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Magnetic Dust Cores

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Following a general discussion of the magnetic properties obtainable by various degrees of subdivision of core material (e.g. into laminations, wire or particles), the author reviews the various methods employed for the manufacture of dust cores and gives examples of the uses to which such cores may be put.

IN the early days of electrical engineering, the necessity for the subdivision of magnetic cores carrying alternating magnetic flux was soon apparent from practical considerations alone. Even at a frequency of 50 c/s, the eddy current losses induced by the flux in the magnetic core, acting as an electrical conductor, were sufficient to cause considerable heat and loss of efficiency; but there was a simple remedy, the building up of the magnetic cores in the form of stampings insulated from each other in one direction at right angles to the flux. It was also found that eddy current losses could be reduced by increasing the electrical resistance of the magnetic metal from which the stampings were made and these were for many years the only two practical methods of realising the possibilities of magnetic cores for the numerous potential uses in the telephone and radio frequency ranges.

During recent years, however, the technique of making magnetic cores from fine magnetic powder or dust has completely altered the position, and the numerous advantages of ferro-magnetic cores are now being extensively applied for a great variety of purposes up to the higher radio frequencies, using the basic principles that are commonplace for electrical machine and equipment design at power frequencies. The considerable time taken in achieving this progress is due more to the technical and engineering problems involved, than lack of appreciation of requirements or to the assumption that air was the only suitable medium for magnetic flux generated by frequencies in the telecommunications range. Thus, over 60 years ago, Heaviside proposed a magnetic core made from iron filings set in wax, but with present knowledge such an arrangement is basically unsound, because the permeability of the "core" would be very little different from that of air.

Requirements.

Modern dust cores are made from highest grade magnetic materials and give very low total losses at the working range of frequencies, so that the "goodness factor" or Q ($=\omega L/R$) of a dust cored inductance can be made, if properly designed, to the same order of value from 50 c/s to 50 Mc/s. To cover this wide frequency range a number of core types are required, and a number of permeability grades of core material, the intrinsic permeability values varying from 12 for the highest frequency, and 120 for the lowest frequency.

But for all these numerous requirements, the principles underlying the construction of the dust cores are the same, and may be summarised into three separate stages of manufacture :—

(1) The magnetic metal or alloy is produced in a finely powdered form with suitable size, magnetic, electrical and physical properties.
(2) This powder is insulated by coating the particles with a tenacious layer of insulating material.
(3) The insulated powder is pressed at high pressures into moulds under conditions which retain the insulation properties of the coated particles even though considerable distortion of particle shape may take place.

The finished product must conform to a number of practical requirements which are universal in the telecommunication field :—

(*a*) Adequate mechanical strength to withstand handling in coil winding departments and test rooms.
(*b*) Stability under varying conditions of temperature, atmosphere, and for indefinitely long periods of time.
(*c*) Constancy of electrical properties under extreme conditions of electric or magnetic fields.

The satisfactory solution of these problems has been the result of very extensive research and development work in many directions; chemistry, metallurgy (in its general and specialised forms of powder metallurgy), microscopy, as well as magnetism and the widespread technology of electrical testing. The extent of the problem is evident from the wide range of patent literature covering all the above aspects of the subject.

Methods of Core Division.

Before considering the properties of modern magnetic dust cores, it is useful to consider critically the various methods of subdividing a solid magnetic core and the effect on the magnetic and electric circuits. For this analysis consider ring-shaped specimens (commonly known as "toroids"), such as are used for standardising purposes, giving a symmetrical magnetic field without appreciable leakage flux. There are three main planes of subdivision (Fig. **1**) which can conveniently be termed

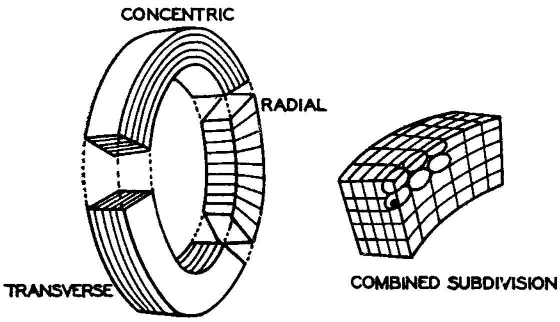


FIG. **1**.—METHODS OF SUB-DIVIDING MAGNETIC CORES.

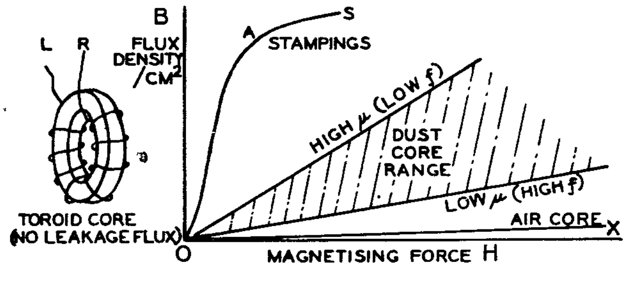
radial, concentric and transverse, the first being at right angles to, and the second and third parallel in two different planes to the direction of the magnetic flux. Either transverse or concentric subdivision has the effect of greatly reducing the eddy current losses by insulating the individual laminations with an insulating layer which, if suitably thin, will not appreciably reduce the flux-carrying capacity of the core. In other words, the permeability and magnetic characteristics are practically the same under low frequency A.C. conditions as would apply to direct current testing. Transverse laminations are commonplace for all 50 c/s machinery and equipment, and need no further comment. The concentric type can only be achieved in practice by winding a spiral of insulated magnetic tape, which results in the introduction of a continuous non-magnetic gap, but of low reluctance, into the magnetic path, reducing the effective permeability of the core but increasing the magnetic stability without distorting the flux. The next step in subdivision is the combination of spiral and transverse methods which results in a spiral of insulated magnetic wire; this results in a further decrease in effective permeability and appreciable decrease in the space factor of magnetic material, hence a fairly stable but rather inefficient magnetic circuit. Finally, if the magnetic wire is chopped up into small pieces by the addition of a radial method of subdivision, the permeability is still further reduced, but the magnetic stability is thereby greatly improved.

The dust core is the practical version of the last combination of the three methods of subdivision and the magnetic characteristics can therefore be deduced from these considerations, together with the inherent properties of the magnetic metal itself.

To appreciate the extent of the subdivision it is necessary to realise that the eddy current loss is proportional to the square of the frequency. The present applications of cores for telephony cover one thousand times, and for radio one million times the normal power frequency of 50 c/s, so the extent of comparable subdivision must be 10^{-6} and 10^{-12} respectively for telephone and radio practice in comparison, for example, with ordinary 16 mil silicon iron stampings used for mains transformers. This shows clearly why very few of the alternative methods of subdivision, spiral, strip or wire, can be important in telecommunications applications. To indicate the extent to which this problem of subdivision has been solved, a typical plug core, as used in vast quantities in radio equipment, and with dimensions $\frac{3}{8}''$ diameter by $\frac{1}{2}''$ long, contains about one thousand million separate magnetic particles, each of which must be properly insulated from its neighbours, in order that the eddy current loss shall be limited to a reasonably low figure.

Magnetic Properties.

The reduction in permeability of the magnetic core by the introduction of innumerable small air gaps results in a very high magnetic stability, as will be seen from the diagram (Fig. **2**), and Table I



PERMEABILITY $\mu = \frac{B}{H}$ $\quad$ $Q = \frac{2\pi f L}{R}$ AT FREQUENCY f

FIG. **2**.—CORE TYPES—MAGNETIC PROPERTIES.

summarises the various advantages and disadvantages of stampings, air and dust cores, in so far as the magnetic properties are concerned, and apart from the reduction of eddy currents just described.

TABLE I

Type.	Advantages.	Disadvantages.
Stampings.	High permeability. Low copper loss.	μ varies continuously from 0 to saturation. Losses limited only at low f. Magnetically unstable saturates at medium H.
Air Core.	No hysteresis loss. No saturation.	Excessive copper loss. Unwieldy size for working Q values. High temperature coefficient.
Dust Core.	Controlled μ and losses over wide f. Constant μ for A.C. and combined D.C. High magnetic stability.	Upper limits to μ for adequate Q.

OAS represents a typical magnetising curve for a solid magnetic core. It is generally known that the permeability B/H varies considerably over every part of the curve and is indicated by the slope of the curve at any particular value of magnetising force H. OX is the magnetising curve of an air gap, that is to say, the permeability is constant at unity, and the hysteresis loss is zero. The shaded area represents the present range of dust cores, being the resultant of the curves for the solid metal and for the air gap, the actual permeability being dependent on the ratio of magnetic to non-magnetic material in the core. This can be varied over a wide range by using coarse powder and very little insulating material for high permeability cores, and fine powder with non-magnetic fillers, in addition to the insulating material, for low permeability cores.

The following points are of great importance :—

(1) The dust core permeability curves are close approximations to straight lines, and in this respect behave as air cores. This applies even at saturation values of H, which are, however, so great that the heat generated is in practice a limiting factor.

(2) The hysteresis loss is of the same order as that of the solid metal, but the shape will be that of an extremely elongated ellipse. Hence, the incremental permeability, or the permeability due to the simultaneous effect of A.C. and D.C. fluxes will be constant at approximately the same value as the core permeability. This is a vast improvement on all forms of stamping cores.

(3) By altering the " effective air-gap " of the dust core, i.e., by altering the amount of insulating and filling materials, the core permeability can be varied over a fair range with the same magnetic metal ; the advantages in (1) and (2) above apply to the whole range and the cores can all be made symmetrical magnetically, i.e. with virtually no leakage field.

In spite of the predominating role of the " effective air-gap " in deciding the permeability of the dust core, the intrinsic permeability of the magnetic metal is of considerable importance for high permeability cores when the thickness of insulation may be as small as a fraction of a micron (·001 mm).

