by setting up a "Depreciation Account." This subject is a very extensive one involving, as it does, questions of both accountancy and economics, and will only be treated very briefly here.

The credits to the depreciation account are such that the cumulative total over a period equal to the average life of the plant will, after due allowance has been made in respect of its residual value (which is defined later) amount to the prime cost. This account, plus the residual value, would normally be used to pay for the renewal of the plant, the assumption being that, on the average, materials and labour costs are constant.

The principal systems of allocating credits to the depreciation account met with in practice, are the straight-line and the sinking fund methods.

* See Inwood's Tables and E.I. Accounts and Statistics General C.0051.

The straight-line method is used generally in most revenue-earning undertakings, including the Post Office, for accounting purposes. In this method the amount to be realised at the end of the life of the plant, that is the total depreciation, or the prime cost less the residual value, is divided by the number of years representing the life of the plant, to give the magnitude of each annual credit. Of the two methods this is the less complicated, and its chief merits lie in the fact that it can be readily understood by the shareholders of a company and is independent of fluctuations in the interest rates received on sums credited. The fluctuation in the income from interest on such credits is, of course, reflected in the profit of the company.

The process of crediting sums annually to the depreciation account is very often more a question of accountancy than an actual monetary transaction, but the financial arrangements should be of such a nature as to ensure that sufficient cash or credit is available to pay for renewals as they arise. In most large revenue-earning undertakings the sums so allocated are either used to provide the capital for expansion, and thus in effect earn interest as though separate investments had been made, or are actually invested in outside securities.

In order to take into account the interest on the credits, the sinking fund method is generally adopted. The annual credits in this case are such that, accumulating at compound interest they will, at the end of the life of the plant, amount to the total depreciation.

A comparison between various accounting methods or a justification of any single method is beyond the scope of this article, but for engineering economic purposes the accounting procedure need not necessarily be followed strictly. The sinking fund method is adopted for cost comparisons since this conforms to general economic principles. In this connection it is usual to assume the same rate of interest for the sinking fund as that payable on the prime cost.

Having determined the basis on which the depreciation account will be set up it is necessary, in order to calculate the required amounts to be credited to this account, to estimate the average life of the class of plant dealt with, and its residual value at the end of its life.

Life of Plant. This period is usually the anticipated average life of the plant, sometimes called the economic life, and it is estimated from past experience, due regard being paid to obsolescence, inadequacy and physical life. In the Post Office Engineering Department the term " life " is defined as the average life in one position, and this definition should be taken as applying throughout these notes, unless otherwise stated. Thus it would be quite possible and consistent with the foregoing definition for a particular item of plant to be recovered and used again elsewhere and thus have more than one period of life. If, for instance, a pole is recovered 10 years after its erection and, being fit for reissue, is re-erected in a fresh location, remaining in that position for a further 10 years after which time it is recovered and scrapped, then its life " in one position " would be 10 years.

Residual Value. At the end of its life, plant is usually recovered and the accountable value of the stores, less the cost of their recovery, is called the residual value. This amount may be an asset or a liability according to the relative value of the recovered material and the labour charges for the recovery and disposal of the plant. The residual value fixed for economic or accounting calculations should be an average figure and should take into account the fact that plant is in some cases recovered before the end of its physical life.

METHODS OF ACCOUNTING FOR DISPLACEMENT OF PLANT IN ENGINEERING COST COMPARISONS

Having dealt with the principles involved, the methods of accounting for the loss incurred when plant is displaced before the end of its useful life will now be considered. There are two ways of treating the economic aspect of plant displacement; firstly, the detailed wastage method, and secondly, the maintenance method.

Wastage Method. If credits of a suitable value are made annually to a depreciation account (on, say, a sinking fund basis) the assets of an undertaking at any time may be regarded as equal to the prime cost (P). These assets will be composed of two amounts, namely, the amount " A " accumulated in the sinking fund and the value " V " of the plant in situ.

$$\therefore P = A + V, \quad \text{or} \quad V = P - A.$$

Fig. 1 shows the above expressions in diagrammatic form. The ordinate cx represents the amount accumulated in the sinking fund at x years and ax the prime cost, which is of course constant. If a point b is taken on ax such that ab = cx, then bx may be regarded as the " in situ " value.

If after x years the plant is abandoned, then the advantage gained by having it in a revenue earning condition is lost.

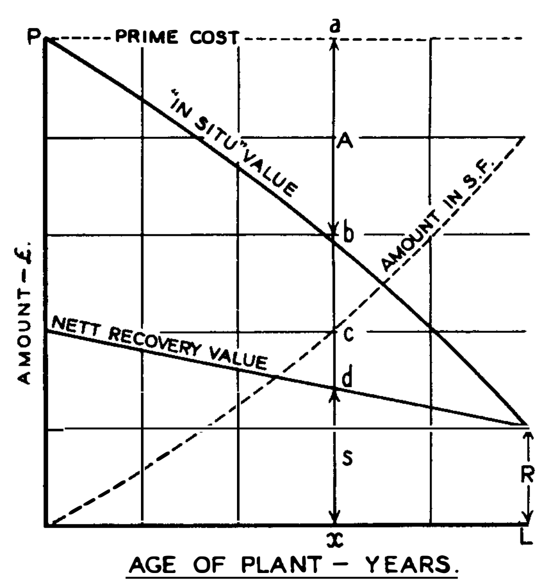


FIG. 1.—GRAPHICAL REPRESENTATION OF THE ASSESSMENT OF WASTAGE.

This loss is represented by the proportion of the prime cost which has not given full service and is equal to the " in situ " value. Thus, the loss or wastage

$$W = V = P - A.$$

The amount W has to be made good by either writing down the capital, or recovering the sum from a third party, or by debiting the sum to the scheme which is to supersede the original one. In the last circumstance, the wastage will be offset by savings due to the introduction of a more economical type of installation.

When the recovery of plant is involved there will be either an asset or a liability in respect of the accountable value of recovered stores less the cost of their recovery and disposal. This is sometimes called the net recovery value to distinguish it from the residual value.

Let the net recovery value be represented by S, then the total liquid assets will be A + S. The term " liquid assets " used here is not strictly true in all instances but may be regarded generally as correct.

The net loss or wastage will be the liability in the shape of the original loan less the liquid assets.

$$\therefore W = P - (A+S) = V - S.$$

The foregoing results have been shown graphically in Fig. **1**., the net recovery value being represented by xd and the net wastage by bd. It will be observed that the net recovery value has been depicted as a linear function of age, falling to the residual value (R) at the end of life. In a specific investigation the magnitude of the net recovery value should be specially estimated and may differ materially from such a hypothetical value.

Maintenance Method. As an alternative to writing off the wastage in one sum at the time of recovery or abandonment it may be assumed that the full interest and depreciation charges are payable in respect of displaced plant for each year until the plant would normally have been replaced at the end of its life. This method leads to a simplification of the assessment of the loss due to displacement of plant.

Thus the annual charges to be borne, from the outset to the date at which replacement would normally take place, by a scheme involving the displacement of plant as compared with its retention under an alternative proposal, are as follows :—

Scheme	*Annual Charges*
Plant displaced	Interest and depreciation.
Plant retained	Interest, depreciation and maintenance.

Neglecting charges common to both schemes, it will be seen that the retention scheme is debited with the maintenance costs only of the plant retained up to the end of its life. Beyond this date, if renewal takes place, the full annual charges on the new plant will be payable. In practice the additional maintenance cost is the sole charge taken into account hence the name of the process. Thus, the effect of the loss of assets in the form of plant in situ is allowed for indirectly and a straightforward calculation of the present value of the annual charges on each scheme may be carried out.

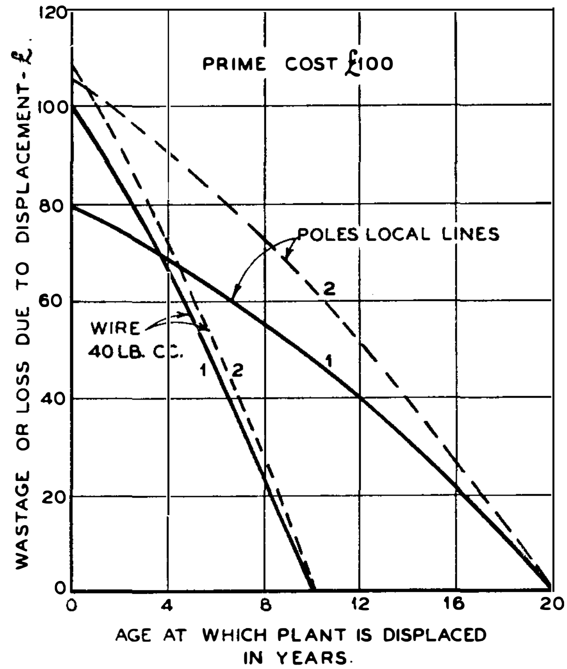


FIG. **2**.—TYPES OF OVERHEAD PLANT. LOSS CALCULATED BY (1) WASTAGE METHOD AND (2) MAINTENANCE METHOD.

Comparison of Wastage and Maintenance Methods. The advantages and disadvantages of the two alternative processes of arriving at the loss due to displacement of plant during its average life will now be examined.

An endeavour has been made to indicate in Figs. **2** and **3** the relative values of the loss incurred when certain classes of external plant are recovered at various ages, calculated by the two methods separately. Fig. **2** shows two typical classes of plant used in overhead construction, and curves for an

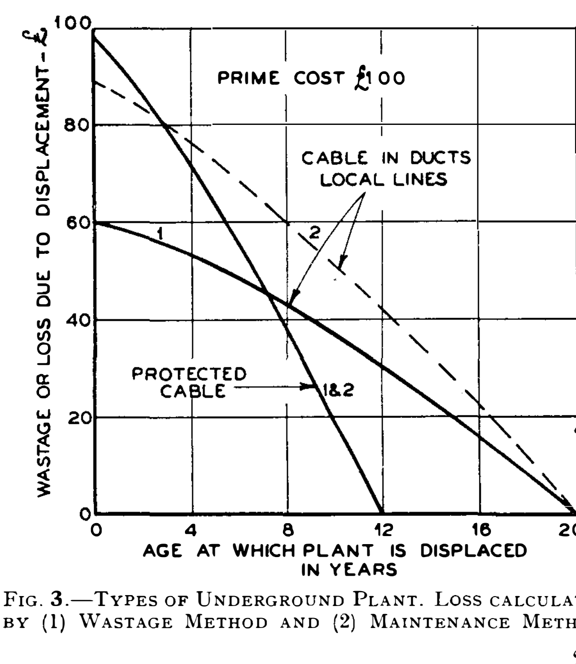


FIG. **3**.—TYPES OF UNDERGROUND PLANT. LOSS CALCULATED BY (1) WASTAGE METHOD AND (2) MAINTENANCE METHOD.

average size of local cable in duct and a protected cable are shown in Fig. **3**.

A scheme involving the recovery or abandonment of plant must bear the loss due to the displacement of the wasting asset in addition to the annual charges on the new plant. Under the wastage method the loss is expressed as a lump sum, whereas the equivalent by the alternative process is an annual depreciation and interest charge over the remaining years of life. A comparison between the two may thus be made by plotting on the same axes, the value obtained by the wastage method for recovery at each year of life, as shown in the curves numbered **1**, and the total worth, at each year, of the interest and depreciation charges over the remaining years of life as shown in the curves numbered **2**. In the former calculations it has been assumed that the net recovery value takes the straight line form shown in Fig. **1** with appropriate intercept on the vertical axis falling to the residual value at the end of life.

The outstanding feature which emerges from an examination of Figs. **2** and **3** is that for various types of external plant under normal conditions the maintenance method produces a result for plant recovered before the end of its life, which is somewhat excessive owing to the omission of part of the credit for the net recovery value. This feature is, on the whole, an advantage since it penalises the scheme involving the recovery of the plant, and tends to prevent the indiscriminate replacement of serviceable plant.

It will be seen that for protected cable (Fig. **3**) curves 1 and 2 coincide. This is due to the fact that the plant would be abandoned in situ, and hence the net recovery and residual values are nil. Indeed, any difference between these curves is dependent on the relative values of these assets or liabilities. There is also a similarity between the results shown in Fig. **2** for overhead wires, and although the short life is not primarily the reason for this similarity between curves 1 and 2, the steep gradient has the effect of bringing them closer together. Here again, the true reason is that the estimated net recovery value falls from zero to −**10** per cent. a very small variation.

Conclusion.

The wastage method conforms to general economic principles and without doubt produces the most accurate results. It is, therefore, the only sound means to be employed in a comparison of costs where the prime cost of the plant to be displaced is a high proportion of the total prime cost of the plant under consideration. Also, where the cost margin between alternative schemes is small, and the magnitude of the wastage is sufficiently high to dictate a particular policy, assuming other factors equal, this wastage method should be adopted.

The disadvantage of this method is that the rather laborious nature of the calculations may occupy a considerable amount of time if several classes of plant are concerned. Apart from the estimate of prime cost, which has to be undertaken in any case, the amount accrued in the sinking fund must be calculated and the net recovery value estimated for each class of plant separately.

With regard to the maintenance method, however, calculation is very simple, involving merely the multiplication of the prime cost by the relative maintenance percentage and the reduction of this annual charge to its present value. Although the results obtained are not necessarily strictly accurate, in certain investigations where the time factor is of some importance this simplified procedure is preferable. In, for instance, calculations of the cost of line plant for serving an exchange area from various available sites as compared with an exchange at the practical centre, the preparation of the cost data is greatly facilitated.

For reasons which have been discussed the wastage method is most suitable when accuracy is essential, but where simplicity is of more importance, the maintenance method should be employed. It follows, therefore, that no hard and fast rule can be laid down as to the specific method to be adopted in any economic investigation, and a decision on this point must necessarily depend on the merits of the case under review.

Book Review

"Wireless Servicing Manual." W. T. Cocking. 288 pp. 111 ill. Iliffe. 5s.

This is the fourth and revised edition of a work which, in the words of the author, is concerned with the maintenance, adjustment and servicing of broadcast receivers and is intended primarily to serve as a handbook and guide to the radio service engineer. No attempt is made to treat with wireless theory and an elementary knowledge of fundamental principles is assumed.

The diagnosis from the symptoms, the location and the correction of the many and varied faults which may be experienced by the radio service engineer are comprehensively treated and the necessary test equipment is described. To quote examples, the "tracing of main's hum" is considered in chapter 5 and the various causes and remedies are detailed, while three chapters are given to a study of the "adjustment of ganging" in straight and superheterodyne receivers. The up-to-date nature of the work is reflected by the inclusion of a chapter on the television receiver.

Useful information as the values of common circuit components, the design of capacitance, resistance and valve bridges and a complete valve data list, is given in the appendices; but it is felt that a table in which the principal receiver faults, their effects and cure were summarised, could with advantage have been included.

The book is considered to be excellent value and can be thoroughly recommended to the radio service engineer who requires a handbook in which the solutions of some of his problems are considered without recourse to more than fundamental principles.

C. F. B.

An Electric Wax Heater

P. R. GERRY

The author describes an electric heater used in the preparation of beeswax for impregnating switchboard cables. Some of the interesting problems which had to be considered during the development of the heater are also mentioned.

Introduction.

CABLES consisting of a core of silk and wool-covered wires with lappings of cotton, paper and lead foil and an outer covering of flame-proof braiding, are used extensively in the Post Office Engineering Department for connecting together the various groups of apparatus fitted in telephone exchanges, telegraph offices, etc. Such cables are known as switchboard cables because they were originally used for extending circuits to manual telephone switchboards. They are now used for joining together the many and various pieces of apparatus which are associated with telephone and telegraph switching. The cables are installed in dry situations where the risk of mechanical damage is small and where they will not be subjected to a great deal of handling once they have been fixed in position.

When terminating this type of cable the flame-proof and other outer coverings are removed for a length sufficient to effect a satisfactory termination, and the exposed silk and wool-covered wires and the first three or so inches of the covered part of the cable are dipped in molten beeswax. This operation fulfils a three-fold purpose. Firstly, it seals the cable against the entry of moisture under the coverings and along the cable ; secondly, it renders the silk and wool insulation impervious to moisture from the atmosphere ; and thirdly, it imparts a stiffening effect on the insulation so that the individual wires are covered by a semi-rigid close-fitting sleeve ; when the insulation is in this state it can be terminated without fraying at any point along the wire.