Materials Available.

So far only the effect of subdivision of the dust core has been considered ; now the available magnetic metals and alloys available will be examined. The desirable properties of the solid metal for dust cores are :—

(*a*) High permeability.

(*b*) Low hysteresis loss, especially for cores in telephone circuits and where high flux density occurs.

(*c*) High specific resistance, which limits eddy current and enables lower degree of subdivision to be utilised. This is of special importance at radio frequencies where hysteresis loss is normally of small importance.

Iron is, of course, the most common and universal magnetic metal, and this has been widely used for all types of dust core. The disadvantage of iron is that the permeability and the specific resistance are low and the hysteresis loss is high in comparison with modern alloys. Very pure and special types of iron, such as is made from iron carbonyl Fe_2C, give very low hysteresis losses and are available in very fine powder, which means that there is a considerable use for this type of material. The well known silicon iron alloys have been made in quantity in powder and dust cores, but their advantages over iron are small for these purposes, and the disadvantages in comparison with high grade alloy cores are very numerous.

There are very many different alloys which give remarkable magnetic properties, but for this analysis it is convenient to divide them into two groups, both widely used under a variety of names in sheet and stamping form : " high nickel alloys " containing over three-quarters nickel, and the remainder mostly iron ; and the " low nickel alloys " containing approximately equal quantities of nickel and iron. Both groups frequently have additions of other metals, which give, or are claimed to impart various advantages in regard to both hysteresis loss and resistivity, but the general properties of each group, with or without the additions, can be compared advantageously.

The "high nickel" group, in the form of stampings, gives permeability values between 10,000 and 100,000, many times greater than that of silicon iron ; the " low nickel " group gives much higher permeability in comparison with the iron group, but not so great as the high nickel alloys. Alloys of the second group have specific resistance values nearly 10 times that of iron and they are more economical of the comparatively expensive metal nickel. All the alloys in both groups are rustless, which is a considerable practical advantage. The disadvantage of all these nickel-iron series of alloys is that they are very sensitive to mechanical strain and must be subjected to critical heat treatments to yield their advantages, but methods of manufacturing powder and cores from these groups of alloy have now enabled the full advantages to be obtained.

Core Manufacture.

Proceeding now to consider the construction of the dust core, the first consideration is the magnetic dust istelf. All the magnetic materials briefly reviewed have the property of toughness rather than brittleness, and this factor greatly complicates their production in the form of fine powder. It may be thought that modern grinding machinery will mechanically reduce any metal in ingot or pellet form to fine powder, but this is not the case, unless the metal is melted together with an embrittling agent. However, there are a number of other methods which will enable metal or alloy powders to be made. Special machines have been developed which disintegrate such metals by melting them and blowing them in molten state into liquids. Other processes operate by drawing the materials into fine wire and then chopping up, subsequently projecting streams of the semi-disintegrated metal against each other or against metal plates. Chemical methods of reduction of pure compounds of the metals are widely used for producing a variety of magnetic powders and these yield great advantages in purity and fineness of the resulting product. A further process to chemical reduction of oxides is the production of the metal carbonyl in liquid form, which is subsequently volatilised and deposited in the form of tiny metallic spheres. The continuous electrolysis of metal compounds in solution can be adapted to yield fine spongy material that can be broken up by a milling process into fine powder. The last process was formerly used in the manufacture of iron dust cores for loading coils in America.

The problem of making magnetic powder is by no means limited to maximum size of particles. The shape, density, size distribution, physical and mechanical properties, must all be controlled to within close limits, and heat treatments are complicated by the fact that all metal powders tend to stick or sinter together even at temperatures far below the melting point. Considerable use is made of this phenomenon in the important new process of making metal parts out of powder, known as "powder metallurgy."

Before pressing the magnetic powder into dust cores, all the particles must be insulated with a tenacious coating which will withstand subsequent pressing and heat treatment processes. Compared with the Plastics Industry technique, the pressures are very high, being up to 20 tons/sq. in. for low permeability cores and up to 100 tons/sq. in. for the higher permeability types. The latter pressure intensity is well over the elastic limit of the metal, and the particles will therefore interlock into a solid mass without any binder whatever. The strains imposed in nickel iron cores are very considerable and they must be overcome by a high temperature annealing of the cores after pressing. The insulation film between the particles must be such that it does not break down either in the shearing action imposed during the pressing of the powder, or in the heat treatment of the core, and this presents one of the greatest problems in dust core manufacture and a limiting factor to the development of cores with still higher permeability values.

The finished cores are tested for permeability, losses, dimensions, mechanical strength and to ensure that toroids are magnetically symmetrical, and that there is no trace of external field. It is possible to keep dimensions to limits and a general tolerance for small cores is 5 thousandths/inch, by careful design of press tools and the close control of the insulating and finishing processes of the powder and cores. Different stages in the production of toroidal coils for loading coils and filters are illustrated in Fig. 3.

Applications.

The first practical application of dust cores on a large scale was by the Bell Telephone Laboratories in America in 1915 for the loading of underground cables. Iron powder made by an electrolytic method was insulated with shellac and pressed into thin ring cores with a permeability of 35. These cores superseded iron wire in the construction of loading coils, the wire giving insufficiently low loss at telephone frequencies and instability of inductance. Air cored toroidal cores had been used in some instances, but they were too unwieldy for most practical applications. Even the iron dust cored coils were of considerable size to give the required electrical performance, and the weight of a loading pot containing a number of these was of the order of one ton or more. Such pots are connected to the telephone cable at intervals of 2,000 yds., and thus the construction of manholes and the installation was a considerable undertaking. The work of Pupin in 1900 in specifying the requirements of the lumped inductance loading of telephone transmission lines is too well known to require a summary of it in this article, but it is sufficient to say that the inductance coils must be of such quality that they do not appreciably add to the effective resistance, capacitance or crosstalk of the circuits. Further advances in loading coil design were made by the introduction of nickel-iron alloys of the permalloy type, which resulted in cores with permeability values of over 100. This reduced the size of cores by about 70% for the same losses, and gave increased stability, lower self-capacitance, and lower crosstalk, and the higher cost and complication of core production was greatly offset by these extensive advantages. Thus, development starting in 1928, together with the improvements in the telephone repeater and cable construction, has enabled a considerable extension of dust core loading coils to the whole underground telephone cable network. During the last ten years, not only have all main trunk line audio cables

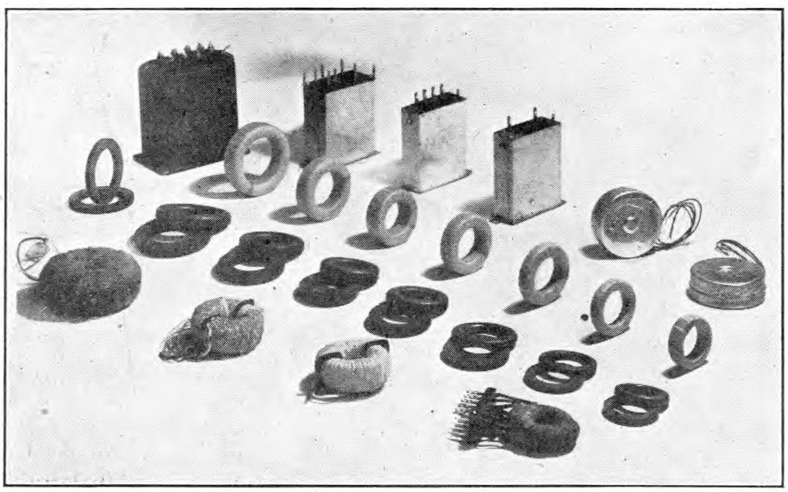


FIG. 3.—TOROIDAL CORES AND COILS FOR LOADING COILS AND TELEPHONE FILTERS.

been loaded with these new coils, but it was found that the performance and design of toll cables, and even junctions could be greatly improved by this means. To-day almost all audio communication in the underground telephone transmission system of the Post Office is by means of cables loaded with coils wound on alloy dust cores.

In 1930, carrier telephony, on underground cables was becoming a practical proposition and dust cores became an essential part of filter design. At that time it was considered that the upper limit of frequency for dust cores would be about 8 kc/s, but improvements in core design kept pace with the expansion of the carrier frequency band, from audio frequency up to 60 kc/s, with the introduction of the 12-channel system. For this, the use of coil loading was discontinued because it imposed an upper frequency limit to the transmission band and extra repeaters were used to overcome the attenuation. The same advantages which dust cores give to loading coils—low losses, zero leakage, low self-capacitance, compactness—are those required for the inductances and transformers for telephone exchange and repeater equipment.

The application of dust cores to radio equipment dates from twelve years ago, when Polydoroff published in America his work on what he called "permeability-tuning"—a method of tuning by altering the inductance of a coil by moving a core inside a solenoid and replacing the conventional variable air condenser with a fixed capacitance. About the same time Vogt in Germany developed a material known as "Ferrocart," which had very low losses at radio frequencies and this could be used for the construction of high Q coils with low leakage for all radio filters, transformers and chokes.

Ferrocart consisted of insulated iron powder coated on to bands of paper, which were then cut into fixed lengths and formed under hydraulic pressure into sheets; alternatively, the paper was wound on a spiral to make tubes and rods of magnetic material.