The effectiveness of this impregnating and sealing process depends to a large extent on the wax being at the correct temperature. Satisfactory results can be obtained with the wax at a temperature of 230° F., but below this temperature the wax adheres to the insulation in lumps and is difficult to remove. At a temperature above 380° F. the wax is liable to burn the insulation of the wire and to become darker in colour. This darkening causes difficulty in distinguishing between the different colours of the insulation, and as these are used for identifying the wires or groups of wires in the cable it is important that the waxing operation should not cause any undue change. A temperature range of 300° to 350° F. is therefore specified for the impregnation process. The lower limit is set to allow for the drop in temperature which occurs immediately a comparatively cold cable is dipped, and the higher one to prevent damage to the insulation and any appreciable change in the colours.

Hitherto use has been made of a bath, bucket, or similar improvised vessel to hold the wax, the heat for melting being supplied from a gas ring. The type of vessel used has depended largely on individual tastes and no restrictions have been placed on the type employed provided it was reasonably safe. Some of the vessels used, however, could not be regarded as entirely free from danger to the user, and it was apparent that considerable care had to be exercised when they were in use. This was particularly evident when it was necessary to climb steps while carrying the wax to a cable end. Furthermore, a suitable gas ring was not always fitted in the immediate vicinity of the cables, and this made it necessary for the molten wax to be carried a considerable distance.

These factors, together with the necessity for accurate regulation of the temperature of the wax, called for some standardisation in the type of vessel to be used and the method of heating. This has now been effected in the Post Office Engineering Department by the recent decision to introduce electric wax heaters.

The Electric Wax Heater.

The heater standardised, together with its stand, is illustrated in Fig. 1. It is a self-contained unit except for a plug and cable by which the heater is connected to the supply point. The component parts consist of heating elements which will raise the temperature of the wax to 300° F. in approximately 40 minutes, a thermostat which regulates the temperature between 300° and 350° F., a lamp to indicate when current is flowing through the elements, and a socket in which the internal wiring is terminated. The layout of the component parts is shown in Fig. 2.

The impregnating process is usually carried out while the heater is held in the hand, and the shape adopted allows this to be done without any undue

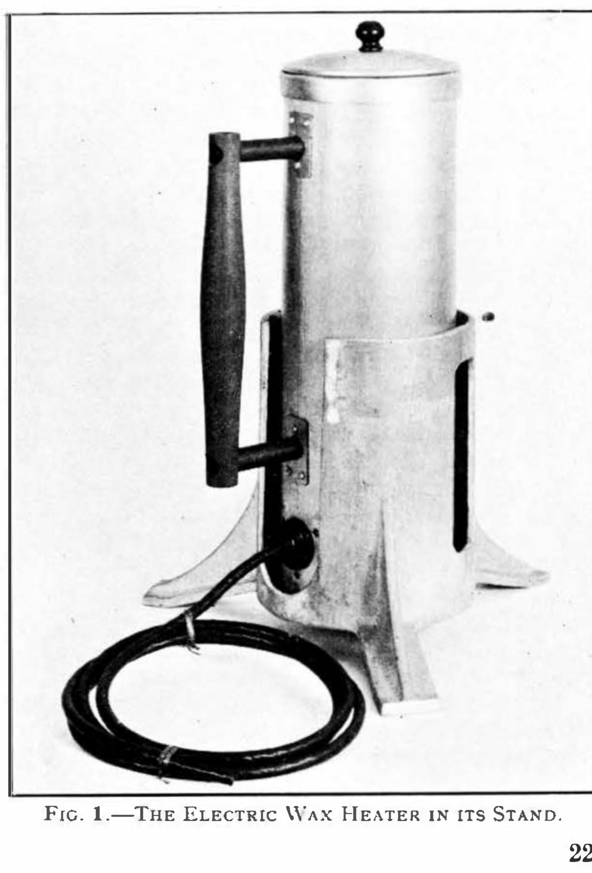


FIG. 1.—THE ELECTRIC WAX HEATER IN ITS STAND.

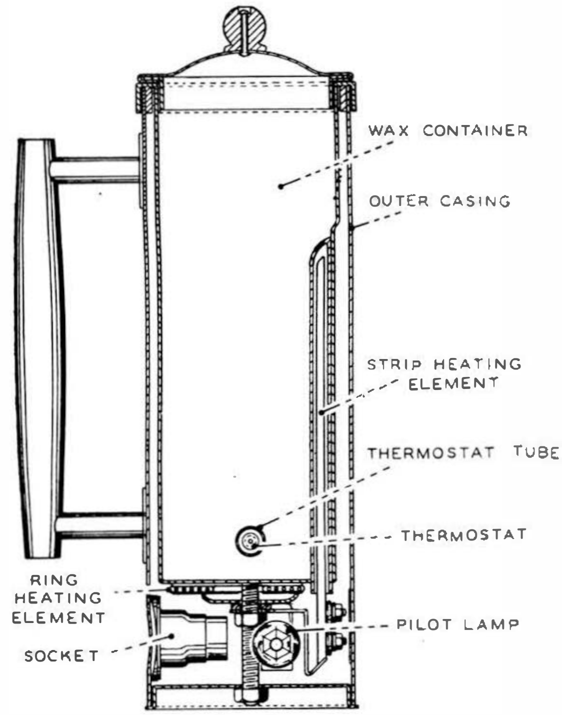


FIG. 2.—CROSS SECTION OF THE HEATER.

strain on the user. To meet the same condition the weight (5½ lbs.) has been kept at a minimum by using aluminium wherever possible. The shape and the lightness in weight also allow the heater to be carried in a comfortable position while walking or climbing steps.

A combination of two differently shaped heating elements is used. The one fitted at the base is in the form of a ring and is clamped in position by a concave washer and a nut which fits the threaded rod welded on the bottom of the wax container. The element at the side is in the form of a strip and is fitted in a flattened aluminium tube which, welded to the inside of the wax container, is in direct contact with the wax.

Both elements are constructed in a similar manner and consist of a long coil of nickel-chrome wire totally embedded in a refractory cement. The underside of the ring element is protected against damage from the concave washer by an iron ring of the same shape as the element. To avoid breakage which might occur owing to its shape, the strip element is totally enclosed in a chromium steel sheath.

The side element, apart from providing a quicker heating time, also precludes the possibility of part of the wax being forced out of the heater. With a single element at the base the wax in the vicinity of the element on being heated would expand, and there being no room for expansion to take place the pressure would be liable to increase sufficiently to force the unmelted wax at the top out of the container.

The type of heating element employed and the method of fitting satisfactorily overcomes the difficulty of melting the whole of the wax without local overheating. When the wax is in a solid state the heat generated by an element may not circulate at a rapid rate, and there is a likelihood of the wax nearest the element becoming overheated. In addition, to ensure a reasonably long life for an element, it is necessary that conditions should be such that it can part readily with the heat it generates. By fitting the side element inside the container and in a flattened tube, thereby increasing the area of wax in contact with the element, it is found that local overheating of the wax and element does not occur.

The thermostat is of the bi-metallic type consisting of two contact springs in a sealed glass tube. Connection to the thermostat is made by two wires which are brought out, one at each end. It is, of course, necessary for the thermostat to be in contact with the wax and yet to be protected against damage which may be caused when dipping the cables. Both these conditions are met by accommodating the thermostat in a thin aluminium tube fitted near the bottom of the wax container (see Fig. 2). Temperature control between 300° and 350° F. is obtained by this method.

The lamp which is fitted at the base serves as a negative signal to indicate when the wax is ready for use. It is connected in the element circuit so that when the heater is connected to the supply, the lamp glows, and when the thermostat operates it is extinguished. The use of a thermometer for testing the temperature of the wax is obviated by the lamp.

If as a result of further experience it is deemed advisable to provide visual indication all the time the heater is connected to the supply, a combined plug and lamp will be provided for the end of the cable which is connected to the supply point. As, however,

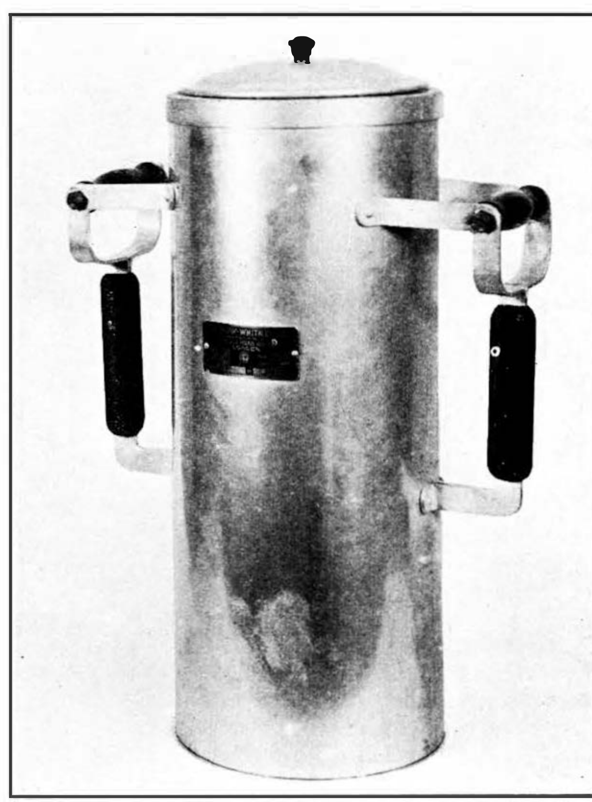


FIG. 3.—LARGER TYPE OF ELECTRIC WAX HEATER.

thermostatic control eliminates the risk of the temperature reaching a dangerous value, the provision of such a lamp at the moment does not appear to be justified.

The wire used for the internal connections is covered with heat-resisting insulation either in the form of beads or asbestos sheathing, and is terminated in a three-pin plug which is recessed in a hole situated below the handle.

The handle is constructed mainly of wood and in such a manner that it will remain reasonably cool for comfortable handling. It has a smooth finish so that any wax which may be spilled on it and so affect the grip, can be easily removed. It is long to enable the heater to be held at different heights during the dipping process, according to the position of the cable.

The design of the heater described and the choice of component parts has been decided on as a result of experimental work carried out in conjunction with Messrs. Barlow Whitney, Ltd., and also as a result of field trials. It is claimed that the new heater has the following advantages over the devices employed previously :—

(1) Reduction of fire risks due to the elimination of the use of a naked flame for heating.
(2) The wax cannot burn.
(3) Unnecessary to stand by while the wax is being heated.
(4) Cleaner in use.
(5) More portable and safer in use.
(6) Obviates the use of a thermometer.

The heater described has a wax container 12 in. deep and $4\frac{1}{4}$ in. diameter, and is intended for cable forms up to 4 ft. in length. It is possible to impregnate longer lengths of the small cables containing 21 and 42 wires. For works where a longer length of cable has to be impregnated the larger heater illustrated in Fig. **3** has been provided. The wax container of this is $6\frac{3}{4}$ in. diameter and 14 in. deep, and is suitable for cables up to 12 ft. in length. Except for a few minor details such as an extra heating element and another carrying-handle, this heater is similar to the one described.

Transportable Battery Charging Sets For Emergency Purposes

Telephone exchange main batteries are designed to have a minimum reserve capacity equal to the 24 hours exchange discharge. Transportable engine-driven charging sets are available for exchanges where stand-by prime movers are not installed, to cover power plant or supply breakdowns of durations greater than can be met by the battery reserve.

At present, 63 sets of various sizes are held at centres throughout the country. With the exception of three, these sets are in poor condition and in need either of extensive overhaul or replacement. The position has been reviewed and a replacement and augmentation programme decided upon.

Considerations of ease and transport have resulted in a decision that sets of 30 kW output should be the largest new machines. These sets have been designed to be towed by the 3-ton Post Office lorries which would be available for use at short notice.

All telephone zone centres are to be covered without the aid of transportable emergency charging sets, the 30 kW sets being intended to cover other main batteries of 1,500 Ah. or more capacity at 50 volts, or 800 Ah. or more at 22 volts. Eight sets have been obtained to function as reserves for the exchanges within this category and are to be held at main centres.

Three existing 67 kW. sets are in good condition and are to be retained in service. These sets need special tractors for towing, but little difficulty in hiring suitable tractorsis likely to be experienced in London, and, in consequence, the three sets will be held at that centre. London will, in addition, have one 30 kW. set in order that the flexibility given by this size of set will not be completely absent.

For smaller exchange batteries, sets of 6 kW. and 2 kW. rated outputs are to be employed. The 6 kW. sets have a dual output capable of supplying either D.C. for battery charging or A.C. for replacing the mains supply at amplifier stations. These sets will be adequate for the demands of amplifier stations, and are intended also for exchanges with main batteries of from 400 to 1,500 Ah. capacity. Forty sets will be distributed throughout the country. Fifty 2 kW. sets will cover the exchanges with main batteries up to 300 Ah. capacity.

It is probable that several exchanges would need emergency charging plant at the same time due to a breakdown of their common power supply. The distribution of the sets has been so designed that one set should be capable of adequately charging the batteries of a number of exchanges in rotation.

If required, the output of a set may be augmented by operating a similar set in parallel, the second set being loaned, if necessary, from the nearest centre.

W. G. R.

Notes and Comments

Punching of the Supplement

It has been suggested that the Supplement to the JOURNAL should be issued with holes punched in the margin in order that copies may be filed for reference in a binder. The Board of Editors consider that this facility will be of convenience to many subscribers and the Supplement issued with this and future parts will be punched.

Reprint of Articles on the London-Birmingham Co-axial Cable System

The four articles by A. H. Mumford, B.Sc. (Eng.), A.M.I.E.E., which were published in Volumes 30 and 31 of the JOURNAL, have been reprinted under one cover, and will be issued as a Printed Paper to members of the Institution of Post Office Electrical Engineers.

In view of the importance and general interest of these articles, it is felt that many readers who are not members of the Institution will wish to have the information conveniently available under one cover. Anticipating this demand a number of copies beyond that required by the Institution membership has been printed, and may be purchased from the Librarian, Institution of Post Office Electrical Engineers, G.P.O. (Alder House), London, E.C.1, at a price of 1s. 3d., plus 1½d. postage.

World Radio Convention, Sydney, April, 1938

At the World Radio Convention, held in Sydney as part of Australia's 150th Anniversary celebrations, over fifty papers were contributed. These are being printed and bound in one volume, copies of which will be available from the Institution of Radio Engineers (Australia), 30 Carrington Street, Sydney, at a cost of one guinea each.

Institution of Electrical Engineers—Summer Meeting

During the summer meeting of the I.E.E. which was held in July in the area of the South Midland centre of the I.E.E., a visit of inspection was made to the trunk, toll and central exchanges in Telephone House, Birmingham.

The history of the telegraph was illustrated by instruments dating from 1837. The instrument patented by Wheatstone and Cooke in that year, consisting of a 4-needle apparatus requiring six wires, and other instruments showing how this form of communication developed through the years until the adoption by the Post Office in 1927 of the Creed teleprinter were exhibited. A model of the first telephone invented by Bell in 1875 was on view; other instruments shown included one with extended ear pieces, and another which was the origin of the present silence cabinet.

Cable exhibits included a specimen used by Wheatstone and Cooke in 1837 between Euston and Camden Town, a rather primitive arrangement consisting of a triangular section of wood with bare copper wires in grooves. Pieces of the earliest lead-covered cable laid at Chalk Farm in 1840 and of the first submarine cable which linked Ramsgate with Ostend in 1852 were seen, together with examples of modern cables.

After the inspection at Telephone House the party, accompanied by their President, Sir George Lee, was entertained by the Post Office at a luncheon at the Grand Hotel, over which Mr. T. B. Braund, Postmaster Surveyor of Birmingham, presided.

An interesting interpolation was a telephone conversation between Sir George Lee and Mr. C. Griffith, Chief Engineer to the Post Office in the Union of South Africa, who was on holiday in Natal. Good wishes were sent to him at his hotel by Sir George Lee through the co-axial cable from Birmingham to London, thence to Rugby by ordinary cable and then via the Post Office radio telephone service to South Africa.

Acknowledging the toast of "The Institution," proposed by Mr. H. Faulkner, Superintending Engineer of the North Wales District, the President said that very shortly a time service from the Speaking Clock would be available in Birmingham by dialling TIM. It had been suggested that weather reports might also be received over the telephone and the appropriate dialling code, judging by the weather this summer, would be "WET."

Regulations for Controlling the Earthing of Electrical Installations to Metal Water Pipes and Water Mains

The above regulations have been drawn up and approved by the Institution of Civil Engineers, the Institution of Electrical Engineers, the Institution of Water Engineers, the British Waterworks Association and the Water Companies Association.

The regulations are intended to be applicable generally, with one exception: Post Office installations, other than those for power and lighting services, are excluded, but are subject to agreement between the authorities concerned. Copies of the regulations can be obtained from William Clowes & Sons, Ltd., 94 Jermyn Street, S.W.1, at a price of 6d. post free. The JOURNAL has been asked by the Institution of Civil Engineers to call attention to these regulations, because it is considered to be in the public interest that they should be generally adopted.

Lt.-Col. C. B. Clay, V.D., M.I.Mech.E., M.I.E.E.

We regret to have to record the death of Lt.-Col. C. B. Clay, V.D., M.I.Mech.E., M.I.E.E., which occurred on August 9th. Born at Liverpool in 1856, he was trained and served for a few years as a marine engineer before joining the United Telephone Company in 1881. Later he was appointed Manager of the Northern District Telephone Company and continued as Manager on the absorption of that Company by the National Telephone Company. In 1896, he was appointed Metropolitan Superintendent in London and occupied that position until the acquirement of the National Telephone Company's system by the State.

Of a commanding presence and a firmness tempered with a deep and sympathetic understanding, Col. Clay obtained from his staff an enthusiastic loyalty.

The high regard in which he was held was demonstrated at a dinner on the eve of the " Transfer," at which more than 900 people were in attendance.

To very many telephone men of the older generation, Col. Clay's passing will be as the breaking of a link, and we express on their behalf our deep sympathy with Mrs. Clay and her family in their bereavement.

Ministerialdirektor Karl Höpfner

On June 11th last, after a long illness, Ministerialdirektor Karl Höpfner of the German Post Office died as the result of a heart attack. Among all engineers in Europe it is safe to say that none will regret his death more than his colleagues of the British Post Office.

He entered the Service on April 4th, 1894, and has thus had a long, as well as a very distinguished career. Herr Höpfner was well known to many British engineers before the war by his writings in technical journals, and after the war he came into personal contact with many of the Post Office staff in connection with international telephony. Shortly after the formation of the C.C.I.F., he was appointed President of the Third " Commission de Rapporteurs," which dealt with the problems concerning international telephone lines, their design, provision, operation and maintenance. Under his presidency the work of this commission progressed very rapidly, and all those members of the British Post Office with whom he came into contact will remember him as a most kindly and courteous gentleman whose firm and broad-minded decisions brought harmony among the

delegates of all nations. Herr Höpfner was a great engineer whose name will always be associated with the rapid post-war development of long-distance telephony, and by his death the telephone world has lost a very progressive, far-seeing as well as a most charming personality.

Book Review

" Electrical Engineering Practice." Vol. I. Fifth Edition. J.W. Meares, C.I.E., F.R.A.S.,M.Inst.C.E.,M.I.E.E., and R. E. Neale, B.Sc., A.C.G.I., A.M.I.E.E. 780 pp. 90 ill. Chapman & Hall. 25s.

There is no lack of new publications intended for the specialist in the various branches of electrical engineering or of those intended for the student but the needs of the practical engineer who is often detached from his fellow workers are apt to be overlooked. A new edition of this Manual of Electrical Engineering Practice, which covers the whole field of generation and transmission in a sufficiently detailed manner for the purpose in view, is therefore very welcome.

The book is by no means confined to the purely electrical side but embraces important sections on prime movers including waterpower which has received meagre attention in text books published in this country. The authors have succeeded in eliminating a great deal of the educational and early experimental work which has often been associated with text books of a general nature, without neglecting those fundamental principles and explanations upon which the practicing engineer is often glad to have his memory refreshed.

It is felt that the needs of the practicing engineer have been well catered for. He is no longer intimately concerned with the design of individual items of plant but with their capabilities and performances. He has become a user and it is for the user that this book has been compiled.

Although the three chapters devoted to waterpower only claim to be a general survey they contain a large amount of up-to-date information and will be found of particular interest.

Chapter 13 will need to undergo some alteration when the 11th edition of the I.E.E. Wiring Regulations is published, as the 10th edition is widely quoted.

The up-to-date character of this work is revealed by the satisfactory description in Chap. 15 of Petersen Coil operation and of earth leakage protection which have received too little attention in this country hitherto.

A most useful and comprehensive index is included which contains references to volumes II and III and when these have been revised the complete work should find a place in every engineer's library.

P. B. F.

Capt. J. Legg, B.Sc., A.M.Inst.C.E., A.M.I.E.E.

Capt. J. Legg, B.Sc., A.M.Inst. C.E., A.M.I.E.E., who succeeds Mr. Jenkins as head of the Telephone Development and Maintenance Branch, entered the Post Office as Assistant Engineer by examination in 1911 after two years' pupil-apprenticeship in the Royal Ordnance Factory, Woolwich. He was appointed to the Test and Inspection Branch, and for three years was engaged on testing cables and loading coils at contractors' works. From 1914 to 1919 Capt. Legg served with the Royal Corps of Signals, chiefly in France.

In 1919 Capt. Legg returned to his old Branch, and in 1919 was promoted to Executive Engineer in charge of stores testing staff at London depots and contractors' works in the south of England. During this period he also served on committees of the British Standards Institution dealing with lead-paints and insulating materials.

In 1934 he was made Assistant Staff Engineer in the Telephone Development and Maintenance Branch, and in this capacity has been responsible for many aspects of telephone development, particularly with respect to trunk working in London.

He was a member of the commission which visited the U.S.A. in 1936 to study the American trunk service, and more recently was a British delegate to the C.C.I. (F)—3rd C.R.—at Oslo in June, 1938. He is also a member of the permanent sub-commission of that body appointed to study the methods of signalling on international lines.

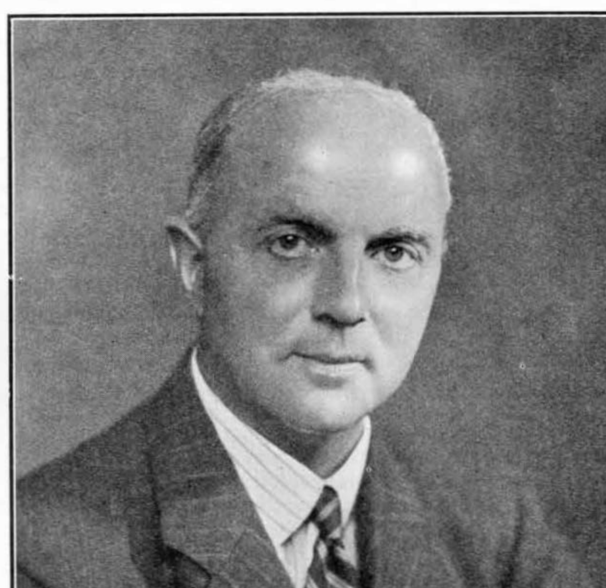
Capt. Legg's promotion is welcomed not only in his own Branch but by a large circle of friends who are impressed by his rapid grasp of the essentials of a complicated problem and who value his fine personality.

G. F. O.

G. J. S. Little, B.Sc., A.M.I.E.E.

Mr. Little, who became Superintending Engineer, North Western District, on September 1st, was in the first instance keenly interested in the structural and mechanical side of engineering, and studied for his degree in those subjects. His studies were interrupted by the war period, and on obtaining his degree after the war he spent some time with a structural engineering firm. He entered the Department by open competitive examination as Assistant Engineer in 1922, and spent the first part of his official career in the Research Branch, where he was engaged on experimental work on telephone repeaters and carrier equipment. In 1930 he was transferred to the Lines Branch of the Engineer-in-Chief's Office, where a year later he was promoted to Executive Engineer.

In 1934 Mr. Little visited the Bell Laboratories in the U.S.A. to report on the developments in carrier and co-axial technique in the United States. In 1936 he was promoted to Assistant Staff Engineer in the Lines Branch and has been intimately connected with the development and application of carrier and co-axial equipment to the underground trunk system of the British Isles.



Since the beginning of 1937 Mr. Little has represented the Engineering Department on the C.C.I.F., being a member of the third " Commission de rapporteurs." He took an active part in the recent C.C.I.F. conference at Oslo, and has been designated President of the " Sous-Commission des systemes à courants porteurs pour cables à tres large bande."

During his time at Headquarters Mr. Little has become one of the recognised experts in carrier transmission, with a reputation abroad as well as in this country. His quiet industry and unfailing sense of humour have made him many friends who are confident he will achieve equal success at his new post. J. S.

Retirement of Mr. C. Brocklesby, M.I.E.E.

At the end of August last the retirement took place of Mr. C. Brocklesby, Superintending Engineer of the North Western District.

Mr. Brocklesby's introduction to telephone engineering was as an apprentice in the service of the General Electric Company in Manchester, but following the disastrous fire in 1895 which completely destroyed the Company's works, he was loaned to the late National Telephone Company and elected to remain. After gaining valuable experience in various parts of the country, he was appointed to the rank of Chief Inspector at Bradford in 1904, and a year later was promoted to the position of Electrician in that centre, controlling all internal engineering and traffic matters.

He was appointed District Electrician in the Birmingham District in 1911, and on the transfer of the company's undertaking to the State in 1912 was graded as Assistant Engineer. In 1925 he was promoted to the position of Sectional Engineer (Internal) at Liverpool, and in 1931 was appointed Assistant Superintending Engineer in the North Eastern District, whence he was transferred later to a similar position in the North Western District where he received further promotion to the position of Superintending Engineer on February 1st, 1935. In his service in the North Western District, he was afforded opportunities of exercising his gifts in District management, and his able administration is testified by the excellent results obtained.

Mr. Brocklesby was held in high regard by his staff, and his colleagues elsewhere in the Engineering Department and in other branches of the Service. They greatly regret the severance of their official association with him and wish him many years of health and happiness in his retirement.

F. S. H.

Retirement of Mr. I. H. Jenkins, M.I.E.E.

The retirement on September 9th, 1938, of Mr. I. H. Jenkins, Staff Engineer in charge of the Telephone Development and Maintenance Branch at Headquarters, means the loss of one who has been closely associated with progress in the telephone switching art over a period extending from the introduction of C.B. manual working to the completion of the standardisation of a range of automatic equipment to cover the whole country. Entrusted as a young man with the installation of Bristol, the first C.B. exchange to be built in this country, he has been responsible during the last few years (*inter alia*) for the concluding steps in automatic exchange equipment standardisation—the introduction of the 2,000 type selector.

Mr. Jenkins commenced his career with the N.T.C. at Bristol and came in 1903 to London as a member first of the National Telephone Company and later of the Engineer-in-Chief's Office. He took an active part in development, notably the introduction of the automatic system of working and of trunk demand working. In connection with the latter, he visited Germany and America and was one of the leading members of the band of enthusiasts responsible for the rapid and successful application of this system of working to the trunk network in this country.

To the solution of the many problems met with during his long career, Mr. Jenkins has brought a shrewd brain, a sound judgment and a steady flow of fresh ideas. To his personal contacts he has brought an essential kindliness of nature which has made him innumerable friends both within and without the Department, all of whom will join in wishing him long life with good health and happiness in his retirement.

J. L.

The Institution of Post Office Electrical Engineers

CORRESPONDING MEMBERS

The following have been elected :—

H. M. Trainor, Divisional Engineer's Office, G.P.O., Capetown.

H. Loney, Posts and Telegraphs, Dar-es-Salaam, Tanganyika.

C. Griffith, Post and Telegraphs, G.P.O. Pretoria.

RETIRED MEMBERS

The following members who have retired from the Service have elected to retain their membership of the Institution :—

W. D. Hamilton, 367 N. Circular Road, N.W.10.

T. Lancaster, Reinerera, Highland Ridge, Quinton, Birmingham, 32.

F. Woollard, 38 South View, Bromley, Kent.

A. Wright, 21 Parkcroft Road, West Bridgford, Nottingham.

PRIZES AWARDED UPON THE RESULTS OF CITY & GUILDS OF LONDON INSTITUTE EXAMINATIONS, 1938.

The following awards of prizes, provided by the Institution of Post Office Electrical Engineers, have been made on the recommendation of the City & Guilds of London Institute :—

Transmission and Lines, Grade II :

First Prize of £3 : I. F. Macdairmid, Post Office Engineering Department., who entered as an external candidate at the Royal Technical College, Glasgow.

Second Prize of £2 : J. E. Varrall, Post Office Engineering Department, student of the Borough Polytechnic, London.

Technical Electricity, Grade II :

First Prize of £2 : E. A. Rix, War Department, student of the Polytechnic, Regent Street, W.1.

Second Prize of £1 : Divided equally between : J. E. Haworth, Post Office Engineering Department, who entered as an external candidate at the Acton Technical College. J. F. Hesketh, Post Office Engineering Dept., who entered as an external candidate at the Polytechnic, Regent Street, W.1.

JUNIOR SECTION PAPER AWARDS RESULT

Annual award of Five Prizes of £2 2s. each for the best papers read by members of, and at meetings of, the Junior Section, 1937-38

The Judging Committee has awarded the five prizes to the following :—

Author	*Junior Centre*	*Title of Paper*
K. Stephenson	Middlesbrough	" Television "
F. H. Allum	Rugby	" Transmitting Valves at Rugby Radio "
S. E. Harvey	Southampton	" Unit Automatic Exchanges No. 13 "
F. W. Stoneman	Rugby	" The Mercury Arc Rectifier "
C. W. Roe	Norwich	" Trunk Routing and Operation "

The Judging Committee specially .commended the following :

Author	*Junior Centre*	*Title of Paper*
E. C. R. Clark	Brighton	" Television "
R. J. Parsons	Leeds	" Trunk Demand Working "
E. A. Thomas	Cardiff	" High Definition Television "

ESSAY COMPETITION, 1938

The Council has decided to offer Five Prizes of Two Guineas each for the five most meritorious essays submitted by members of the Engineering Department of the Post Office below the ranks of Inspector and Draughtsmen, Class II, and, in addition, to award a limited number of Certificates of Merit.

A prize-winner in any previous competition is not eligible to enter, but this restriction does not apply to a Competitor who has been awarded a certificate only.

In judging the merits of an essay, consideration will be given to clearness of expression, correct use of words, neatness and arrangement, and although technical accuracy is essential, a high technical standard is not absolutely necessary to qualify for an award. The Council hopes this assurance will encourage a large number of entries. Marks will be awarded for originality of essays submitted.

Information concerning the competition is given in the leaflets which have been issued to the centres for distribution. The Council hopes that supervising officers generally will bring the competition to the notice of those eligible to compete.

The Essays must reach the Secretary, The Institution of Post Office Electrical Engineers, G.P.O. (Alder House), E.C.1, before the 31st December, 1938.

Local Centre Note

South Lancashire Centre

The 1937/8 session opened on October 11th, 1937 and the Chairman, Mr. Morris, addressed the meeting. During the succeeding six months papers were read at the rate of one per month. Every paper was both interesting and informative. The average attendance for each meeting was 91 members, which represents approximately 60 per cent. of the membership. Considering that those eligible to attend the meetings of the South Lancashire Centre are scattered over a wide area, the attendance is regarded as satisfactory.

The influx of new members during the year ended March 31st, 1938, was very good and the total is still rising. The programme for the forthcoming session will maintain the high standard of quality which has characterised those arranged for past sessions and members of the Centre will, no doubt, discover an interest in the subjects dealt with.

Junior Section Notes

Bradford Centre

It is gratifying to to be able to take a very optimistic outlook of Junior Section activities during the forthcoming winter session, and a renewal of interest in these activities is evident among a large number of the staff.

Efforts have been made, with some measure of success, to obtain support for the Bradford Centre from members of the Keighley staff, and also to amalgamate the Huddersfield and Halifax members to form a joint centre with meetings to be held alternately at Halifax and Huddersfield. It is hoped by this means that the interchange of opinions and experiences between the various staffs, and the introduction of some friendly rivalry in the lectures and discussions, will make for better and well-attended meetings.