This material could be cut up or drilled in much the same way as ebonite, and so a large variety of shapes and sizes of magnetic core could be made up without difficulty. The intrinsic permeability (as measured by toroidal fieldless cores) was about 10, and Q values of 200 or more were attained at frequencies of 100 to 3,000 kc/s. This magnetic material showed great promise due to its good performance and working properties, but the advantages of technical performance were offset by a severe limitation of stability due to the wax incorporated in the material to bind the layers of coated paper together. Ferrocart became obsolete when new methods of moulding dust cores from insulated powder in automatic machines were introduced about 1935. These cores, which are similar in properties, performance and stability to the dust cores made for loading coils and carrier coils, are made in a great variety of sizes and shapes, and have found very extensive applications in all branches of radio equipment. Due to the lower pressures involved in the making of these small cores for radio frequencies, it is possible to manufacture them at comparatively high speeds in automatic presses, provided that the shapes are simple and regular. Composite cores can, however, readily be made by cementing several pressed pieces together.

Advantages of Dust Cores.

The advantages compared with air-cored coils can be briefly summarised:

(1) Higher Q for same size.
(2) Use of adjustable inductance (screw cores, brass insert cores, etc.).
(3) Variable inductance ("permeability tuning").
(4) Self screening to considerable extent (ironclad cores).
(5) Low or controllable temperature coefficient.
(6) Suppressor cores with heavy D.C. magnetisation, and appreciable temperature rise.

Radio cores have been used up to well over 50 Mc/s. with considerable success, and for these higher frequencies the open type magnetic circuit or plug cores (Fig. 4) is the type generally used. For the lower radio frequencies, however, the closed magnetic circuit core (Fig. 5) has considerable advantages, especially when the coil is wound on a low loss bobbin of polystyrene.

In considering the application of dust cores for any purpose, it is necessary to study the performance of

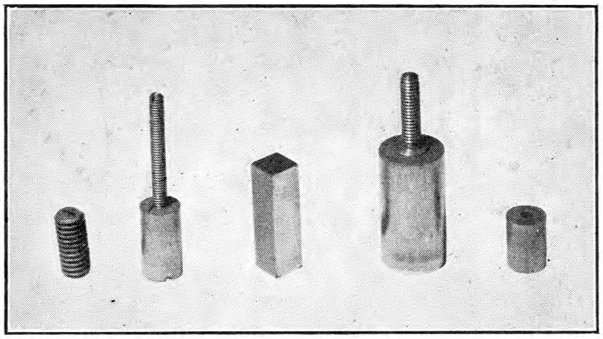


Fig. 4.—Plug Cores for Fixed and Adjustable Radio Inductances.

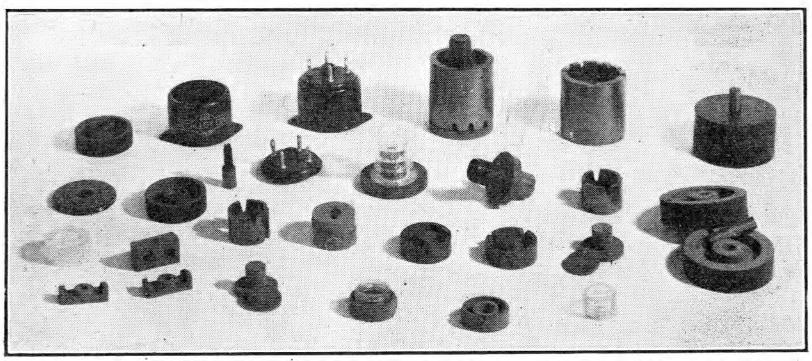


Fig. 5.—Typical Iron-Clad Dust Cores showing Construction.

the complete coil as a self-contained electrical unit. Equipment designers sometimes complain that they cannot obtain the performance of the dust cores claimed by the manufacturers, but the usual reason is that they have overlooked the fact that the core is one of many links in a chain of materials which affect the ultimate electrical performance. Thus, the core insulating material or bobbin must be of suitable loss material, and the wire must be stranded to a suitable degree in order to ensure that the eddy current loss in the copper wire is of the same order as the core losses. The screening case must be of correct dimensions and construction, and the impregnating compound must be of suitable dielectric and physical properties. It is possible to analyse these losses by testing a coil at a range of frequencies to give the eddy current factor at several current values, to give hysteresis loss and by extrapolation to zero frequency to obtain the "magnetic viscosity," a factor of considerable importance for low frequency applications. Hence, the full details of the core performance can be assessed by the core manufacturers with reasonable accuracy, and the ultimate performance of the completed coil should therefore be predictable and controlled within close limits.

The completed and sealed dust core coil will retain its inductance value to a small fraction of 1% for an indefinite period irrespective of any currents, A.C. or D.C., which may be applied continuously or suddenly.

Conclusion.

To summarise the type of core required for any particular application for any frequency band, a diagram has been drawn up (Fig. **6**), in which both the frequency and permeability are plotted on log scales, and thus the relative position and importance of both stamping cores and air cores can readily be appreciated. The Q values which can be obtained will, of course, depend on the size of core and details of the construction, so the diagram should be taken as a first approximation only. It will be seen that higher permeability toroid cores are predominant at the lower frequencies, and the open magnetic circuit cores of low permeability material are most important for higher radio frequencies. At medium and low radio frequencies, closed magnetic cores other than toroids, usually referred to as "ironclad," cores give the best results, and afford a considerable degree of screening without increase of loss, and within a small space. It is important to note, however, that there will always be more external field around an ironclad core than there would be in a similar shape and type of stamping core used at power frequencies, because in the latter the "air-flux" due to the coil without the magnetic core is generally negligible, but in all radio dust cores it is an appreciable proportion of the total flux.

Normally, for medium size cores, the space between the two curves in Fig. **6** denotes Q values of well over 100, which can be expected within a wide range of frequencies; for small frequency ranges the Q will be between 200 and 300, but the range can be extended and the Q increased by using larger cores and coils, especially at the lower frequencies.

For special purposes it is desirable to work outside the maximum Q range of any particular core. For instance, for very low hysteresis loss requirements, large low permeability cores are used; conversely, at radio frequencies long cylindrical cores of high permeability are sometimes used to give a wide inductance variation for "permeability tuning." In both these examples, the Q value is sacrificed in order to gain the alternative advantages, and this will apply in a variety of directions.

It will be seen from this short review of magnetic dust cores that there are considerable further possibilities in their applications to the many and varied purposes of electrical engineering.

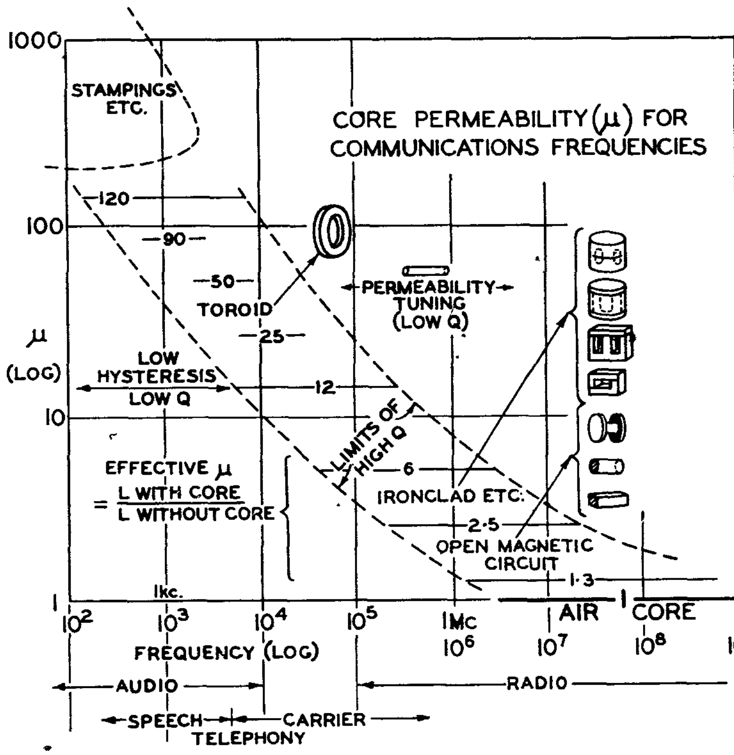


Fig. 6.—Core Permeability at Communication Frequencies.

The Development of a New Wheatstone Transmitter

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The author describes a modern version of the old Wheatstone transmitter. This incorporates a novel speed regulator with direct speed indication. The transmitting mechanism has also been redesigned to eliminate chatter at high speeds and facilitate adjustment. The transmitter operates over the range 13-250 words per minute.

Introduction.

A FEW years ago the author contemplated the design of a new Wheatstone telegraph transmitter and formulated one of the chief requirements as being that the instrument should run at an absolutely constant speed, irrespective of whether an A.C. or a D.C. motor were used, within a transmitting speed range with at least a 1 : 10 ratio without gear changes and without having to stop the motor to make governor adjustments for the various speeds required. It was thought by many at the time that this aim would be well nigh impossible of attainment.

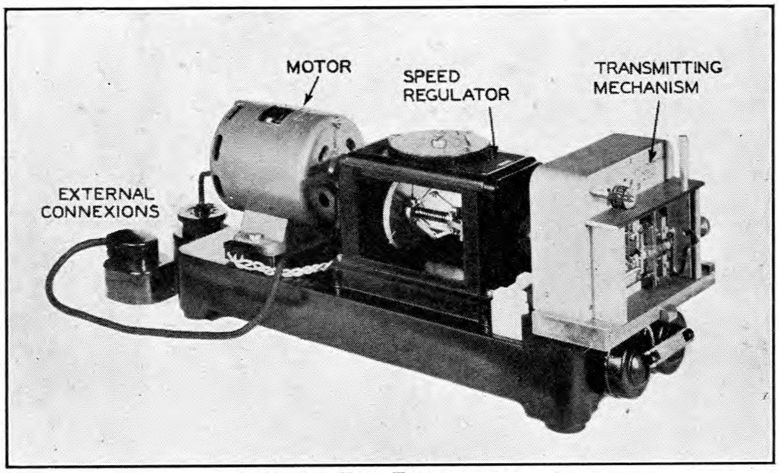


FIG. 1.—THE TRANSMITTER.