All members are asked to make special efforts this winter to attend the meetings, so that this optimism may be justified.

The Bradford Centre is commencing its programme with a visit to the North Regional B.B.C. Transmitting Station, on September 24th, and the success of this visit is assured.

The Halifax/Huddersfield members are scheduled to meet at the Elland new automatic telephone exchange on September 29th, for a practical demonstration of line finder working, and also for a preliminary meeting to re-elect the officers, and arrange the winter's programme.

Members can rest assured that an interesting and educative programme will be available at each of the centres.

Leeds Centre

The 1937-38 session proved to be a successful one, and a slight increase in membership has to be reported. This is considered satisfactory, having regard to the claims of other educational bodies, etc.

The programme carried through was as follows :—

1937

October.—Open Meeting. " Any Questions."

November.—" Impressions of German Telecommunication Systems." G. R. Hudson.

December.—" Electrical Interference With Radio." J Field.

1938

January.—" Manufacture and Testing of A.C. Induction Motors." A. C. Holmes.

February.—" Local Line Plant Development." R. C. Wormald.

March.—" Trunk Demand Working." R. J. Parsons.

May.—" Annual General Meeting and Talk on Promotion Procedure." H. McLean.

The papers read were by members of the centre and all were of a good standard and well received by good average attendances.

The prize presented by the Chairman, Mr. H. McLean, for the best paper read was awarded, in accordance with Mr. A. E. Morgan's (Regional Engineer) decision, to Mr. R. J. Parsons, for his paper on " Trunk Demand Working."

The officers elected for the 1938-39 session are as follows :—

Chairman—Mr. H. McLean.
Vice-Chairman—Mr. J. Field.
Secretary—Mr. A. C. Holmes, Leeds Repeater Station.

A representative committee has also been duly elected and a splendid programme of papers arranged for next session.

It is hoped that both senior and junior internal and external officers will avail themselves of the opportunity which awaits them to further their technical knowledge by taking advantage of the Central Library and attending local centre meetings.

The Centre desire to thank the President, G. P. Milton, Esq., for his interest and help during the past session.

Manchester Centre

The 1937-38 session of the Manchester Centre has again been most successful, the attendance at the meetings and visits being considerably more than last session. An increase of membership from 215 to 300 has also been achieved. A total of eight meetings and five visits were arranged, the visit to the Fairey Aviation Co. being so successful that a second visit had to be arranged later in the session.

At the Annual General Meeting the following officers were elected for the 1938-39 session :—

Chairman—Mr. Andrew Jones.
Vice-Chairman—Mr. W. Hyde.
Secretary—Mr. A. R. Powell.
Asst. Secretary—Mr. E. G. Owen.
Treasurer—Mr. R. R. Gaythorpe.
Librarian—Mr. A. Bentley.
Committee—Messrs. Pratt, Pickles, Shore, Brown, Pauline and Albert Jones.

The debate after the Annual General Meeting was " That this House considers the automatic system of telephony is far superior, both in the service which it offers to the public and also from the engineering point of view, to the manual systems which it is replacing," which produced much interesting discussion among the members ; being put to the vote the motion was carried by an overwhelming majority.

Subscriptions are now overdue and should be paid to the Treasurer or to any Officer or member of the Committee.

Salisbury Centre

The following lectures were given during the 1937-38 session :—

" Transmission without Tears." Victor Smith.
" Primary Vouchers etc." H. J. King.
" Salisbury Auto-Exchange." E. H. Granger.
" Multi-metering." S. N. Wathen.
" Day-to-day Faults and their Treatment." E. E. Baugh.
" The House Telephone System." E. J. Donohue.
" The Police Street Pillar System." E. H. Granger.
" The Sleeve Control Manual System." W. Llewellyn.

and one meeting in which questions of general interest were discussed, thus making a total of nine meetings. Two other meetings had to be cancelled owing to the pressure of work occasioned by the storm in December last.

The average attendance at meetings was 20. The total membership was 47, which included 9 Youths-in-Training, but no labourers.

It is hoped to enrol more members from the external staff during the next session.

The Centre was fortunate in being able to borrow a blackboard for all lectures from St. Thomas's School, and a donation of 10s. was made towards the School sports fund.

Lantern slides illustrated five of the lectures, the lantern being hired locally.

During the session, a large number of books were borrowed from the Institution library, this being the first session in which the Centre availed itself of the library facilities.

During the session, two parties paid visits to the Southampton Centre, where they were accorded a very hearty welcome.

The Centre suffered the loss of one of its most enthusiastic supporters in the passing of Mr. W. Hoxley. Several members attended the funeral and his passing was mourned by all.

The promotion and consequent transfer of Mr. G. Parrott, meant the further loss of a very staunch supporter and wise counsellor.

In spite of somewhat poor attendances at meetings, and various other setbacks, the session has been very successful, in fact so far as membership is concerned, the most successful yet. It is hoped that next session will be even more successful.

At the Annual General Meeting the following officers were elected to serve for the ensuing year :—

Chairman—Mr. F. D. Traviss.
Vice-Chairman—Mr. R. H. Read.
Secretary—Mr. W. Llewellyn.
Treasurer—Mr. S. N. Wathen.
Auditors—Mr. A. E. Pearcy.
Mr. E. W. Brown.

It was proposed and carried, that the Committee should be increased from three to five members, who are as follows :—

Mr. E. H. Granger. Mr. H. J. King.
Mr. S. A. Vokes, Mr. L. J. A. Cox.
Mr. F. J. Heath.

In view of the substantial balance in hand it was unanimously agreed to send a donation of 10s. to the Salisbury Infirmary in appreciation of their kindness to various members of the staff. It was also decided to inaugurate the next session with a Dinner or Smoking Concert.

The subscription rate of 2s. per annum will remain as at present, no reductions being called for by any member.

The meeting closed at 9.30 p.m., votes of thanks being passed to the officers for their work during the 1937-38 session.

Sheffield Centre

The Sheffield centre is now getting into its stride and a very fine programme has been arranged for the coming session. It is hoped that members will make an effort to attend all the meetings and so give support to the men who have been good enough to offer their services as lecturers.

The officers for the 1938-39 session are as follows :—

Chairman—Mr. E. Shipman.
Vice-Chairman—Mr. W. G. Boston.
Treasurer—Mr. A. Hancock.
Secretary—Mr. S. B. Jarman, Telephone House, West Street, Sheffield.
Committee—Messrs. J. Carrington, F. Sellars, T. Meller, J. Bell, A. Armitage.

The programme is shown below. All meetings are to be held in the Refreshment Club Room, Telephone House, West Street, Sheffield, at 8 p.m.

October.—" Maintenance Control and Fault Procedure." Mr. J. Carrington.

October.—Visit to Steel Peech & Tozer.

November 9th.—" Introduction to Auto." Mr. Hyde.

November.—Visit to Nunnery Colliery.

December 14th.—" Cable Interference." Mr. Cantrell.

January 11th.—Film Unit.

January.—Visit to Sheffield Telegraph.

February 8th.—" Underground Construction." Mr. Spink.

February.—Visit to Callenders or Connellys.

March 8th.—" Preselection v. Linefinder System." Messrs. R. Powell and W. B. Green.

April.—Pie Supper. Annual General Meeting.

Southampton Centre

The 1938-39 session now being open, the following programme has been compiled to maintain as far as possible the previous high standard of material for lectures. The papers will be given as follows :—

October.—" The 12-Channel Carrier Telephony System." L. T. Jennings.

November.—" Works Supervision." A. Payne.

December.—" Unit Automatic No. 7 Exchanges." A. S. Hale.

January.—" Regional Organisation." F. W. Friday, A.M.I.E.E. (Sectional Engineer).

February and March.—Open Meetings.

The officers elected for this session are :—

Chairman—Mr. C. S. Hale (Inspector)
Vice-Chairman—Mr. R. J. White
Secretary and Treasurer—Mr. N. E. Dodridge
Committee—Messrs. C. F. Middleton, L. T. Jennings, F. Baker, W Couzens, C. Hislop and F. Evans.
Auditor—Mr. F. Evans.

The committee extend a hearty invitation to all members of the staff, especially the external section, to attend the meetings which will be held on the second Thursday in each month. This arrangement has been made to enable night school students to share an interest in their local I.P.O.E.E. activities. Colleagues from Winchester, Brockenhurst and the H.T.O. are welcomed as before.

Members wishing to enrol for 1938-39 should approach any of the following officers who will be glad to assist in any way : Messrs. Baker, Jennings, White, Middleton, Couzens, Evans, Hale or Dodridge.

We congratulate Mr. S. E. Harvey who has received an award for his paper on " Units Automatic No. 13," a creditable achievement for so difficult a subject.

N. E. D.

District Notes

London Region

AVENUE AUTOMATIC EXCHANGE

The City of London is now completely automatic. Avenue, the last remaining manual exchange in the Lord Mayor's area, was replaced on July 2nd by the new Avenue automatic exchange which is, incidentally, the first 2,000 type exchange in the City.

The new Avenue is housed in the same building as Mansion House and one feature of the transfer scheme was the conversion of the existing Mansion House power plant to full float working to supply both installations.

The ultimate capacity is 6,000 subscribers' lines, but the number of lines transferred was 2,874 subscribers' lines and over 1,900 junctions.

KING'S CROSS UNDERGROUND STATION RECONSTRUCTION

The London Passenger Transport Board recently commenced the reconstruction of King's Cross Underground Station and, as usual with works of this nature, it was necessary to shift all other Undertaker's plant to new positions. Other cases of the kind: Piccadilly Circus, Marble Arch, Leicester Square, Chancery Lane and St. Pauls all had their own difficulties but in all these the railway is at a deep level, with a comparatively limited area used for booking hall, escalators, etc. King's Cross differs from these inasmuch as this station was one on the old Metropolitan Railway where the track is almost immediately below the roadway level with only a few feet clearance, the tunnel being built in the form of a continuous brick arch. The first part of this railway was between Paddington and Victoria, opened on January 10th, 1863. Other sections were added from time to time and the section between Baker Street and City, which includes King's Cross, was opened in 1884.

The reconstruction work covers the whole area of the station, in this case at shallow depth. New direct communication is being made between the new station and the tube which crosses below at a deep level.

About half of the street is closed to traffic, and enclosed by hoardings. The reconstruction work is being carried out entirely from the surface, foundations, retaining walls, staircases, etc. being provided and the roadway is finally to be carried on heavy girders.

The Department's plant consisted of a main route carrying 12 cables together with a number of distribution pipes and lesser plant. A new duct route was provided during the early reconstruction work and the cables diverted, the distribution cables being dealt with as opportunity arose. An interesting feature is that all work must be controlled by the major operations. The excavations are heavily timbered and there are travelling cranes, temporary gantries, suspended plant, etc., to avoid. Access can only be obtained at particular phases and in some cases plant must be cleared to allow other work to proceed. The result is that constant attention will be necessary for the whole of the two years of the reconstruction.

THE C.T.O.

Recent changes on the control of the C.T.O. arising out of Regionalisation have recalled an earlier change.

In January, 1874, the telegraph plant at the old Telegraph Street office was transferred to the new St. Martins-le-Grand building at the corner of Newgate Street, now known as the C.T.O. The Engineer in charge at the time was Mr. H. Eaton and the accompanying photograph shows Mr. Eaton and his staff of the period.

Although the Telegraph Act of 1868 authorised the Postmaster-General to acquire the business of Inland Telegraph the monopoly was conferred by the 1869 Act, resulting in the transfer of telegraph plant to the Engineering Department in February 1870. Mr. Eaton, therefore, was one of the earliest in the roll of engineers who have been associated with the telegraph system as a state service.

Although the instruments of those days appear to present-day staff as very elementary, it is well to realise that the maintenance of the service required men no less capable than it does to-day and that the telegraph service owes much directly or indirectly to its early engineers.

North Midland

FAULT ABATEMENT

In common with others, this District has taken special steps directed towards a reduction of fault incidence on telephone equipment.

The following results covering the four main exchanges in one Engineering Section were obtained—

(*a*) by the very active co-operation of the staffs concerned, and

(*b*) by strict insistence on the clearance of R.W.T. faults.

March (U.A.X.7, and 429 stations)	0.63
Boston (N.D. and 1424 stations)	1.19
Peterborough (N.D. and 2405 stations)	1.43
Stamford (U.A.X.7, and 745 stations)	0.81

The figures for the first three exchanges are the faults per telephone per annum for the twelve months ended July, 1938, and the figure for Stamford is for the past five months only.

CITY & GUILDS EXAMINATION RESULTS, 1938, FOR PETERBOROUGH SECTION

The City & Guilds examination results for 1938 for the Peterborough Section are interesting and very satisfactory because they show what can be done in a rural section where educational facilities are not so readily available as in the larger centres.

The results are tabulated as under :—

(1)	Number of entrants	59
(2)	Number of 1st class certificates	52
(3)	Number of 2nd class certificates	24
(4)	Number of failures	12

AUTOMATISATION OF DERBY

Automatic working was introduced at Derby at 2 p.m. on Saturday, 2nd July, 1938.

The Scheme comprises :—

1. A main auto. exchange and associated manual board to replace the existing C.B.1 exchange, which has been in service approximately 34 years.

2. Satellite exchanges at Mickleover and Spondon to replace the existing C.B.S.2 exchanges.

3. New satellite exchanges at Allestree and Alvaston.

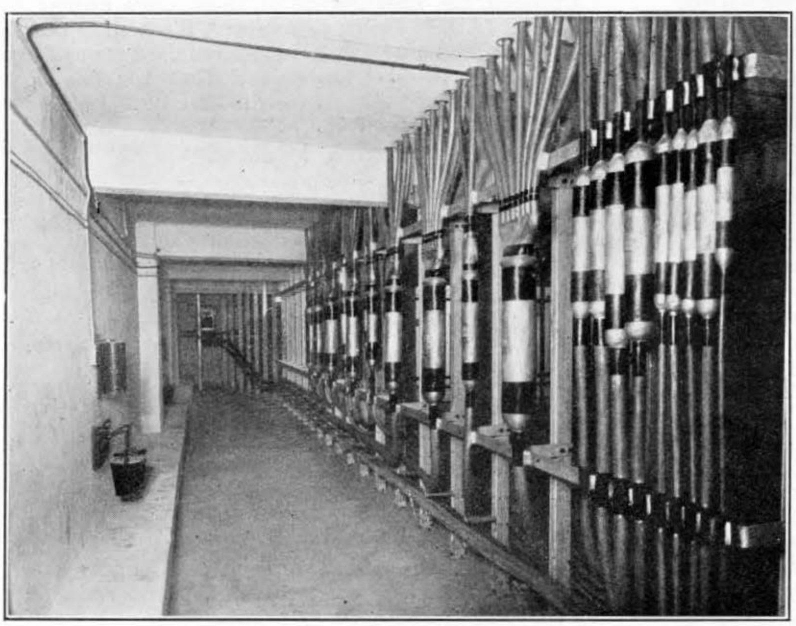
In conjunction with the Derby scheme, it was decided that the existing magneto exchange at Duffield should be replaced by a U.A.X. No. 7, and a new U.A.X. No. 13 exchange be opened at Breadsall.

Accommodation.

The main exchange is housed in a new fire-proof building of latest design, which has been erected on land adjoining the old exchange and repeater station. The building consists of four storeys which are allocated as follow :—

GROUND FLOOR :	Auto. apparatus room.
FIRST FLOOR :	Power room, battery room and extension to the repeater station apparatus room.
SECOND FLOOR :	Offices, welfare accommodation, meter room, ventilating plant.
THIRD FLOOR :	Auto. manual switch room and night staff accommodation.

The basement covers the full area of the building and, except for the heating chamber and E.L. & Power Room, is used for leading in the underground cables.



The cables are led in to the exchange from three directions, and a total of 59 ways have been provided. The cables are supported on special racking and some idea of the spacious layout is given in the accompanying photograph.

Apparatus.

The system is of a 200-line finder type with ballast resistors in the transmission bridges, giving a permissible subscribers' line resistance of 600 ohms. The following is the equipment provided :—

Name of Exchange	*Calling Equipment*	*Multiple Provided Initial*	*Ultimate*
Derby	4,160	4,600	7,000
Spondon	420	500	800
Allestree	400	400	1,000
Alvaston	220	300	700
Mickleover	350	400	600

The auto-manual exchange consists of 31 operating positions, one four position monitors' desk and one supervisors' desk.