In the event, however, the Great Northern Telegraph Company's new Transmitter, Model 112, has proved to fulfil much more stringent requirements, namely :—

(1) A speed range of 13–250 words per minute (w.p.m.), i.e., a 1 : 19 ratio, without gear change.

(2) Governed speed at all settings. Variations are of the order of $\pm\frac{1}{2}$ per cent., and even large supply voltage variations have no effect on the constancy of the speed.

(3) Direct speed indication.

(4) Ability to return to the exact speed used previously after a temporary excursion to a different setting.

(5) Ease and simplicity of adjustment after contact cleaning.

In addition, the transmitter mechanism is provided with a contact arm which makes contact with a complete absence of rebound and which has a very short transit time, capable of being reduced to zero if required.

The transmitter (Fig. **1**) consists of three units, namely, the motor, the speed regulator and the transmitter mechanism, all mounted on the main base.

Speed Regulator.

Governor Mechanism.

The speed regulator is a slipping clutch governor comprising two governor sections. It was realised that according to known designs of governors with the simple Watt governor configuration, the speed range of a single governor could not be increased materially beyond a ratio of 1 : 4 or 1 : 5. The inspiration to combine two governor sections in one governor and thus obtain a range equal to the product of the ranges of the two sections was due to a printer's error in a catalogue which stated that the speed of a certain instrument was adjusted by governors. The fact that the word governor appeared in the plural at once gave the clue to the solution sought. Inspection of the instrument in question, however, revealed that it had, in fact, only a single governor to control its speed.

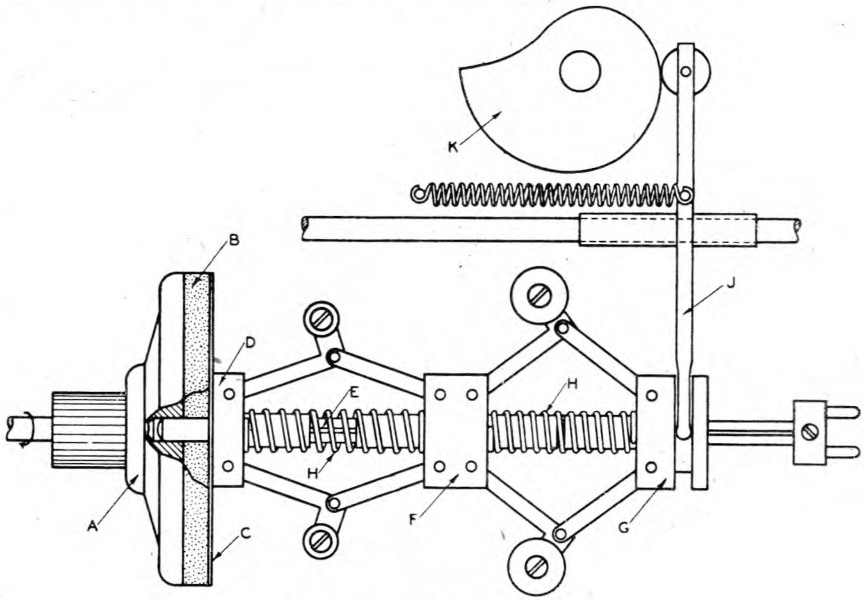


FIG. 2.—GOVERNOR MECHANISM.

A slipping clutch in a governor for telegraph instruments was first used in the Doignon governor, but in that case the range was extremely narrow. However, the extraordinarily good results obtained with that governor were to no small degree responsible for the adoption of the slipping clutch principle in the present design.

In Fig. **2** is shown an exploded view of the governor combination of the G.N.T. Co. transmitter. A driving disc A is driven through gearing by an electric motor. To this driving disc is fixed a cork ring B which makes frictional contact with a light friction disc C mounted on collar D of the revolving unit. . The governor spindle E has one bearing in the driving disc while the other end of this spindle has a bearing in part of the outer frame, not shown.

On the governor spindle are mounted, in addition to the friction disc collar D, the centre collar F and the control collar G. In the spindle is a groove, and in the control collar G a feather key, causing the spindle to rotate with the revolving unit. All the collars are free to move along the spindle. Between the three collars are two governor springs H.

In the control collar G is a groove into which fit the prongs of a forkshaped control bar J which is able to slide on a fixed spindle parallel with the governor spindle. A spring pulls the control bar towards the left until a roller on the bar stops against the speed setting cam K.

As the motor rotates, it will drive the governor unit at a speed determined by the position of cam K. In whatever position the control bar J is set, the friction between B and C will drive the centrifugal unit at such a speed that the centrifugal force acting on the governor masses due to rotation nearly balances the compression of the governor springs. The further the control bar J is allowed to move to the left by the cam K, the more will the governor springs have to be compressed before slipping takes place ; this entails a higher centrifugal force, i.e, a higher speed.

The two governor springs are similar, but the masses of the governor section nearest the control collar are about 16 times heavier than the masses of the other section. At low speeds the high speed section masses will hardly be deflected, the heavier masses alone performing the governing action. At a speed of about 2,000 r.p.m.—80 w.p.m.—the low speed section closes up, i.e., the control collar and the centre collar meet so that their further movement is prevented, and the high speed section alone takes charge over the remaining range of speed.

In the actual construction the governor spindle is supported in ball bearings and a deep groove ball bearing is also used to form the coupling between the control collar and the control bar in place of the groove and fork construction illustrated.

The governor configuration is, of course, identical with that used in the simple Watt governor, and it is interesting to note that although the centrifugal forces and the consequent reaction of the governor spring increase with speed, and at high speeds attain quite high values, this does not give rise to increased loads on any rotating bearings, as would have been the case had more modern governor configurations, such as that of the Hartnell governor, been employed in a similar manner, i.e., in conjunction with a slipping clutch.

Speed Indication.

To ensure that when operating the speed setting cam, any speed once selected can always be repeated quickly without special attention—a point of importance when working to automatic receivers (reperforators, etc.) which will always have the greatest margin for distortion when the speed is absolutely correct—the dial used to set the cam (see Fig. **3**)

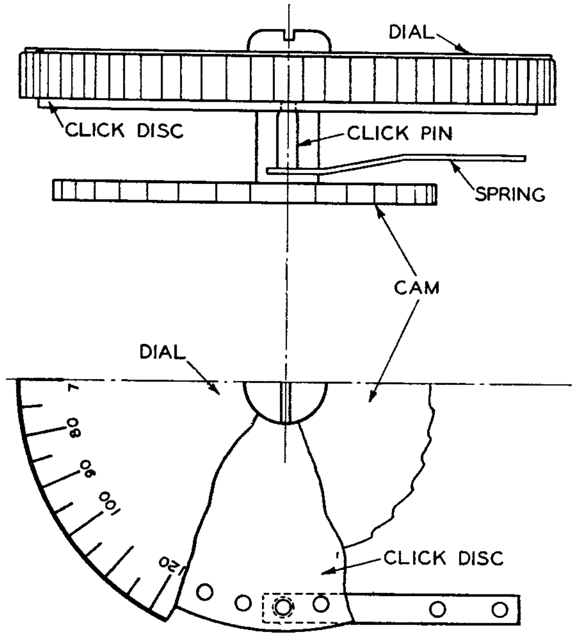


FIG. 3.—SPEED REGULATOR DIAL AND CAM.

registers with a click disc having a series of holes near the periphery which co-operate with a spring loaded locating pin : the settings are spaced 6°. As any chosen setting would be still more definite if the cam were not smooth, the cam is actually stepped with a number of steps corresponding to the number of speed selections given by the dial.

A logarithmic cam contour which would give a constant percentage speed variation per degree rotation of the cam would probably appeal from a purely logical point of view, and even if definite steps were employed an approach to such a scale might be attempted. Although a grading of the steps to accomplish this is possible, too many gradings would obviously be confusing, so it was decided to arrange the cam with steps of 1 w.p.m. between 13 and 30 w.p.m. and steps of 5 w.p.m. from 35 to 250 w.p.m.

In order that the actual speed shall correspond with the setting of the cam as given by the dial fixed to the cam spindle, a number of requirements must be fulfilled, namely :—

(1) The governor arm pivots must be accurately located, entailing high accuracy in the drilling of the holes in the governor arms and in the collars, accurate machining of the collars,

especially of the spring seating with respect to the pivot holes, and the length of the reduced portions of the centre and control collars must be correct with respect to the spring seatings.

(2) The cams must be accurately made, and so must the governor masses.

(3) The governor springs must be accurate as regards free length and compressive force per inch compression.

(4) With all the above requirements fulfilled, correct alignment of the friction disc C with respect to, say, the centre of the cam spindle must be ensured.

The requirements under (1) and (2) are fairly easily met by normal production methods. The production of a master cam certainly involves accurate measurements and machining, but once this has been produced, exact reproduction is not difficult.

The governor springs, mentioned under (3), created a problem, as it proved impossible to obtain springs accurate enough. The springs are, therefore, finally adjusted in the G.N.T. Co. works to their correct free length within $\pm$·0015 in. and to a compression ratio of 6·02—5.98 lb./in. Special gauging equipment was produced for this purpose.

The problem under (4) was solved by mounting the driving disc spindle in a bearing bush capable of adjustment axially. To provide a standard of reference, a reed is incorporated in the transmitter mechanism. This reed is operated by a small eccentric on the main spindle and arranged to resonate at 50 cycles per second, corresponding to 120 w.p.m. When adjusting, the speed dial is, therefore, set at 120 w.p.m. and axial adjustment made until maximum deflection of the reed is obtained. To render self-destruction of the reed impossible it is made inoperative automatically when the cover for the transmitter mechanism is put on.