The power plant at Derby and Alvaston is of the floated battery type, with motor generators, whereas at Mickleover, Alvaston and Spondon the parallel battery scheme with mercury arc rectifiers has been provided.

A full description of the Derby scheme has already been given in the I.P.O.E.E. paper, No. 163, and it is not proposed, therefore, to give details of the trunking and numbering schemes in these notes.

Change-over Procedure.

The transfer to automatic working involved a transfer of 4,690 subscribers' and call office lines and 622 trunks and junction circuits. The transfer of the majority of the circuits was effected by teeing, change-over strips being used for approximately 800 circuits only.

On the Friday before the transfer, a severe thunder storm was experienced during the afternoon and evening, and hopes for a good transfer began to fade. However, by the hearty co-operation of the staff all lines were re-tested for continuity and insulation, and all faults, which included two cable faults due to the storm, were cleared before the time fixed for the transfer.

The actual cut-over was commenced at 1.56½ p.m. and completed at 2 p.m. The testing of the subscribers' lines after transfer was carried out with test panels connected to the test final selectors and the test of the whole of the lines was completed within one hour after the transfer.

The engineering tests proved entirely satisfactory and in spite of the severe thunderstorm preceding the transfer the number of faults was below one per cent.

Official Opening and Celebrations.

The celebration of the opening of the new automatic exchange took place on July 22nd, 1938. Sir Walter Womersley, the Assistant Postmaster-General, honoured the District by performing the opening ceremony in company with the Deputy Mayor and other officials of Derby.

C.E.J.

South Lancashire

HOOTON U.A.X. No. 14

On August 20th, 1938, 306 subscribers' circuits connected to the Hooton manual exchange in the Liverpool Telephone Area were transferred to a U.A.X. No. 14. The change-over was satisfactorily effected, faults occurring on only three subscribers' circuits. This automatic exchange is the first of its kind opened in the South Lancashire District. The apparatus is housed in a standard building type D, and there is at present provision for 800 subscribers' circuits.

South Western

SERIOUS DAMAGE IN WEST COUNTRY DUE TO LIGHTNING AND FLOODS

A series of severe lightning storms accompanied by torrential rain was experienced in various parts of the District between August 1st and August 11th. The Plymouth, Exeter and Taunton Sections were affected most and a particularly severe storm on the 4th caused serious flooding at several exchanges, cable breakdowns and lightning damage over a wide area, and resulted in 119 exchanges being isolated, 13,000 subscribers' circuits, and 1,060 trunks and junctions being put out of order. A total of 256 cable faults occurred in the space of a few days and the jointing staff was worked to a standstill dealing with them.

At Torquay where water in the streets was several feet deep at the height of the storm, more than 2,000 subscribers' circuits were affected and the following extract from a report by the exchange maintenance Inspector indicates the abnormal conditions experienced :

" Being apprehensive of abnormal happenings at the telephone exchange I was about to leave my home at 7.45 a.m. on Thursday, August 4th, when I found the water knee-deep in the street. I waited a little time for the flood to subside, but as there was no sign of abatement, I waded to my car and after several detours to avoid floods, arrived at the H.P.O. where the water was 2 ft. deep outside the staff entrance. On reaching the exchange the early-duty man reported that everything was apparently normal at 7.30 a.m., but soon after, P.G's. began to show up and rapidly increased in number ; at 8 a.m. line switches were racing on all groups, at 8.30 the ammeter was showing a discharge of 120 amps. and only 3 group shelves held fuses for any length of time. All available staff was employed tracing P.G's. and challenging lines requesting subscribers to replace their receivers, but little progress was made, subscribers being inclined to question.

" At 9 a.m. I decided to plug out all subscribers by placing insulating strips between the test springs on the protectors.

" The three positions on the test desk were staffed and three men assigned an equal number of the verticals on the frame and every line tested out, those proving normal being freed and others plugged up.

" About the same time it became apparent that Cable A 600 pairs had broken down. At this juncture also the Head Postmaster reported the cellar full of water and the main switches submerged. A motor pump was obtained from the Corporation and the work of pumping out began.

" At midday cable B 600 pairs was showing low insulation and rapidly getting worse.

" By 4 p.m. the last strip was removed from the test springs, revealing 590 separate circuits plugged out, 640 patrol dockets prepared and the faults segregated."

Ashburton manual exchange was also put out of action at 8.50 a.m. on the 4th by flood water which rose as high as the keyboard. Here the linemen found that the roads surrounding the exchange were flooded and that the only means of access to the exchange room was by wading waist-deep through the street, climbing a rope fastened to the first floor and thence down the stairs inside the premises. The prompt work of the linemen, who without waiting for instructions or considering damage to their clothing, etc., enabled much of the equipment to be saved before it was affected by the water, and the switchboard was renewed and service restored to the exchange by 10.15 p.m. the following day.

Great credit is due to the whole of the staff employed on the breakdown work throughout the District for their unstinted service following the storm : without this it would not have been possible to restore normal conditions by the 16th instant, by which time some 17,000 subscribers' faults had been located and cleared.

LANDING OF THE JERSEY-GUERNSEY-COMPASS COVE SUBMARINE CABLE AT DARTMOUTH

The District and Submarine staffs co-operated on August 8th, 1938, in landing a new cable laid between Jersey-Guernsey and the mainland.

The cable ship " Faraday " had previously steamed over the proposed sea route of the cable and buoyed the position where it was to be laid in the English Channel.

The ship commenced laying the cable from the Compass Cove end, the shore end of the cable being loaded into a large barge, hired locally, which was controlled by a local powerful motor launch, the cable ship being anchored approximately ½ mile from the shore.

When sufficient cable was paid out on to the barge to reach the shore, the motor launch towed the barge towards the cove and eight men on board passed the cable into the sea, the barge being brought to within 10 yards of the shore. Fortunately the sea was very calm and this enabled the hauling line on the end of the cable to be thrown ashore, these operations being carried out by the cable ship staff.

The Department's staff then co-operated and took ashore the remaining cable from the barge which was laid on the beach in large bights. Originally it had been arranged that four drag horses should be used to haul the cable up the cliff side with a party of ten Department's men, but after an exhaustive search of the country side

it was found impossible to obtain the necessary horses due to harvesting, so that arrangements had to be made to manhandle the cable up the cliff side from the beach to the cable hut. The cliffs at this point rise steeply to a height of 140 ft. and it was impossible for men to stand on the cliff side without some means of support; a 3-in. rope was therefore made off around a stout telephone pole at the rear of the cable hut on top of the cliff and laid down the face of the cliff to the beach; along this rope at distances of 10 feet, lengths of No. 12 sash line were fastened and these lengths provided a safety line for each man handling the cable up the cliff side, the men making the sash line fast around their bodies as shown in the photograph. This method was found to be satisfactory in spite of the considerable weight of the cable and at no time during the operations were the men in danger. In addition, two sets of tackle and blocks were rigged up to another 3-inch rope, made fast around the cable hut, one at the top of the cliff and the other half way down to take the weight of the cable, in case it exceeded the handling strength of the men employed, and especially if it was found necessary to take up a bight of surplus cable above the cable hut. Actually 170 yards of surplus cable was brought ashore and to handle this additional amount up the cliff it would have been necessary to use the two sets of tackle. Twenty-two Department's men were required to take the cable up the cliff face, an operation which was completed in approximately 30 minutes.

The new cable was laid as far apart as possible from the two existing cables and was brought into the cable hut in a different position.

After the cable was made fast four sets of straps were fitted to the cliff face by means of expanding bolts and the cable on the rock concreted over to protect it from the sun, the remaining length being buried in the shore. A Warsop breaker was used to cut a groove in the rock.

North Wales

ERECTING KIOSKS WITH THE CRANE LORRY

Several trials of erecting telephone kiosks on site by a crane lorry have been carried out in this District, and the results are promising. The kiosks are built up at Headquarters Section Stock or other convenient place and painted. After about a week to allow the paint to get thoroughly hard each kiosk is taken direct to site by the lorry and, as shown in the photograph, dropped by the crane direct on to the prepared base. On connection of the leading-in wires the kiosk is ready for public service.

Four kiosks have been installed within a radius of 8 miles, and brought into service in one day by one working party.

FIRE DAMAGE TO COAXIAL CABLE

On August 2nd, the Department's 9-way duct and cables at Great Hampton Street, Birmingham, were severely damaged by a "burn-out" caused by the failure of the 400 volt, 3 phase mains.

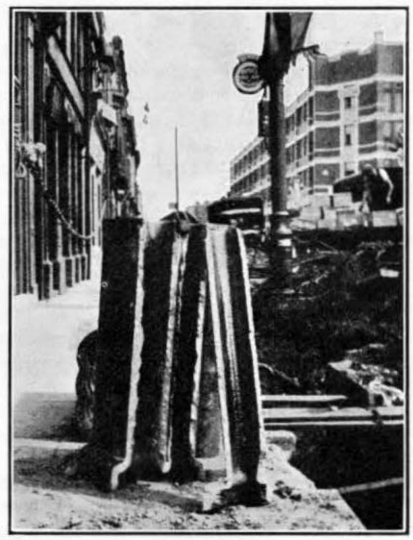


FIG. 1.—THE SPLIT 9-WAY DUCT.

The 9-wayduct was reduced to a molten massand some of the cables completely destroyed over a length of approximately 10 yards and damaged over a length of 25 yards. The cables concerned were as follows:—

Birmingham-Manchester Coaxial	
Birmingham-Liverpool	352/25+4/40
Birmingham-Wolverhampton No. 1	100/40
Birmingham-Wolverhampton No. 2	160/40
Birmingham-Wolverhampton No. 3	254/40
Birmingham-Walsall No. 2	160/40
Local Cable (in bore)	50/100
Local Cable (in bore)	3/40+17/10
Birmingham-Manchester	122/Composite
Birmingham-Walsall No. 1	100/40

The two last-mentioned cables sustained damage to the sheath only, the cores being unaffected.

The replacement of duct and cable was completed on August 6th.

Two of the cables were not out of service and it was decided not to interfere with these until the other cables had been restored. These two cables could not be diverted and it was decided to split open two ways of the 9-way duct (Fig. 1), fit these on to the cables and patch the duct with the piece split off. This was successfully accomplished (Fig. 2).

FIG. 2.—COMPLETION OF REPAIRS TO DUCT.

FIG. 1.—HAULING THE CABLE TO THE HEADLAND.

NEVIN-HOWTH (1938) CABLE

An additional link with Ireland has been made possible by the laying of the 1938 Nevin-Howth Cable, which is a duplicate of a similar cable provided last year.

Nevin lies at the entrance to the Menai Straits. Nevin has been for many years a very important point from a telegraphic aspect and it contains a telegraph repeater station linked with submarine cables entering the sea at Abergeirch cable hut, about 1½ miles distant. The repeater station is a museum of telegraph history, and its inevitable disappearance, owing to the recent rapid developments in the technique of communications, must be a matter of more than regret to the specialists by whom it has been staffed, day and night. The Department has provided at Nevin a modern building which is now being equipped as a multi-channel repeater station, and it is to this that the new cables, which are of the coaxial type, are being connected. Pending the completion of the new station, the 1937 cable has been terminated in a battery hut in the forecourt of the premises, being extended from that point by a very ordinary, but highly important pair of aerial wires, to Bangor, where carrier equipment provides four channels forming London and Liverpool—Dublin trunks. It is understood that ultimately the two cables will provide sixteen 4-wire circuits to Dublin, and that these will include an eighteen channel VF telegraph circuit.

The new cable was manufactured and laid by Messrs. Submarine Cables, Ltd., and the cable ship Faraday was chartered for the laying of the under-sea portion, 52·78 nautical miles. The ship arrived at Abergeirch on Monday, 25th July, and programmed to land the shore end on the following morning. Horses were hired from a local farm, and in a very short time a rope of suitable size was hauled (Fig. 1) from the ship to a headland near to the cable hut. Members of the staff who were privileged to be spectators of the operations formed the opinion that the cable would follow as quickly, but the ship veered round under the influences of wind and tide and there was an anxious period for those responsible, as the cable, after being hauled part of the distance, had now passed underneath the ship, and the possibility of damage was feared. This danger was averted, but it was deemed inadvisable to proceed further that day. On Wednesday, July 27th, the cable was brought to a point near to low water mark, sufficient to reach the cable hut, being coiled on a raft (Fig. 2), but by this time the tide was so low that the raft could not be drawn sufficiently close to shore to permit of the cable being landed without serious risk of damage by rocks. A gale now sprang up, and the ship had to be put to sea, carrying with it the landing staff. Ultimately the end was brought into the cable hut, successfully, on the evening of Friday, July 29th, from which time the cable was under electrical observation by the contractors' testing staff throughout the laying operations, the final splice, midway between Nevin and Howth, being made at 6.15 p.m. on August 4th. Then began a period of one month during which the contractors will make daily tests of the cable.

The North Wales District staff have had no small part to play in the operations, since, in addition to the usual assistance in landing operations requested by contractors it was necessary, at very short notice, to provide an entirely separate duct line and trench for the new cable throughout the distance of nearly 1½ miles between Nevin and the Abergeirch cable hut. The necessity for this was the very exacting conditions for the prevention of cross-talk between the 1937 and 1938 cables. Efforts to place this work to contract at short notice were unsuccessful, but the local staff rose to the occasion and the job was completed in a fortnight, thus avoiding delay to the major operations.

The cable consists of a central copper conductor, surrounded by about ½ inch of an insulating material known as "paragutta." This is followed by a thin layer of ozokerite tape on which six copper tapes are wound side by side. Next is a very thin layer of copper tape wound in such a way as to serve as a protection against

FIG. 2.—LANDING THE CABLE FROM THE RAFT.

teredo worms, and finally a layer of fabric tape. Up to this point the land and sea portions of the cable are alike and it has been considered of such importance to maintain continuity of the electrical characteristics that the advantage of having terminations in the cable hut to serve as a localising point between the land and sea sections has been sacrificed, and straight through joints have been made. For the submarine portion, after a serving of tarred yarn, the cable is armoured by 12 No. 2 S.W.G. iron wires, or more precisely, 11 No. 2 S.W.G. and one equivalent cable of three smaller wires. This is to serve for the ready identification of the particular cable, obviously a matter of some importance. The shore end of the cable has a lead sheath over the copper tapes. This is for the purpose of keeping light and air from the paragutta insulation. For the land section, the lead sheath is "protected" from corrosion by rubber-wax covering, and the whole is steel tape armoured except for about ½ mile where it is drawn into ducts.

The following figures have been quoted by the Contractors :—

Length	62·78	nautical miles (in sea)
	1·195	nautical miles (land)
	63·975	nautical miles

D.C. resistance at sea temperature 55 deg., 2·26 ohms per nautical mile

Capacitance, ·200 μF per nautical mile

Insulation Resistance 75,000 megohms per nautical mile

Weight

Centre conductor	508 lbs. per nautical mile
Paragutta	690 lbs. per nautical mile
Copper tapes	852 lbs. per nautical mile
Complete cable (wet)	9·6 tons per nautical mile
(Shore end)	11 tons per nautical mile
Overall diameter	1·7 in. per nautical mile
(Shore end)	1·8 in. per nautical mile

Singing point,

0.3 kc.p.s. to 16 kc.p.s. over 54 db.

16 kc.p.s. to 70 kc.p.s. over 42 db.

Attenuation (at 50 kc.p.s.), 0·951 db. per nautical mile

It may be of interest to note that tests on the 1937 cable following the cutting out of terminations at Abergeirch hut revealed that the insulation resistance had fallen to 30,000 ohms instead of the normal figure of over 1,000 ***megohms*** but no difficulty in working the circuits was reported. The fault was measured, by Varley Test, on August 18th, 1938, and indicated as being some 43 nautical miles at sea from Nevin. Pending the clearing of this fault the circuits have been changed over to the new cable. Under normal working conditions, in the event of a breakdown of either of the two cables, a change-over scheme will provide seven 4-wire circuits (including the VF telegraph circuit) on the remaining good cable.