Calibration of the reeds is carried out by comparison with a set of reeds, one being of standard tuning and the others differing slightly up and down from the standard. In this way, the observer will know instantly whether a reed under test requires to have its frequency raised or lowered.

Normally, a motor driven transmitter will run as long after the current is switched off as it takes the motor and other revolving masses to come to rest, but many telegraph operators object to having to pull the slip back for an unspecified length when resuming sending. In some designs, the guide roller for the slip is therefore lifted, thus disengaging the tape feed, when the motor is switched off, but in the G.N.T. Co. transmitter the desired result is achieved by disengaging a simple clutch between the speed regulator and the transmitter mechanism. This function is carried out by the switch coupling bar on the front of the base pushing back a clutch actuating bar, when the switches are put in the "off" position, thus decoupling the transmitter mechanism.

The Transmitter Mechanism.

The transmitter mechanism differs from the ordinary Wheatstone transmitter in that the rocking beam has been dispensed with and replaced by a twin eccentric, operating direct on the bellcranks, as suggested by Harrison,* and instead of the ordinary jockey roller construction magnetic bias adjustment is employed. The design is shown in Fig. **4.**

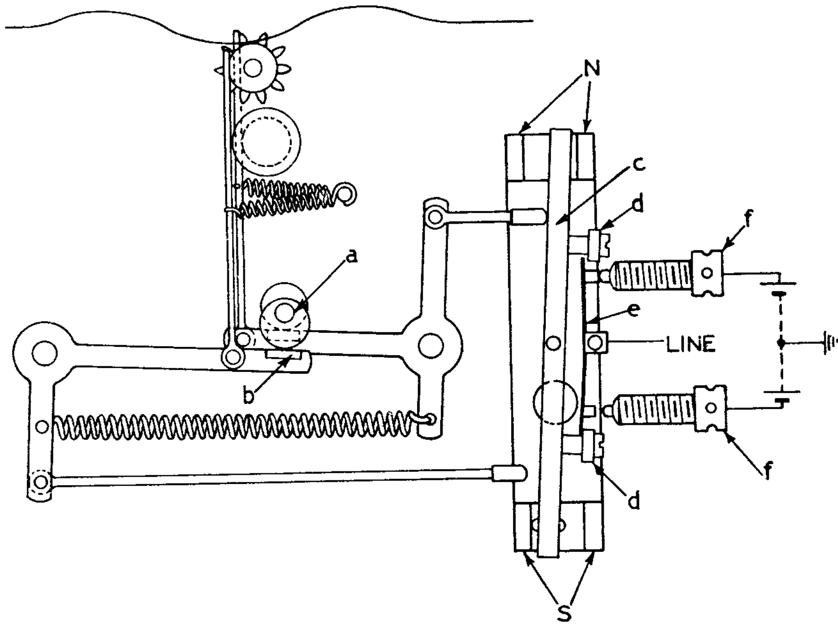


Fig. **4.**—Transmitter Mechanism.

The twin eccentric is shown at *a*. Sapphires, *b*, are fitted in the bellcranks to withstand wear. The push rods fitted to the bellcranks are able to throw the armature, *c*, against either of the two prongs of the lower pole, S, of the bias magnet, the north pole, N, of which is also bifurcated to accommodate the other end of the armature without this touching the prongs. The magnet is pivoted at a point away from its centre to allow of adjustment to the neutral position.

The armature carries two sapphires, *d*, which are fitted with screws having insulated distance sleeves. Behind each of these sapphires lie the ends of the contact spring, *e*. This spring is independently pivoted and carries two platinum-iridium contacts which connect with the contact screws *f*, each of which is wired to one side of a split battery, the contact spring being connected to line.

The pecker movement is somewhat larger than in the old Wheatstone transmitter, namely, 2·3 mm. against approximately 1·45 mm. This is mainly due to it not being possible to reduce the armature movement. No anxiety with respect to this

* *J.I.E.E.*, Vol. 68, No. 407, November, 1930, p. 1409.

elatively large movement was felt at the design stage, as the pecker movement in the G.N.T. Co's. old standard transmitter was already 2·3 mm. In practice it was found, however, that at high speeds the peckers had a tendency to pierce the paper of a continuous test band after it had been used relatively few times, and to overcome this, duralumin was used instead of brass for the bellcranks, resulting in a marked improvement.

Adjustment.

The construction renders contact making absolutely without chatter, but this entails a special adjustment. Whereas in the old transmitters it was considered sufficient for the pushrods to push the battery lever just past its centre position and leave the jockey roller or other bias arrangement to bring the lever the rest of its way towards a contact screw, it was found, when evolving the present design, that to avoid rebound, it was essential to let the pushrods follow the lever (armature) on the whole of its travels.

The design makes adjustment particularly simple. It will be realised that two adjustments are necessary, namely, (1) bias adjustment of the armature to obtain equal pressure in either deflected position, and (2) adjustment of the contact screws with respect to the contact spring. In the old Wheatstone design these two adjustments were combined in one adjustment which was, therefore, more difficult than in this case where the first adjustment need not be interfered with in normal routine.

The top half of each contact screw holder can be removed by unscrewing its clamping screw, and the contact spring bearing with the contact spring is also easily detachable.

Magnetic bias adjustment was first introduced by J. W. Willmot about 40–50 years ago. However, according to the experience of the G.N.T. Co. the adjustment was liable to deteriorate with time, so that if the transmitter was neutral when initially adjusted, it would no longer be so if put in circuit some days afterwards. This would appear to be due to the fact that in the Willmot design the leakage field producing attraction was reversed in the thin steel lever. In the present design the field is unidirectional and of the same magnitude in either deflected position of the armature. Advantage has of course, also been taken of the use of the present day superior permanent magnet alloys which were unknown half a century ago.

Design and Manufacture.

Very great attention was paid in the design stage to all parts of the instrument. The aim was to design each part to be as simple as possible. These efforts have resulted in a very considerable reduction in the production time required for the instrument.

The old Wheatstone transmitter presented many oddities from a modern point of view. For instance, the cover was made of three sliding panels and two sliding (or, one sliding and one fixed) corner pieces. In the present design the cover is simply a U-bent strip of brass which clicks into position. Also, the tape platform was in the old design made of brass with steel inserts in the trough for the guide roller, and at one end. The present design is steel all through, and in addition it is hard-chromium plated, so that it will withstand wear better than the old design. Many more instances of improvements could of course be quoted. Bakelite is used for several parts, including the main base and the speed regulator frame. The bakelite regulator frame is much more rigid than the fabricated brass sheet construction first used. Pressings are also employed where possible.

The final instrument is both light and compact, weighing 22 lb. and measuring $6\frac{3}{4}$ in. across its width. It is, in comparison, fairly deep, namely about 17 in., but it was realised that for the sake of economy in table length, a narrow instrument was more attractive than one which occupied a smaller area but was wider.

Production Testing.

The testing of the speed regulator is carried out stroboscopically against a standard tuning fork vibrating at 50 cycles per second. The speed regulator is fitted on the transmitter base while being tested and at the end of the twin eccentric spindle is fixed a stroboscopic disc with 24 equally spaced white dots, thus enabling the speed to be checked at 5 w.p.m. intervals. Each speed regulator is run in for a day before being tested.

The transmitter mechanisms are first adjusted to a definite routine in which spring pressures especially are laid down. In the beginning difficulty was experienced in adjusting the bias magnet for neutrality. Obviously, the deflecting force in either position of the armature must be the same. When measured with an ordinary spring gauge of the barrel type with a helical spring and a piston rod varying results were obtained due to unavoidable friction of the piston rod in the holes through which it projects from the barrel. A frictionless spring gauge based on the deflection of a flat spring was, therefore, developed. For the present purpose it covers up to 350 g. (approx. 12 ozs.) to either side of a centre zero, and two readings can be registered.

The transmitter with the speed regulator is tested in situ on its base by a cathode ray oscillograph. All speed settings are covered and observations are made for reversals, and dots and dashes alternating. Bias is checked on a meter and, especially at low speeds, by making marking and spacing half-reversals overlap on the oscillograph image. In addition, a trial slip of mixed signals is run at all speeds and recorded on an undulator (G.N.T. Co's Model 309). Difficult cases are further examined by means of a stroboscope, using the General Radio of America's "Strobotac" for this purpose. The oscillograph test also serves as a further check on the performance of the speed regulator.

A Brief Survey of Synthetic Alternatives to Natural Rubber

U.D.C. 678.7

D. W. GLOVER, M.Sc., F.I.C.

The author outlines the methods by which the primary components (or monomers) of the principal synthetic alternatives to natural rubber are produced and the results of polymerising these. The physical properties of the resulting products after compounding with sulphur, carbon black, etc., are also discussed.

Introduction

AT the present time a wide range of materials varying from cork to steel are rubber substitutes insofar as they are used for purposes which have in the past been fulfilled by soft or hard natural rubber. Although many of these such as bakelite are certainly synthetic they possess no obvious rubber-like properties, nor can they be applied to many of the purposes for which rubber has hitherto been used. It is therefore proposed to restrict this article to a description of those manufactured substances which are employed purely on account of their high elasticity and extensibility. For this class of materials as a whole the recent name "synthetic elastomers" is very convenient and descriptive, but even these must not be regarded as "synthetic rubber" because, strictly speaking, a synthetic material is one which has been built up from its constituent elements and is chemically and physically indistinguishable from its naturally occurring prototype. For example, synthetic methylsalicylate is identical with the main component of oil of wintergreen, but colloquially the term "synthetic" has acquired a very much wider meaning and is used incorrectly to describe any manufactured substance which can be used in place of a natural product regardless of even the most profound chemical dissimilarity between the two.