Scottish Region

CONVERSION OF GLASGOW AREA

The conversion of the Glasgow telephone area to director working is now well under way. The smaller exchanges and the relief exchanges in the outlying sectors are under construction and it is anticipated that seven of these exchanges will be working under auto conditions by the end of this year. All these exchanges are being installed by the A.T. & E. Co. and though delay has unfortunately taken place in every case these exchanges are now showing signs of early completion.

Milngavie and Shettleston, with 526 and 794 working lines respectively were transferred to auto on August 15th, 1938, and are functioning satisfactorily.

A miniature tandem for miscellaneous services has also been brought into service and is housed in the existing Central manual exchange, which also houses the temporary auto-manual exchange for the initial ten auto exchanges.

The temporary tandem was installed by the G.E.C. and is primarily used for TIM, ENG. and the 999 service.

The G.E.C. have also commenced installation of the two M.D.Fs. in Telephone House, which will house two auto units together with the joint trunk and the auto-manual board.

RAILWAY TUNNEL CROSSING, GLASGOW

One of the difficulties in laying down duct routes to the new Telephone House and adjacent repeater station, Glasgow, in connection with the auto conversion programme and extension of long-distance equipment, has been that of getting a line of 32 pipes across Argyle Street, one of Glasgow's busiest thoroughfares. This street, which carries a double track electric tramway system running east and west of the city, is supported over the London, Midland and Scottish low-level railway on which a steam-operated service runs.

The carriageway is supported on "H" girders spaced laterally at about 7 ft. 6 in. centres and connected by brick jack arches, a layer of asphalt covering the whole. Above the asphalt is a layer of soil, then concrete and normal granite sets. The tops of the "H" girders supporting the carriageway are 15 inches from the carriageway surface and therefore the pipes could not be placed clear of the tunnel.

The problem was discussed with the L.M.S. engineers who produced plans of the tunnel, or covered way as it is termed, which was constructed by open cut method about 50 years ago. The plan showed that when the tunnel was built a bay was provided to the requirements of the Corporation Gas Department and it was hoped that arrangements could be made to gain access to this bay, but from later enquiries it was ascertained that any available space was required for renewal purposes.

Tunnelling below the railway and main sewer was out of the question, and, after discussion with the railway engineers, it was agreed that the pipes could be laid within one of the lateral jack arches, on bearers to be placed between the "H" girders, provided that no encroachment be made upon the normal tunnel clearance.

Pilot holes were taken out at each side of the tunnel to ascertain whether conditions were suitable for approaching the actual crossing point, and it was found that on both sides there were gravitation, gas and hydraulic mains. Further excavation on the north side exposed an 18-in. main which, fortunately, after some investigation proved to be derelict and on being cleared away provided a ready means of access.

The presence of the other services, which on account of lack of available space could not be diverted, meant that the Post Office pipes would have to rise under the mains on each side passing through the 7 ft. thick tunnel walls before entering the jack arch.

A further appeal was made to the railway engineers who appreciated the difficulties and agreed to the pipes encroaching within the loading gauge of the tunnel from one foot at each inside wall to zero at the outermost rail. This gave just sufficient space for the purpose, it being intended to lay as many pipes as the jack arch would accommodate (estimated at 32).

Asbestos cement pipes were considered particularly suitable for the work, but as difficulty arose regarding suitable bends it was later decided to lay steel pipes.

By arrangement with Messrs. Stewart & Lloyds, P.O. pipe contractors, the P.O. plans were scrutinised by

Fig. 1.—Laying the Last Pipe.

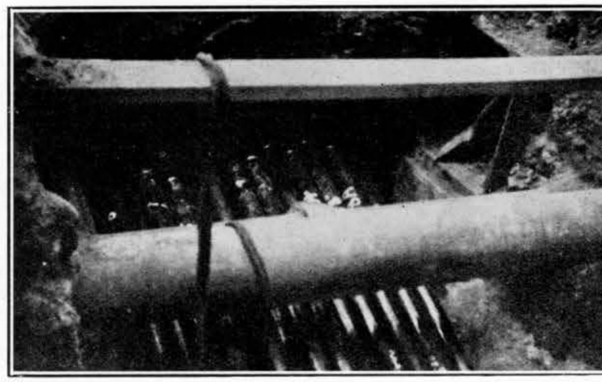


Fig. 2.—Pipes Finally in Position.

their draughtsman and sufficient data obtained to enable the pipes to be prepared and requisite bends made. In order to facilitate the laying of the pipes each section of pipe was coded before delivery and this precaution undoubtedly speeded up the work.

At midnight on Saturday, 16th April, the L.M.S. workmen erected the necessary scaffolding within the tunnel and proceeded to fit the bearers, while the P.O. workmen brought the steel pipes approximately 278 yards on to the ground, and, working in conjunction, the two parties had the pipes in position, the last two (Fig **1**) with considerable difficulty by 10 a.m. in time for the normal first train about 11 a.m. Fig **2** shows the pipes finally in position.

The pipes are placed on bearers 7 in. by 1 in. at about 3 ft. centres, each bearer being covered with thicknesses of felt to absorb vibration. The thickness of felt, which is used by the L.M.S. engineers for similar work, had to be reduced to $\frac{5}{8}$ in. on account of the limited space available.

On the underside of the bearers are bolted buffer plates in order to protect the pipes from engine blast. These buffer plates are let into the tunnel wall at either side, the whole being sealed as a protection against the normal deleterious effect of atmosphere which obtains in steam-operated underground railways. Further protection in view of the electric tramway system will be hessian tape protected cables in the tunnel section, with insulating gaps in the manholes, which have been built on each side of the tunnel.

Continuing on the north side of the tunnel towards Telephone House the Contractors exposed timbers which had been used when a main sewer was laid in Pitt Street over 40 years ago, the state of preservation of some of these timbers being remarkably good.

A.K

Book Reviews

" Radio Laboratory Handbook." M. G. Scroggie, B.Sc., A.M.I.E.E. 384 pp. 211 ill. Iliffe. 8s. 6d.

In this work the layout of a radio laboratory and the practical operation and design of the equipment are considered in some detail. A knowledge of fundamental principles is assumed, and the author states that the handbook is written both for the amateur and the professional radio engineer.

The first three chapters are concerned with the layout of a laboratory and with the principles of measurement, particular stress being laid on the interpretation of results. Sources of power supply and of audio and radio frequency signals, together with indicators, including the cathode-ray tube, are considered in Chapters 4 and 5, while the next four chapters describe the design, construction and measurement of components, such as resistors, capacitors and inductors. Measurements on complete sets, frequency characteristics, gain, harmonics and intermodulation are considered in Chapter 9, while Chapter 10 is concerned with ultra high frequency work. Methods of dealing with results are discussed in Chapter 11, and the last chapter contains a collection of information of particular interest to the radio engineer.

The handbook is based on the author's long experience in the radio laboratory, and although its scope is such that it is not possible to give complete and detailed information, it can be confidently recommended as a practical laboratory handbook. C. F. B.

" Dare You Speak in Public." Arthur Duxbury. 170 pp. English Universities Press, Ltd. 5s.

Mr. Arthur Duxbury is a lecturer and consultant in elocution and public speaking and, as those members of the Institution who heard him at a London Centre I.P.O.E.E. meeting can testify, is a very good exponent of his principles. In this book he explains some of the causes of bad speaking and gives advice on how to become an effective public speaker. This advice can be summarised into headings that would probably be accepted by most people as axioms, but it certainly stimulates thought on the problem as a whole. The author's main principle is that a good speech can result only if the speaker has sound knowledge of the subject and the confidence which is born of practice. He favours practice at home as an aid to delivery and makes it clear that an apparently spontaneous speech is probably, if successful, based on a knowledge of the subject acquired over a period of years. He also emphasises the necessity for constructing a speech on a logical basis and favours the use of notes except for short speeches.

The book is well worth the serious attention of all would-be speech makers. H. E. B.

Staff Changes

Promotions.

From S.E. to Asst. E.-in-C.

Name	District	Date
Gill, A. J.	E.-in-C.O.	1.7.38

From A.S.E. to S.E.

Name	District	Date
Legg, J.	E.-in-C.O.	10.9.38
Little, G. J. S.	E.-in-C.O. to N.W.	1.9.38
Mumford, A. H.	E.-in-C.O.	1.7.38

From Exec. Engr. to A.S.E.

Name	District	Date
Palmer, W. T.	N. Ire. to E.	3.10.38
Wylie, T. O. K.	E.-in-C.O.	10.9.38
McDonald, A. G.	Ldn. to E.-in-C.O.	22.8.38
Gray, H. C.	S. Midland	1.1.39
Williams, H.	E.-in-C.O.	1.9.38
Palmer, R. W.	E.-in-C.O.	1.1.39
Beer, H. G.	E.-in-C.O.	13.8.38

From Chief Insp. to Asst. Engr.

Name	District	Date
Walton, W. R.	N.E.R. to L.T.R.	28.8.38
McDougald, F. M.	N. Mid. to S. La.	28.8.38

From Chief Insp. to Chief Insp. with allowance.

Name	District	Date
Hill, C. H.	S. Lancs	23.6.38

From Insp. to Chief Insp.

Name	District	Date
Rudham, J. L.	L.T. Reg.	2.1.38
Harbage, H.	N. Midland	15.5.38
Porter, W. F.	L.P.R. to L.T.R.	To be fixed later
Tucker, D. G.	E.-in-C.O.	11.5.38
Redington, F. D.	E.-in-C.O.	12.4.38
Corke, R. L.	E.-in-C.O.	18.6.38
Benzies, A. C.	N. Ire. to N.W.	26.6.38
Thompson, G.	N. Western	5.6.38
Crane, L. H.	S. Lancs	15.7.38
Taylor, G. W.	N. Midland	15.7.38
Bydawell, P. J.	L.T. Reg.	1.7.38
Williams, J. E.	N. Ire. to S.W.	22.6.38
Atkinson, J.	E.-in-C.O. to S. Mid.	10.7.38
Easterbrook, A. B.	E.-in-C.O.	23.6.38
Patrick, F. H.	L.T. Reg.	1.8.38
Richards, A.	S. Wales	To be fixed later
Bartholomew, C. P.	L.T. Reg.	To be fixed later
Wiltshire, R. E.	S.Western	To be fixed later

From Chemist to Senr. Chemist

Name	District	Date
Linch, R.	T.S. B'm to T.S. Ldn.	1.9.38

From S.W.1 to Insp.

Name	District	Date
Gray, C.	Scot. Reg.	To be fixed later
Lickorish, H. J.	T.S. B'm	26.6.38
James, C. H.	T.S. B'm	8.5.38
Seach, E. G.	Eastern	20.6.38
Roberts, C. J.	Eastern	To be fixed later
Gresswell, F.	Eastern	14.7.38
Raby, P. C. A.	Eastern	20.7.38
Francis, R. S.	Eastern	17.7.38
Buck, S. E.	Eastern	To be fixed later
Harrington, J. A.	Eastern	24.7.38
Pyle, D. W.	Eastern	29.6.38
Wright, K. R.	Eastern	17.7.38
Dawson, F.	N.E. Reg.	10.4.38
Potts, J. R.	N.E. Reg.	5.6.38
Gill, J. S.	N.E. Reg.	1.4.38
Trotter, R.	N.E. Reg.	1.4.38
Ellis, D. W.	N.E. Reg.	1.4.38
Clarke, Z. C.	N.E. Reg.	21.5.38

From S.W.1 to Insp. (continued).

Name	District	Date
Davies, J. H.	N.E. Reg.	1.6.38
Atkinson, B. M.	N.E. Reg.	12.6.38
Hollely, H.	N.E. Reg.	1.4.38
Thomson, W. J. R.	N.E. Reg.	4.5.38
Smurthwaite, J.	N.E. Reg.	5.6.38
Ramsden, W. E.	N.E. Reg.	22.5.38
Odes, G. E.	E.-in-C.O.	14.9.37
Chinchen, H.	E.-in-C.O.	3.10.37
Mooney, B. H.	E.-in-C.O.	10.10.37
Wheldon, E. V.	E.-in-C.O.	10.10.37
Beattie, F.	E.-in-C.O.	3.10.37
Samson, G. S.	E.-in-C.O.	19.9.37
Hope, H. R.	E.-in-C.O.	24.10.37
Hill, H.	E.-in-C.O.	7.11.37
Bates, A. W.	E.-in-C.O.	18.7.38
Mitchell, M.	E.-in-C.O.	22.6.38
Ridd, J. M.	E.-in-C.O.	2.7.38
Thwaite, H.	E.-in-C.O.	8.6.38
Bradman, W. A. G.	E.-in-C.O.	1.5.38
Thurlow, H. J.	E.-in-C.O.	10.6.38
Renshaw, G. A.	N. Midland	9.4.38
Miles, J. V.	S.E. to E.-in-C.O.	7.5.38
Dickinson, R. B.	E.-in-C.O.	2.7.38
Brinkley, J. R.	E.-in-C.O.	2.7.38
Benson, T. A.	Scot. Reg.	To be fixed later
Forster, A. E. T.	E.-in-C.O.	To be fixed later
Hiscocks, W. I.	N. Ireland	2.5.38
Swanton, J. G.	N. Ireland	8.5.38
Kingston, F.	N.E. Reg.	11.6.38
Ball, C. W.	L.P. Reg.	19.2.38
Bryan, T. H.	L.P. Reg.	6.12.37
Garnham, J. R.	Eastern	1.10.37
Gletcher, E. A.	Eastern	1.10.37
Wilson, F. E.	Eastern	26.6.38
Abbott, S. E.	Eastern	4.7.38
Ashwell, J. W. G.	L.P. Reg.	3.7.38
Waterhouse, W. H.	E.-in-C.O.	2.7.38
Pendrey, S. J.	T.S. B'm to E.-in-C.O.	16.7.38
Edleston, E. T.	N. Western	5.6.38
Belcher, O. G. J.	E.-in-C.O.	2.5.38
McClure, J.	N. Ireland	19.6.38
Bradley, E. A.	N. Ireland	21.8.38
Long, M. C.	S. Western	13.8.38
Jenner, J. W.	T.S. B'm to T.S. Ldn.	To be fixed later
Collins, F. L.	T.S. B'm to T.S. Ldn.	To be fixed later
Nisbet, T. H.	Scot. Reg.	20.6.38
Hunter, A. S.	Scot. Reg.	12.8.38
McIntosh, A.	Scot. Reg.	19.7.38
Morrison, G.	Scot. Reg.	2.8.38
Park, W. D.	Scot. Reg.	15.7.38
McGhee, A. B.	Scot. Reg.	12.8.38
Kelcher, B.	Scot. Reg.	14.8.38
Wonson, J. F.	E.-in-C.O.	28.8.38

From S.W.II to Insp.

Name	District	Date
Turner, W.	N. Mid. to E.-in-C.O.	7.5.38
Benford, H.	N. Mid. to E.-in-C.O.	11.6.38

From U.S.W. to Insp.

Name	District	Date
McLusky, R. F.	E.-in-C.O.	30.8.38

From Draughtsman Cl. II to Insp.

Name	District	Date
Norman, R. H.	Eastern	To be fixed later

From S.W.II to Cable Foreman.

Name	District	Date
Rosbrook, J. M.	Woolwich Depot	1.5.38

Transfers.

Name	District	Date	Name	District	Date
Exec. Engr.			*Chief Insp. (continued)*		
Beach, W. R.	.. Personnel Dept. to Scot. Reg.	3.7.38	Bridges, J. T.	.. S.E. to E.-in-C.O.	5.6.38
Jones, C. E. P.	.. E. to E.-in-C.O.	31.7.38	*Inspector*		
			Jones, V. H. ..	.. Colney R.S. to Cupar R.S.	28.8.38
Chief Insp.			Mullard, R. T. S.	.. Ldn. to E.-in-C.O.	22.5.38
Howarth, H. ..	.. N.E.R. to N.W.	1.4.38	Gallagher, P.	.. E.-in-C.O. to N. Ireland ..	17.7.38
Johnstone, W. S.	.. Cupar to E.-in-C.O. ..	1.9.38	Kelly, T. S. ..	.. E.-in-C.O. to S.E.	4.9.38

Retirements.