No truly synthetic rubber has yet been made in quantity owing to lack of any plentiful source of isoprene—a hydrocarbon which would be required in large quantities for the purpose, but synthetic bodies embodying many features of fundamental similarity to natural rubber are now widespread. The first of these to be used with some success commercially, called methyl rubber, was produced in Germany during the Great War, but under the influence of the subsequent self-sufficiency policies of that country and, also, Russia, it was soon superseded by a number of other materials possessing such novel characteristics that interest became aroused in America and to a less extent in Britain, though in the last two countries the main attention has been directed to improving upon specific properties of the natural product, rather than to replacing it for general purposes.

Prior to their fall in 1941 Malaya and the Dutch East Indies produced about 90 per cent. of the world's natural rubber, so that the importance of synthetic elastomers at the present time cannot be overemphasised, although the labour involved in their manufacture is stated to be much greater than that required to tend a rubber plantation of equal productivity.

Chemical and physical evidence indicates that natural rubber is a polymer of the relatively simple hydrocarbon isoprene, i.e. it consists of many hundreds of isoprene molecules united in a chain-like fashion and bound by certain cross linkages to similar parallel chains. The synthetic elastomers and synthetic resins are built up from various simple components in an essentially similar manner, but exhibit modified properties which are conditioned by the nature of the primary molecular units, the number of such units in the chains, and the number and positions of cross linkages between adjacent chains. There is a wide range of chemical compounds which, by reason of their constitution, might be expected to yield elastic bodies either on polymerisation alone or on copolymerisation of two or more kinds together, but, as only a dozen or so of these are available in large quantities the possible number of final products, though large, is correspondingly limited.

Of these primary units or monomers as they are called to distinguish them from the polymers which they form, the most important are butadiene, styrene, isobutylene, ethylene, acrylonitrile or vinyl cyanide, chloroprene, vinyl chloride, dichlorethane or ethylene dichloride and other fairly common chlorinated organic compounds.

Owing to the totalitarian urge in some countries, quite extraordinary ways of manufacturing some of these bodies have on occasion been attempted, but the following description of their main sources and more usual methods of preparation serves to indicate in a general manner the multiplicity of steps which may be involved.

PRIMARY MATERIALS

Butadiene: $CH_2 = CH - CH = CH_2$

Gas. Boiling point: 4°C.

Although butadiene may be obtained by the thermal decomposition under suitable conditions of heavy natural oil, a process known as "cracking," which is used also to produce petrol, it is usually prepared in Europe either from quicklime and coke via calcium carbide or from alcohol:

A. From Quicklime and Coke.

$3\,C$ (Coke) $+$ $Ca\,O$ (Quicklime) $\xrightarrow{\text{Heat in electric furnace at 3,000°C}}$ $Ca\,C_2$ (Calcium Carbide) $+$ CO (Carbon Mononide)

$Ca\,C_2$ (Calcium Carbide) $+$ $2\,H_2\,O$ (Water) $\longrightarrow$ $CH \equiv CH$ (Acetylene) $+$ $Ca\,(OH)_2$ (Slaked lime)

$CH \equiv CH$ (Acetylene) $+$ $H_2\,O$ (Water) $\xrightarrow{\text{In presence of catalyst}}$ $CH_3 - CHO$ (Acetaldehyde)

$2\,CH_3 - CHO$ Polymerise in presence of dilute alkali
Acetaldehyde

$\longrightarrow CH_3 - CH(OH) - CH_2 - CHO$
Aldol

$CH_3 - CH(OH) - CH_2 - CHO$ Reduce with hydrogen
Aldol

$\longrightarrow CH_3 - CH(OH) - CH_2 - CH_2OH$
Butanediol or Butylene glycol

$CH_3 - CH(OH) - CH_2 - CH_2(OH)$. Dehydrate in presence of catalyst
Butanediol

$\longrightarrow CH_2 = CH - CH = CH_2$
Butadiene

The essential raw materials required for this most important synthesis are plentiful in most industrialised countries, but the initial step of converting them to calcium carbide is only economical in situations where ample hydro-electric power is available to furnish the heat required by the first reaction. It is stated that 1 ton of calcium carbide requires 4,200 kWh for its production.

B. From Alcohol.

$CH_3 - CH_2\,OH$ Oxidise
Ethyl alcohol

$\longrightarrow CH_3 - CHO + H_2O$
Acetaldehyde Water

The subsequent reactions are similar to those employed in handling the acetaldehyde obtained in the previous method of preparation.

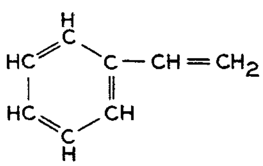
There is also a process for manufacturing butadiene from alcohol in which the latter is simulanteously dehydrated and dehydrogenated; this may be represented as shown below:

$2\,CH_3 - CH_2\,OH$ Dehydrate and dehydrogenate in presence of catalysts
Ethyl alcohol

$\longrightarrow CH_2 = CH - CH = CH_2 + 2\,H_2O + H_2$
Butadiene Water Hydrogen

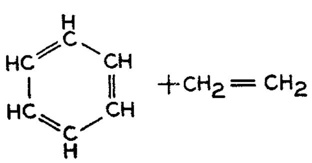
Alcohol is usually made by the fermentation of sugar or starchy materials such as potatoes. It may also be synthesised from certain components of oil-field gas, but the cracking process for manufacturing butadiene would, of course, be employed in regions where such gas is to be found.

Styrene :



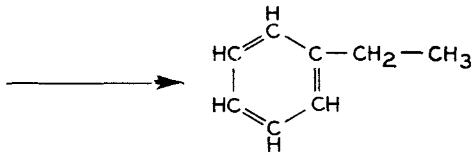
Liquid. Boiling Point : 145°C.

The raw materials for manufacturing this body are usually benzene (from coal tar) and ethylene (from natural oil or gas).

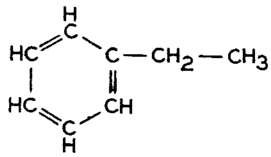


In presence of catalyst

Benzene Ethylene

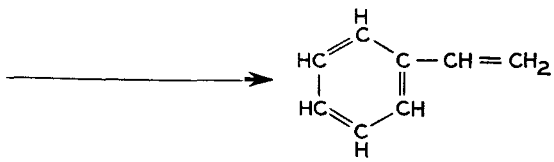


Ethyl benzene



Dehydrogenate at high temperature

Ethyl benzene



Styrene

Isobutylene :

CH_3
|
$= CH_2$
|
CH_3

Gas. Boiling Point : 1°C.

Isobutylene is obtained from natural gas or oil either directly or during cracking of the heavier hydrocarbons.

Ethylene : $CH_2 = CH_2$

Gas. Boiling Point : $-$ 103°C.

Ethylene, as previously mentioned, occurs in oil-field gas and is obtained during the cracking of heavy fractions of natural oil; it is also present in coal gas to the extent of a few per cent.

Acrylonitrile : $CH_2 = CH - C \equiv N$

Liquid. Boiling Point : 77°C.

Ethylene from natural gas or oil is the usual starting point in the manufacture of acrylonitrile. Many different ways of bringing about the conversion are practised.

Chloroprene : $CH_2 = C\,Cl - CH = CH_2$

Liquid. Boiling Point : 59°C.

This compound is generally synthesised from acetylene:

$2CH \equiv CH$ Polymerise in presence of catalyst
Acetylene

$\longrightarrow CH \equiv C - CH = CH_2$
Mono-vinyl-acetylene

$CH \equiv C - CH = CH_2 +$ H Cl In presence of catalyst
Mono-vinyl-acetylene Hydrochloric Acid

$\longrightarrow CH_2 = CCl - CH = CH_2$
Chloroprene.

Vinyl Chloride : $CH_2 = CH\ Cl$
Gas. Boiling Point : $-14°C$.

Like chloroprene, this material is synthesised from acetylene :

$$\underset{\text{Acetylene}}{CH \equiv CH} + \underset{\text{Hydrochloric Acid}}{H\ Cl} \quad \text{In presence of catalyst} \longrightarrow \underset{\text{Vinyl Chloride}}{CH_2 = CH\ Cl}$$

1:2 *Dichlor-ethane* : $CH_2\ Cl. - CH_2\ Cl$
Liquid. Boiling Point : 84°C.

The preparation of this body is typical of the means used for manufacturing a number of other chlorinated compounds employed in what are called the organic polysulphide class of synthetic elastomers :

$$\underset{\text{Ethylene}}{CH_2 = CH_2} + \underset{\text{Chlorine}}{Cl_2} \longrightarrow \underset{\text{1:2 Dichlor-ethane.}}{CH_2\,Cl - CH_2\,Cl}$$

From the descriptions just given it will be seen that one or more of the following raw materials are required in abundance for the foundation of a synthetic industry :

(1) Calcium carbide.
(2). Alcohol.
(3) Benzene.
(4) Natural oil.

The first requires copious hydro-electric power, the second a large surplus of starchy foodstuff, the third a coal gasification industry and the fourth oilfields. Of these the United Kingdom possesses only the third, and this by itself is insufficient. Even if all the prerequisites were available the intermediate processes of manufacture are numerous and complex, and certainly seem in the aggregate to involve more labour per unit of product than the maintenance of natural rubber plantations and the collection of their harvest. Coupled with our unique pre-war facilities for obtaining unlimited quantities of the last-named material, these facts, in the previous absence of well-established evidence of the technical superiority of the synthetic products, afford an adequate reason why the industry has not hitherto been established in this country.