Name	District	Date	Name	District	Date
Asst. E.-in-C.			*Chief Inspr.*		
Anson, B. O..	.. —	30.6.38	Gallard, G. N.	.. L.T. Reg.	31.5.38
			Dunstan, H. J.	.. L.T. Reg.	30.6.38
S. Engrs.			Jermy, B. J. ..	.. N.E. Reg.	7.8.38
Powell, W. H.	.. E.-in-C.O.	31.7.38	Fisher, G. E. ..	.. N. Ireland	31.8.38
Wood, P. T. ..	.. S. Western	30.6.38			
Exec. Engr.			*Senr. Chemist*		
Stevenson, B. J.	.. E.-in-C.O.	6.7.38	Jupp, J. ..	.. Test Secn. Ldn.	31.8.38
Robinson, R. T.	.. E.-in-C.O.	31.7.38	*Inspector*		
Neate, E. P. ..	.. L.T. Reg.	30.6.38	Coe, W. J. ..	.. Eastern	31.12.37
			Simmonds, A. S.	.. L.T. Reg.	31.5.38
Asst. Engr.			Ellenden, T. H.	.. L.T. Reg.	26.5.38
Dring, J. ..	.. S. Wales	31.5.38	Huckfield, T. H.	.. N. Wales	25.7.38
Sadler, H. ..	.. E.-in-C.O.	30.6.38	Hargrave, A.	.. S. Lancs	30.6.38
Lewis, T. ..	.. L.T. Reg.	31.7.38	Stearn, J. ..	.. Eastern	19.6.38
Adams, W. J.	.. T.S. B'm	31.8.38	Goodall, R. ..	.. S. Lancs	23.7.38
Prickett, W. ..	.. E.-in-C.O.	31.8.38	Betts, H. C. ..	.. E.-in-C.O.	1.8.38

Deaths

Name	District	Date	Name	District	Date
Inspector			*Inspector—(continued)*		
Miller, G. M. ..	.. Scot. Reg.	21.5.38	Kinroy, J. W.	.. N.E. Reg.	28.8.38

Appointments.

Name	District	Date	Name	District	Date
To P.A.E. (Limited Comp., May, 1938).			*(Open Comp., May, 1938).*		
Tucker, D. G.	.. E.-in-C.O.	1.9.38	Bellairs, G. F.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Revell, H. J. ..	.. Scot. Reg.	1.9.38	Triffitt, L. A..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Scowen, F. ..	.. E.-in-C.O.	1.9.38	Duerdoth, W. T.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Humphries, W. A.	.. E.-in-C.O.	1.9.38	Stoneman, F. W.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Balchin, D. B.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38	Hayward, R. K.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Wass, C. A. A.	.. E.-in-C.O.	1.9.38	Rattue, P. J. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Watt-Carter, D. E.	.. L.T. Reg.	1.9.38	Crow, D. A. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Easterbrook, A. B.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38	Swaffield, J. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Horner, G. H.	.. L.T. Reg.	1.9.38	Morris, D. W.	.. E.-in-C.O.	1.9.38
Rossiter, G. E.	.. Eastern	1.9.38	Copping, G. P.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Billen, J. C. ..	.. S. Wales	1.9.38	Ferris, J. H. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Renshaw, G. A.	.. E.-in-C.O.	1.9.38	Loosemore, E. S.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Pugh, S. E. ..	.. S. Eastern	1.9.38	Forty, A. J. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Harris, E. T. C.	.. E.-in-C.O.	1.9.38	*To Proby. Insp. (Open and Limited Comps., March, 1938).*		
Burr, D. W. ..	.. N. Midland	1.9.38			
Adams, W. E.	.. N. Western	1.9.38	Adkins, J. E...	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Wells, H. M. ..	.. S. Eastern	1.9.38	Arnott, H. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Collins, J. E. ..	.. N.E. Reg.	1.9.38	Aspinall, E. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Macpherson, A.	.. E.-in-C.O.	1.9.38	Axe, G. A. ..	.. E.-in-C.O. (Trg. Sch.) ..	5.9.38
Lunn, G. R. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38	Balaam, N. B.	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38
Lovegrove, L. W.	.. S. Midland	1.9.38	Baker, L. M. ..	.. E.-in-C.O. (Trg. Sch.) ..	1.9.38

Appointments—*continued.*

Name	District	Date
To Proby. Insp. (Open and Limited Comps., March, 1938). *(continued).*		
Barker, A. J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Barnes, F. G.	E.-in-C.O. (Trg. Sch.)	1.9.38
Barralet, A. F.	E.-in-C.O. (Trg. Sch.)	1.9.38
Berge, M.	E.-in-C.O. (Trg. Sch.)	1.9.38
Burton, A.	E.-in-C.O. (Trg. Sch.)	1.9.38
Carberry, J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Chappell, A. J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Cook, D. T.	E.-in-C.O. (Trg. Sch.)	1.9.38
Cook, S. V.	E.-in-C.O. (Trg. Sch.)	1.9.38
Cridlan, D. E.	E.-in-C.O. (Trg. Sch.)	1.9.38
Curry, W. R.	E.-in-C.O. (Trg. Sch.)	1.9.38
Davies, W. M.	E.-in-C.O. (Trg. Sch.)	1.9.38
Dickinson, L. W.	E.-in-C.O. (Trg. Sch.)	1.9.38
Dowsing, D. R. F.	E.-in-C.O. (Trg. Sch.)	1.9.38
Edge, J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Edwards, H. C.	E.-in-C.O. (Trg. Sch.)	1.9.38
Evans, J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Faulkner, G. B.	E.-in-C.O. (Trg. Sch.)	1.9.38
Feldwick, D. A.	E.-in-C.O. (Trg. Sch.)	1.9.38
Finnamore, A. J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Gandon, N.	E.-in-C.O. (Trg. Sch.)	1.9.38
Gates, J. F.	E.-in-C.O. (Trg. Sch.)	1.9.38
Glover, A. G.	E.-in-C.O. (Trg. Sch.)	1.9.38
Hales, A. C.	E.-in-C.O. (Trg. Sch.)	1.9.38
Harbord, C.	E.-in-C.O. (Trg. Sch.)	1.9.38
Harrison, M.	E.-in-C.O. (Trg. Sch.)	1.9.38
Hesketh, J. F.	E.-in-C.O. (Trg. Sch.)	1.9.38
Humber, A. J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Jeffery, D. A.	E.-in-C.O. (Trg. Sch.)	1.9.38
Jelliffe, C. A.	E.-in-C.O. (Trg. Sch.)	1.9.38
Jones, J. R.	E.-in-C.O. (Trg. Sch.)	1.9.38
Lawrence, T.	E.-in-C.O. (Trg. Sch.)	1.9.38
Lewis, R. C. G.	E.-in-C.O. (Trg. Sch.)	1.9.38
Lewis, T. A.	E.-in-C.O. (Trg. Sch.)	1.9.38
Manaton, R. P. C.	E.-in-C.O. (Trg. Sch.)	1.9.38
Marsh, R. V. R.	E.-in-C.O. (Trg. Sch.)	1.9.38
McKane, J. C.	E.-in-C.O. (Trg. Sch.)	1.9.38
Mockeridge, F. R.	E.-in-C.O. (Trg. Sch.)	1.9.38
Munt, E. F.	E.-in-C.O. (Trg. Sch.)	1.9.38
Partridge, J. G.	E.-in-C.O. (Trg. Sch.)	1.9.38
Pritchett, J.	E.-in-C.O. (Trg. Sch.)	1.9.38
Radcliffe, G. K.	E.-in-C.O. (Trg. Sch.)	1.9.38
Rawlinson, W. A.	E.-in-C.O. (Trg. Sch.)	1.9.38
Ross, J. M.	E.-in-C.O. (Trg. Sch.)	5.9.38
Rudge, M. S.	E.-in-C.O. (Trg. Sch.)	1.9.38
Seamans, K. R.	E.-in-C.O. (Trg. Sch.)	1.9.38
Slater, T. G. W.	E.-in-C.O. (Trg. Sch.)	1.9.38
Slough, H. R.	E.-in-C.O. (Trg. Sch.)	1.9.38
Smith, C.	E.-in-C.O. (Trg. Sch.)	1.9.38
Smith, C. E.	E.-in-C.O. (Trg. Sch.)	1.9.38
Sollick, F. R. G.	E.-in-C.O. (Trg. Sch.)	1.9.38
Sparkes, G.	E.-in-C.O. (Trg. Sch.)	5.9.38
Spurlock, K. E.	E.-in-C.O. (Trg. Sch.)	1.9.38
Stamp, R. G.	E.-in-C.O. (Trg. Sch.)	1.9.38
Thomson, W. E.	E.-in-C.O. (Trg. Sch.)	1.9.38
Tones, C. K.	E.-in-C.O. (Trg. Sch.)	1.9.38
Truslove, E. H.	E.-in-C.O. (Trg. Sch.)	1.9.38
Warren, A. R.	E.-in-C.O. (Trg. Sch.)	1.9.38
Williams, M. B.	E.-in-C.O. (Trg. Sch.)	1.9.38
Yates, A. W. J. J.	E.-in-C.O. (Trg. Sch.)	1.9.38

Communications

All Communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone : NATional 6321. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Cases for binding are available, and may be obtained from the Local Agents for 1s. 9d. Subscribers can have their copies of Volumes bound, at a cost of 3s., by sending the complete sets of parts to the Local Agents or to the *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering will be the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the Journal, which is published quarterly, is 1s. (1s. 3d. post free) per copy, or 5s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. each (1s. 3d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

T.M.C. HOLLINGSWORTH WORKS WEST DULWICH, S.E.21

M.C. CARRIER TELEPHONY & TELEGRAPHY EQUIPMENT

We are manufacturers of both Single and Multi-channel Carrier Telephony and Telegraphy Systems.

Apparatus is now in course of manufacture at our works for the supply of such equipment to the Posts and Telegraph Department of India and the Commonwealth of Australia.

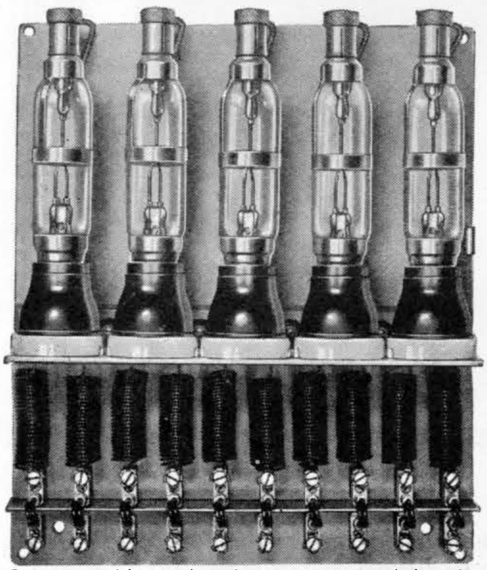
Our Engineering Department and Laboratories are at your disposal for the solving of any transmission problems.

Enquiries should be addressed to :—

TELEPHONE MANUFACTURING CO. LTD.,
Transmission Dept.,
Hollingsworth Works, Martell Road,
West Dulwich, S.E.21

EDISWAN

TELEPHONE LINE PROTECTOR PANELS



5-circuit panel for overhead lines incorporating choke coils, spark gaps, etc.

EDISWAN-SHOTTER-GREETHAM PATENT (British Patent No. 353924)

for the protection of telephone systems against surges induced by faults on neighbouring power lines

Of the difficulties attendant upon the employment of overhead systems one of the most serious is to ensure uninterrupted working of the telephone system, by providing adequate protection against induced surges caused by switching or line faults in adjacent power lines or by lightning.

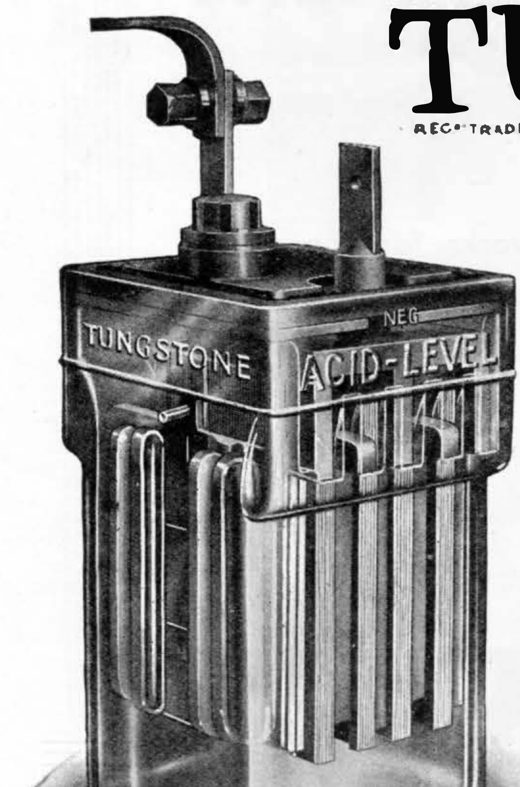
The Ediswan Patent Protectors provide the solution. They are inert at the normal working pressure of the telephone line, they keep the voltage on the line down to a pre-determined figure by providing a path of low resistance to earth whereby the surge is cleared and they again become inert immediately the surge is cleared.

They ensure simultaneous discharge of both lines and are capable of clearing heavy discharges without detriment to the system or the protector.

Ediswan Telephone Line Protectors have now been in use by Supply Companies for many years.

THE EDISON SWAN ELECTRIC CO. LTD., 155 CHARING CROSS ROAD, LONDON, W.C.2

T.E.I.



TUNGSTONE

REGD TRADE MARK PATENTED

BATTERIES

Are being regularly supplied to the

GENERAL POST OFFICE

MUNICIPAL CORPORATIONS

INTERNAL TELEPHONE SYSTEM MANUFACTURERS, etc.

- Open or Enclosed types in Glass Containers.
- Large Capacities in Lead Lined Teak Boxes.
- **TUNGSTONE** High-pressure Die-cast Plates conform to British Standard Specification.
- **British Empire Lead exclusively used.**

TUNGSTONE ACCUMULATOR CO., LTD.,
SALISBURY SQUARE, LONDON, E.C.4
Works: MARKET HARBOROUGH, LEICS.

AUTHORITATIVE CORRESPONDENCE TRAINING

for

ENGINEERING QUALIFICATIONS

- **POST OFFICE EXAMINATIONS —**
  Probationary Inspectors
  Assistant Superintendents
  Assistant Engineers
- **A.M.Inst.C.E., A.M.I.E.E., A.F.R.Ae.S., B.Sc.(Eng.), C. & G., etc.**

17 FIRST PLACES

and HUNDREDS of PASSES have been gained by T.I.G.B. students in the above examinations. The T.I.G.B. Guarantees training until Successful for the one fee.

Write to-day for " The Engineer's Guide to Success " — Free — which alone gives the Regulations for Engineering Qualifications and contains the world's widest choice of engineering courses — over 200 —including **Electrical Engineering, Telephony, Telephonic Transmission, Telegraphy, Radio Engineering, Wireless and High Frequency Engineering, Sound Reproduction, Television,** etc. Mention branch, post or qualification that interests you.

THE TECHNOLOGICAL INSTITUTE OF GREAT BRITAIN

115 Temple Bar House, London, E.C.4

FOUNDED 1917 *20,000 SUCCESSES*

Fit "TripleX" Regd and be safe

THE

G.P.O.

DO

THE "TRIPLEX" SAFETY GLASS CO. LTD.,
1 ALBEMARLE STREET · LONDON · W.1

Everyone in the telephone field depends on

TELEPHONY

for NEWS and TECHNICAL DATA

The telephone industry to-day is international; and it requires a magazine o international scope to interest telephone people. TELEPHONY answers the need. We invite you to join the thousands of readers throughout the world who are getting complete, timely and vital news, also technical data from the editorial and advertising pages of TELEPHONY each week.

TELEPHONY

Address : Odhams Press, Ltd., Technical Book Dept., 85 Long Acre, London, W.C.2 (Telephone : Temple Bar 2468) for a sample copy of TELEPHONY, or write direct to :

TELEPHONY PUBLISHING CORPN.
608 S. Dearborn Street, Chicago, Ill., U.S.A.