Main Commercial Synthetic Elastomers

From the starting materials just described different products may be prepared by changes in the following variables :

(1) The monomer or monomers polymerised or copolymerised.

(2) The chain length of the polymer or copolymer ; this may be altered by modifying the conditions under which polymerisation is brought about.

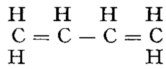
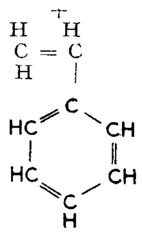
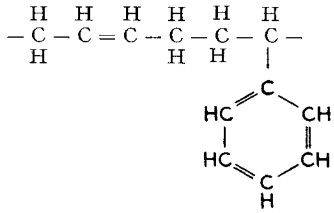
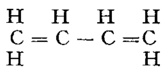
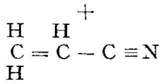
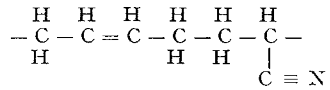
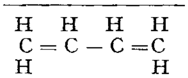
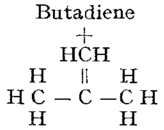
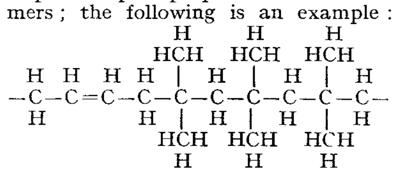
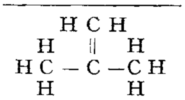
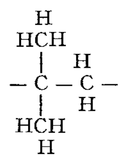
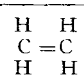
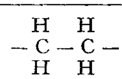
(3) The compounding materials employed in processing the polymers or copolymers into manufactured articles.

All these devices are practised to a certain extent, and it is clear that the total number of possible final variants is very great. An important factor tending to retard new development is the amount of experimental processing and testing required, both in the laboratory and under field conditions before the value of new polymers can be assessed ; indeed a reliable estimate of a promising material can be obtained only after a range of products has been subjected to wide industrial use. Hence, development of novel materials is extremely slow and the number of synthetics at present manufactured on any appreciable scale is small. Until the outbreak of war the only one at all well known in Great Britain was polychloroprene. In Table I are given the idealised chemical structures, properties and common trade names of the materials which may become common in this country as a result of the production plans now being put into operation in America and Canada. Others which are stated to be used in Russia and Japan are omitted as they are unlikely to be met for a considerable time.

TABLE I

General Data concerning the more important Synthetic Elastomers

Material	Molecular structure of		Uses	Remarks	Common Trade Names
	Monomer	Polymer or Copolymer			
Natural rubber	H H C H H | H H C = C – C = C H H Isoprene	H H C H H | H H – C – C = C – C – H H	Various	Grows in Malaya, Dutch East Indies, South America. The most versatile elastomer so far known	
Butadiene polymer	H H H H C = C – C = C H H Butadiene	H H H H – C – C = C – C – H H	Hard mouldings. Footwear. Tyres.	General purpose material having good mechanical properties and heat resistance.	Buna 85. Buna 115. (German)

Material	Molecular structure of — Monomer	Molecular structure of — Polymer or Copolymer	Uses	Remarks	Common Trade Names
Butadiene-Styrene copolymer	 Butadiene +  Styrene		Tyres and other purposes requiring the highest abrasion resistance.	Said to be superior to natural rubber for tyres. This material will constitute a high proportion of American production during the next few years. It is very difficult to process.	Buna S. Buna SS. (German). American material not yet named.
Butadiene-Acrylonitrile copolymer	 Butadiene +  Acrylonitrile		Purposes requiring high resistance to petrol, oil and other organic liquids.	Somewhat less elastic than the previous materials.	Perbunan. Perbunan Extra. (German)
Butadiene-Isobutylene copolymer	 Butadiene +  Isobutylene	Depends upon proportions of monomers; the following is an example: 	Purposes requiring high resistance to corrosive chemicals, oxidation and light.	The example represents a type of synthetic in which a hydrocarbon containing two double linkages between adjacent carbon atoms in the molecule is copolymerised in suitable proportions with another containing only one such linkage. The product, whilst having enough double linkages to be vulcanisable by sulphur, has insufficient of them to render it sensitive to attack by oxidising influences.	Butyl Rubber (American)
Isobutylene polymer	 Isobutylene		As modifying agent for other elastomer mixes to confer resistance to corrosive agents, oxidation and moisture penetration	The absence of double linkages in the molecule of the polymer renders it extremely inert to all chemical influences.	Oppanol (German). Vistanex (American)
Ethylene [1] polymer	 Ethylene		Cable sheaths, dielectrics, other purposes requiring high resistance to water and oxidation.	Very inert material with outstanding electrical properties. Generally compounded with Isobutylene polymer. Elastic properties not very marked.	Polythene (British).

[1] Although not an elastomer in the accepted sense of the term, this material is included here on account of its great importance in the Communications Industry.

Material	Molecular structure of		Uses	Remarks	Common Trade Names
	Monomer	Polymer or Copolymer			
Vinyl chloride polymer	H H C = C H Cl Vinyl chloride	H H – C – C – H Cl	Moulded and extruded articles requiring high resistance to abrasion, organic solvents, fire, oxidation and sunlight.	The pure polymer is brittle, and softeners are always added to commercial mixes. Owing to its chlorine content, it is virtually non-inflammable, but its elastic properties are poor. A reversible softening occurs on heating it. This is a serious defect for many purposes.	Flamenol Koroseal (American). Welvic (British)
Chloroprene polymer	H Cl H H C = C – C = C H H Chloroprene	H Cl H H – C – C = C – C – H H	Purposes requiring high resistance to organic liquids, abrasion, oxidation and fire.	Very easy to process. Its elastic properties, though good, are not equal to those of natural rubber. It is included in the American production programme.	Neoprene (American)
Organic polysulphides	H H Cl C – C Cl H H 1.2.Dichlor-ethane + S S ‖ ‖ Na–S–S–Na Sodium tetrasulphide	S S H H ‖ ‖ – C – C – S – S – + 2 Na Cl H H Sodium chloride	Purposes requiring high resistance to abrasion in conjunction with organic liquids and oxidation.	The example shown is typical of this class of materials. Many other chlorinated organic compounds may be treated with sodium tetrasulphide in a similar manner. The products, which have a foul odour, are considerably inferior to natural rubber, both in mechanical strength and elastic properties, but they withstand many organic liquids which tend to attack other synthetics.	Perduren Thiokol (German) Vulcaplas (British)

Manufacture

The polymerisation of the monomer or monomers is brought about in the presence of a catalyst—usually, but not invariably, at high temperature and pressure, but a recent development enables certain polymers to be produced in aqueous emulsion so that the products are very similar to natural rubber latex and possess many of its conveniences in certain industrial applications. These include the property of being depositable in film form on moulds by the application of an electric field.

Processing

Natural rubber is seldom used alone,[2] but is compounded according to the properties required in all proportions between about 5% and 99%, with a wide range of materials of which the more common are sulphur, carbon black, zinc oxide, magnesium oxide, china clay, waxes and pitches. The compounding operation is usually carried out by kneading between hot rollers. Of the additions the most important is sulphur which, when the mix is heated (or vulcanised) combines with the molecular chains of the rubber hydrocarbon, introduces cross linkages between them, and converts the mass from a more or less plastic to an elastic or rigid state depending upon the proportion used. Thus about 0·5% of sulphur to rubber gives a product possessing great extensibility, whereas 30% yields ebonite. The sulphur also stabilises the product to some extent against oxidation and changes in mechanical properties with variations in temperature. Although the action of sulphur is imperfectly understood it seems reasonably certain that it is associated in some way with the double linkages which occur between certain adjacent carbon atoms in the rubber molecule.

Carbon black has the property of increasing the tensile strength of pure rubber; the waxes and pitches soften the mix and the remaining materials function mainly as fillers and diluents.

[2] *P O.E.E.J.*, Vol 33, p. 95.

The so-called perishing of rubber is due to attack by atmospheric oxygen; like vulcanisation this action also occurs at the double linkages in the molecule, and to retard it small proportions of complex compounds known as anti-oxidants are invariably added to modern mixes.

It is thus clear that compounding of natural rubber offers a wide field for the application of both scientific and empirical knowledge and the same applies also to the synthetic bodies.

The butadiene polymers and copolymers are compounded with a range of materials similar to those used with natural rubber, and can be vulcanised by sulphur; if a sufficient proportion of sulphur be used hard materials similar to ebonite are formed.

Polyisobutylene is seldom used alone but is often incorporated in other mixes as a softener; it is, for example, practically the only addition made to polyethylene.

Chloroprene polymerises very rapidly and tends to develop molecular cross linkages with consequent stiffening unless the process is stopped at an early stage; the reaction, in fact, continues slowly during storage of the initial product unless certain "stabilisers" are added. This polymer does not react with sulphur but can be hardened by heat to a certain extent, but not to a state like ebonite. It is compounded with a similar range of materials to natural rubber.

Polymerised vinyl chloride or "P.V.C." as it is usually known, is itself a brittle substance, but by mixing with it large proportions of certain plasticisers (usually tricresyl phosphate or dibutyl phthalate), which are liquids having exceedingly low evaporation rates, somewhat elastic properties are developed. These mixtures cannot be stabilised by heating as this merely causes a reversible softening to occur and is a serious drawback to their use at either extreme of temperature.

There are a considerable number of compounds of the organic polysulphide type in use in various parts of the world; Thiokol and Vulcaplas are understood to be produced by reacting dichlorethyl formaldehyde acetal and glycerin dichlorhydrin respectively with sodium tetrasulphide. These bodies can be vulcanised by heating and are compounded with the usual range of materials.

Owing to their refractory nature the synthetic materials on the whole require heavier machinery and are mechanically more difficult to work than natural rubber.