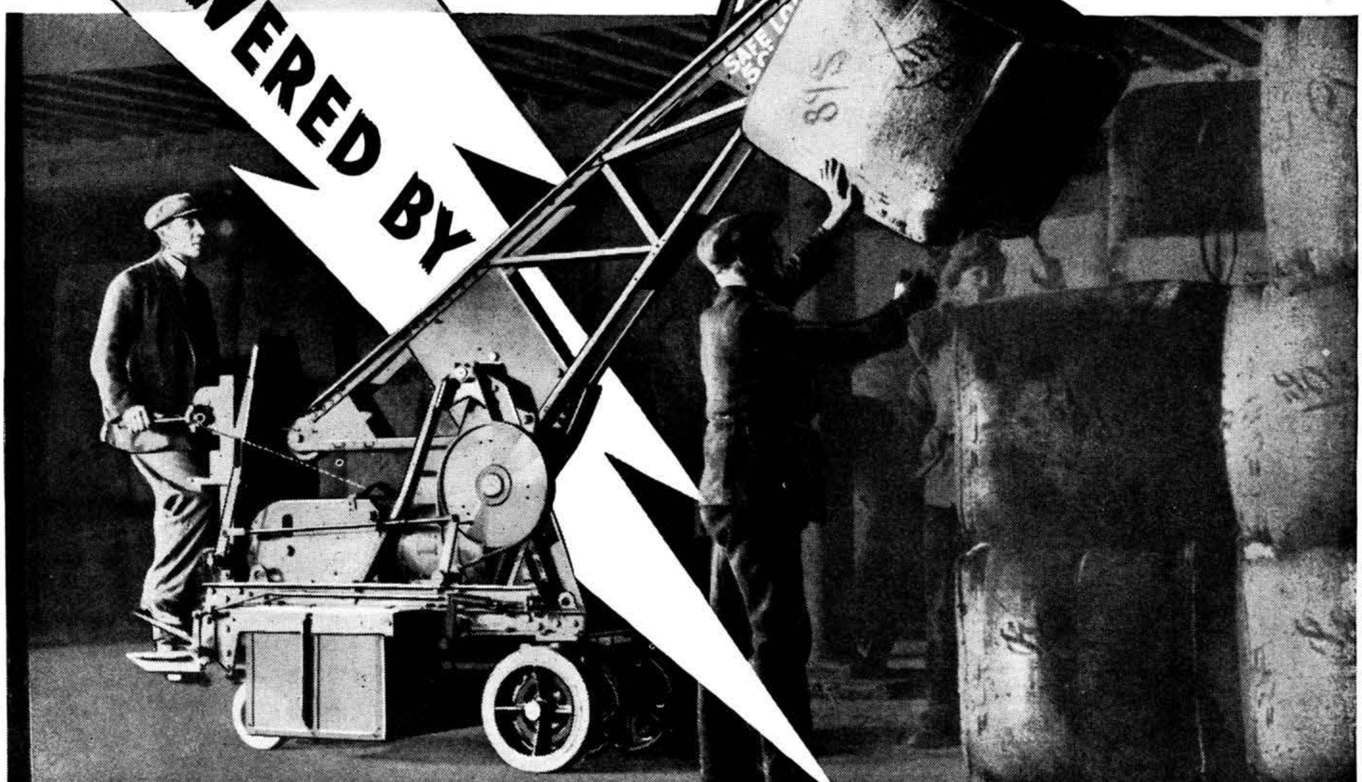
Power from Exide-Ironclad speeds up material-handling

'ELECTRICS' POWERED BY

YOU SAVE time, save trouble *and* save money when you install Exide-Ironclad Batteries. The reason?—because Exide-Ironclads have more vitality, and never lose their drive. They do tremendously hard work year after year without loss of power. That's why Exide-Ironclads are such a dependable aid to smooth production. And, moreover, they have very long life in relation to price—they *reduce* maintenance cost.

And don't forget that Exide-Ironclads are made by Chloride—the biggest battery makers in the British Empire, with experts stationed all over the country to give free service to Exide-Ironclad users.

EITr56b

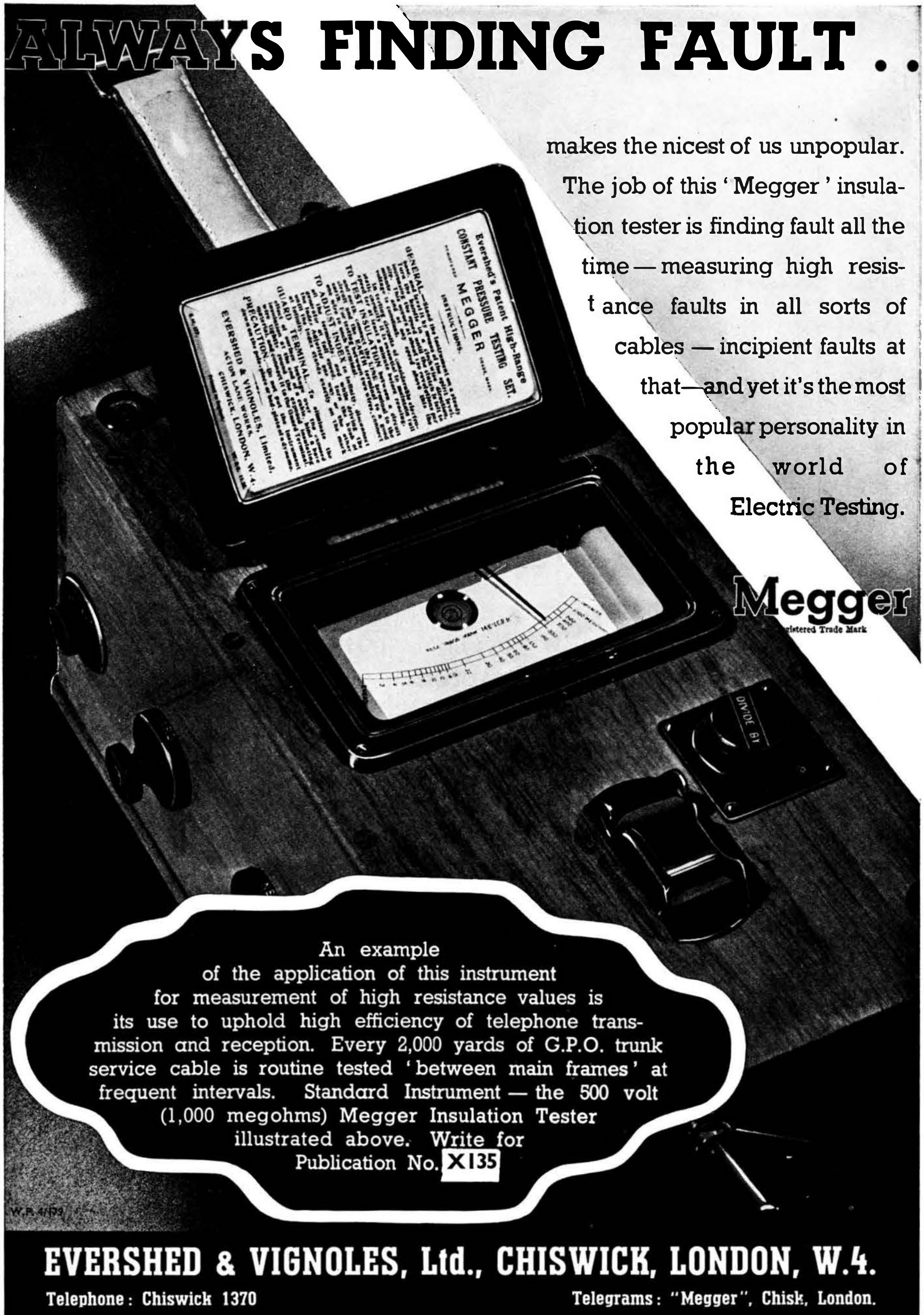


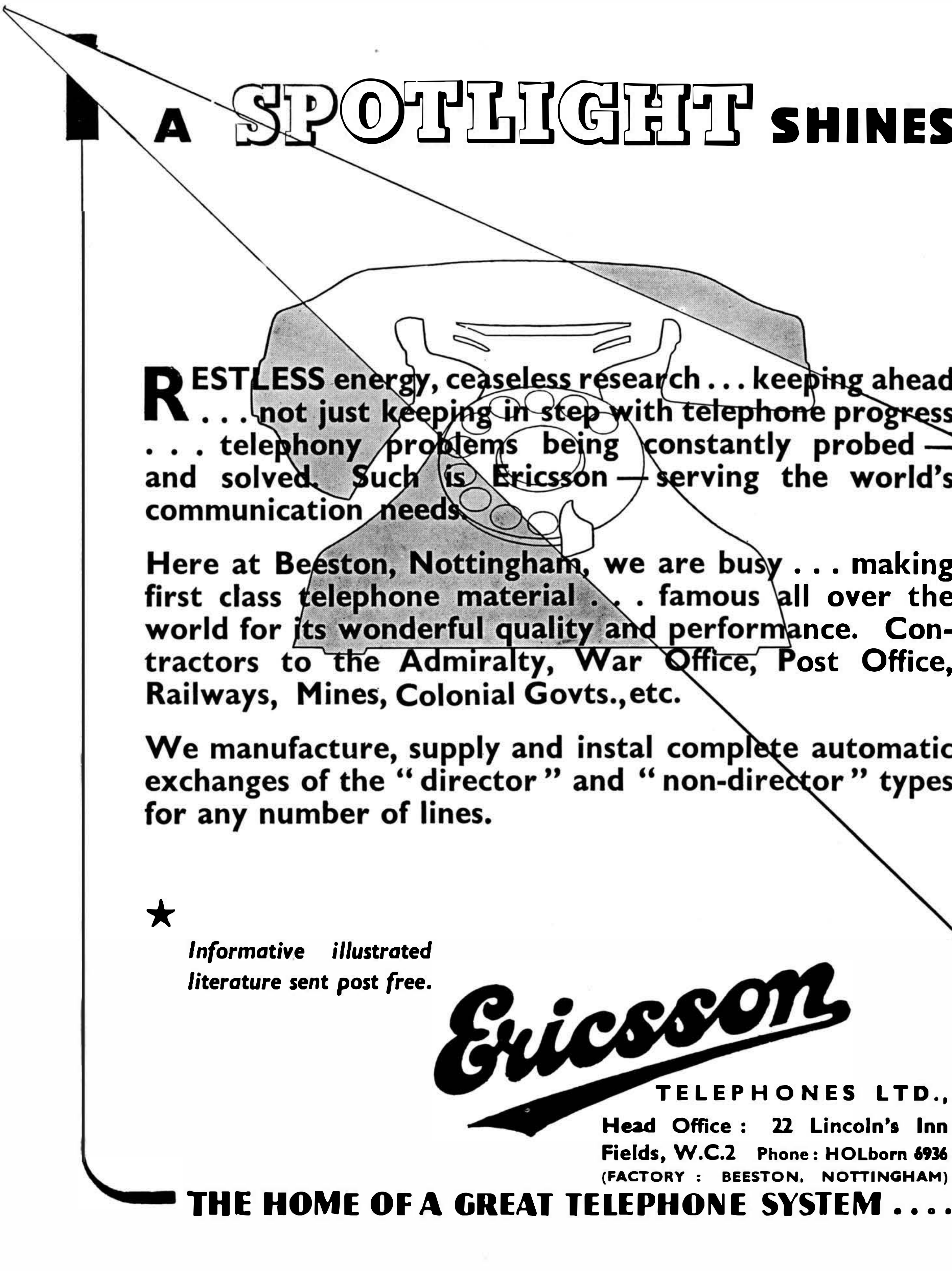
Bale Stacking with a B.E.V. Truck

Exide-Ironclad BATTERIES

RELIED ON BY 600 BRITISH FIRMS IN 50 INDUSTRIES

● *If you want further details about electric vehicles please write to* The Chloride Electrical Storage Co. Ltd., Battery Traction Dept., Exide Works, Clifton Junction, near Manchester, or 137 Victoria Street, London, S.W.1


ALWAYS FINDING FAULT . .
makes the nicest of us unpopular. The job of this 'Megger' insulation tester is finding fault all the time — measuring high resistance faults in all sorts of cables — incipient faults at that—and yet it's the most popular personality in the world of Electric Testing.
Megger
Registered Trade Mark
An example of the application of this instrument for measurement of high resistance values is its use to uphold high efficiency of telephone transmission and reception. Every 2,000 yards of G.P.O. trunk service cable is routine tested 'between main frames' at frequent intervals. Standard Instrument — the 500 volt (1,000 megohms) Megger Insulation Tester illustrated above. Write for Publication No. X135
EVERSHED & VIGNOLES, Ltd., CHISWICK, LONDON, W.4.
Telephone: Chiswick 1370
Telegrams: "Megger", Chisk, London.


A SPOTLIGHT SHINES
RESTLESS energy, ceaseless research . . . keeping ahead . . . not just keeping in step with telephone progress . . . telephony problems being constantly probed — and solved. Such is Ericsson — serving the world's communication needs.
Here at Beeston, Nottingham, we are busy . . . making first class telephone material . . . famous all over the world for its wonderful quality and performance. Contractors to the Admiralty, War Office, Post Office, Railways, Mines, Colonial Govts., etc.
We manufacture, supply and instal complete automatic exchanges of the "director" and "non-director" types for any number of lines.
★
Informative illustrated literature sent post free.
Ericsson
TELEPHONES LTD.,
Head Office: 22 Lincoln's Inn Fields, W.C.2 Phone: HOLborn 6936
(FACTORY: BEESTON, NOTTINGHAM)
THE HOME OF A GREAT TELEPHONE SYSTEM . . . .

ON *Ericsson* PROGRESS . . . . .

2. *Testing the hardness of materials.*

INDEX TO ADVERTISERS

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

PRINTED PAPERS

The following papers contributed to the proceedings of the Institution have been printed by authority of the Council and may be obtained, if still in print, from

"THE LIBRARIAN, The Institution of Post Office Electrical Engineers, G.P.O. (ALDER HOUSE), LONDON. E.C.I."

The prices do *not* include postage, and in every case, Members, Associate Members, and Associates have the privilege of purchasing copies at two-thirds the stated price.

No. 149	"RECENT DEVELOPMENTS IN UNDERGROUND CONSTRUCTION, LAYING AND LOADING ARMOURED CABLES."—J. E. Z. Bryden, B.Sc.(Eng.), A.M.I.E.E., and T. Hargreaves, A.M.I.E.E. 1933	1s.
No. 150	"TELEPRINTERS."—E. S. Ritter, M.I.E.E. 1933	1s.
No. 151	"RECENT REPEATER STATION INSTALLATIONS."—Major F. E. A. Manning, M.C., B.Sc.(Eng.), M.I.E.E., A.M.I.Mech.E. 1933	1s.
No. 152	"SOME NOTES ON EXCHANGE EQUIPMENT FACTORY COSTING AND THE ECONOMICS OF PRODUCTION."—S. J. Husband, Assoc.I.E.E. 1933	1s. 3d.
No. 153	"MODERN DEVELOPMENTS IN TELEPHONE TRANSMISSION OVER LINES."—J. Stratton, A.C.G.F.C., and W. G. Luxton. 1933	1s. 3d.
No. 154	"THE TELEGRAPH POLE."—W. H. Brent, B.Sc., A.M.I.E.E. 1933	1s.
No. 156	"MODERN TENDENCIES IN THE SUPPLY OF POWER TO TELEPHONE EXCHANGES."—H. C. Jones, B.Sc.(Eng.). 1935	9d.
No. 158	"ULTRA SHORT WAVE RADIO TELEPHONE CIRCUITS."—D. A. Thorn, B.Sc.(Eng.), A.M.I.E.E., and H. T. Mitchell, A.M.I.E.E. 1935	1s.
No. 159	"MODERN ELECTRIC PASSENGER LIFTS."—R. S. Phillips, A.M.I.E.E. 1935	9d.
No. 161	"MODERN TELEPHONE REPEATER STATION POWER PLANT."—F. W. G. Dye. 1936	6d.
No. 162	"VOICE FREQUENCY SIGNALLING ON TRUNK CIRCUITS."—T. H. Flowers, B.Sc., A.M.I.E.E., and B. M. Hadfield, B.Sc., A.M.I.E.E. 1937	1s.
No. 163	"AUTOMATIC EXCHANGE DESIGN."—H. E. Francis. 1936	1s. 3d.

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co. [Epsom], Ltd.*), Epsom, Surrey.