The Relative Properties of Natural and Synthetic Elastomers

The most remarkable characteristic of natural rubber is its versatility of response to different kinds and proportions of compounding materials. Certain of the synthetic polymers, notably butadiene, butadiene-styrene and butyl rubber also possess this property, though to a considerably smaller extent, whereas the materials containing chlorine, nitrogen or sulphur such as the butadiene-acrylonitrile, chloroprene, vinyl chloride polymers and the organic polysulphides are more suitable for specific purposes.

None of the synthetic materials can be compounded to give quite as high tensile strength as the best natural rubber mixes, but the butadiene-styrene and butadiene-acrylonitrile copolymers hold very high places in respect of abrasion resistances; it is, in fact, claimed that in the form of tyres they have given 20-30% more mileage than natural rubber.

The chlorinated polymers are virtually non-inflammable and will only burn while in actual contact with flame.

The synthetic materials on the whole show markedly greater resistance to swelling by oils and other organic liquids than does natural rubber, and their permeabilities to gases are also lower; both these properties are most strikingly manifested by those containing nitrogen, chlorine and sulphur. As a class they are also more effective for damping out vibration, although the energy thus absorbed may lead to undue heating in some circumstances. In electrical properties no great advantages are offered by any of them except polyethylene which has outstandingly low permittivity.

As mentioned earlier both the vulcanisation of natural rubber and its deterioration by oxidation are due to the presence of double linkages between certain adjacent carbon atoms in the molecular chain. The structures shown in Table I, however, indicate that isobutylene, ethylene and vinyl chloride polymers possess no such double linkages or "unsaturation" as they are called in chemical language, and suggest that these materials should be unvulcanisable and perfectly inert to oxidising influences. Both inferences are borne out in practice, and all these substances are in fact remarkably resistant to many kinds of chemical attack.

In the butadiene-isobutylene copolymer, however, and others of the same type (in which a hydrocarbon containing two double linkages is copolymerised with another containing only one such linkage) the degree of unsaturation can be closely controlled by varying the proportions in which the two hydrocarbons are used. It is thus possible to obtain products with sufficient double linkages to be vulcanisable by sulphur to any desired extent, but leaving none to be subsequently attacked by oxygen.

Conclusion.

It must be fully appreciated that practical experience of compounding, processing and using synthetics is so far very restricted in the Allied countries generally, and in the United Kingdom in particular, but it is hoped that as increased supplies become available this unfortunate state of affairs will be remedied. In the meanwhile it is clear that, from the technical aspect at all events, the natural product may be replaced and sometimes improved upon for all purposes by one alternative or another. For instance resistance to oils and oxidation is a very valuable property which even in peace-time would amply justify extra costs for some purposes.

Safeguarding of Essential Records by Photography

W. R. WICKENS

U.D.C. 778.1

Photographic methods for the safeguarding of essential records have been adopted by the Post Office Engineering Department. The author describes the apparatus used for photographing and reproducing card records and linen tracings.

Introduction.

IN 1938 a committee was appointed to consider the question of air raid precautions in the Post Office Engineering Department, and the safeguarding of essential records was one of the problems dealt with. A recommendation was made and ultimately adopted, that records relating to main and local cables, and also certain staff, accounting, costing and radio records should be duplicated. As these records were subject to frequent amendment it was obviously desirable that some method should be employed whereby accurate duplication could be carried out periodically with a minimum expenditure of labour. Duplication by photography offered many advantages and was eventually decided upon. The records concerned, numbering hundreds of thousands, are located at centres throughout the country and are in the main on cards, though a small proportion are on loose sheets; moreover they are in regular use, so it was vital that the photographic apparatus employed should be mobile, easily operated, and capable of a high standard of performance. After a thorough investigation the Recordak system of Kodak, Ltd., was adopted.

Later, after experience in the air raids of 1940, it was decided to take similar steps to safeguard certain linen records and after experimental work on alternative methods, the photographing of these tracings with a Littlejohn copying camera was adopted. This article describes both the Recordak system and the Littlejohn camera and printing apparatus.

RECORDAK SYSTEM.

Description.

The "Recordak" is a compact motor-driven machine about the size of a radiogram (see Fig. **1**).

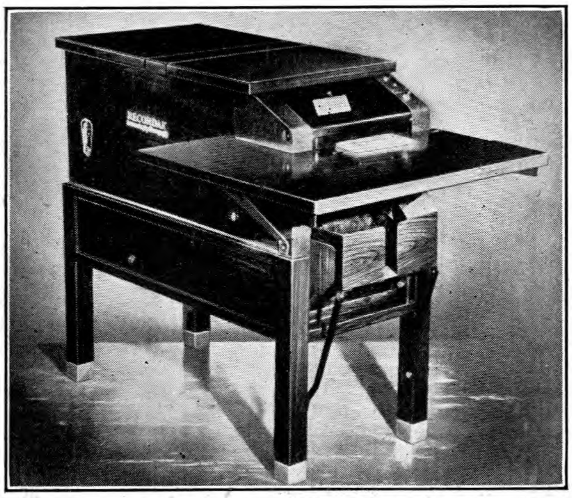


FIG. **1**.—THE "RECORDAK."

The documents are fed by hand through an aperture, on to a rotating drum, automatically photographed on to a 16 mm. film, counted, and discharged in the same order, into a hopper below. The machine is available in two sizes, one to take documents up to 8½ in. wide producing an image 1/17th full size, the other taking documents up to 10½ in. wide, this image being 1/23rd full size. The former size is in use by the Post Office Engineering Department. (Letters for transmission by the "Airgraph" service are photographed by a machine of this type, some 1,700 letters being contained on 100 ft. of film, weighing with spool about 4¾ ozs.).

The unit is self-contained, with a lighting system and camera totally enclosed, the camera carrying 100 ft. of film at one loading sufficient for about 3,000 exposures of documents 8 in. by 5 in.

A somewhat unusual principle of photography is employed by the Recordak. It records a moving document on a continuously moving film, in phase with the document. An ordinary ciné camera takes pictures only when the film is stationary, a shutter preventing the light entering the lens while the film is moved between successive exposures. High speed ciné cameras[1], however, taking up to 8,000 pictures per second[2], use a continuously moving film with rotating prisms displacing the images to follow the film movement, a "blackout" period occurring between exposures when the prisms become aligned with the lens axis.

In the Recordak, although the film moves during exposure, it is not at a high speed. The document is photographed as it moves past an aperture ⅜ in. wide (Fig. **2**) in a masking plate, placed about 1½ in.

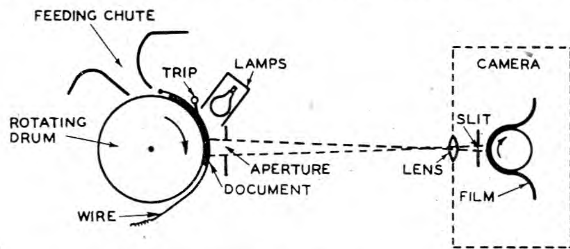


FIG. **2**.—OPERATING PRINCIPLE OF "RECORDAK."

in front of the document, at an approximate speed of 14 inches per second. Behind the lens, immediately in front of the film, is a slit about 1/30 in. in width, the image occurring as a narrow band 1/17 original size across the focal plane of the lens. Any point on the document is thus produced in turn on the film and moves in phase with it for a period of 1/37 sec.

[1] *P.O.E.E. Journal*, Vol. 31, p. 293.

[2] Western Electric Fastex High Speed Motion Picture Camera.

The film is driven by chain and sprocket via a friction clutch on the spindle of the rotating drum. This clutch is mechanically operated by a trip bar depressed by documents in passing through the machine, so that the film moves only when a document is being photographed. By the same means a cam operates a micro-switch controlling the lighting system. To overcome the inherent falling off of illumination towards the edges of a lens field, the seven 190 V 15 W lamps of the Recordak are arranged in a curve with the outer lamps nearest to the document, thus a greater strength of light falls towards the edges, resulting in a negative having an even density over the whole area.

Operation.

After being connected to suitable electric mains and the machine switched on, the drum commences to rotate at a constant speed. The document, fed by hand (Fig. **3**), is held in position against the face of the drum by thin steel wires. In its passage round the drum, the document depresses a trip bar which simultaneously brings into operation the lighting unit and film movement a fraction of a second before the leading edge of the document appears before the masking slit and photographing begins. This condition is maintained until the trip bar is restored to normal after the document has passed, with sufficient lag to allow the trailing edge to clear the slit, and for the film to move for about 1/32 in., making a space between each image, after which the lights go out and the film comes to rest. As the speed at which a document passes through the machine and the film movement are constant, the density of the negative is determined by the amount of light falling on the document. This is controlled by a rheostat in the lighting circuit, and it has been found, with the film in regular use, that 186 V fed to the lamps results in a negative of suitable density. Coloured or dirty records, however, require more exposure, i.e. more light, so a switch is arranged to short-circuit sufficient resistance to increase the voltage by 10 V, slightly overrunning the 190 V lamps, thus obtaining the required density of negative. This switching arrangement is not standard. It was fitted to the Recordak by the Post Office Research Station, after early experience in photographing mixed coloured and white originals. Considerable fluctuations in mains voltages have been experienced, particularly in "blitzed" towns, often resulting in under-exposed films. To overcome this difficulty the Post Office Research Station fitted a constant voltage transformer unit with an input between 190–260 V and a constant output of 230 V, as an integral part of the Recordak. The Recordak is fitted with a warning system, a buzzer, sounding when 100 ft. of film have been exposed, indicating that the camera needs reloading; it also sounds should the camera be incorrectly loaded, or incorrectly fitted into the machine.

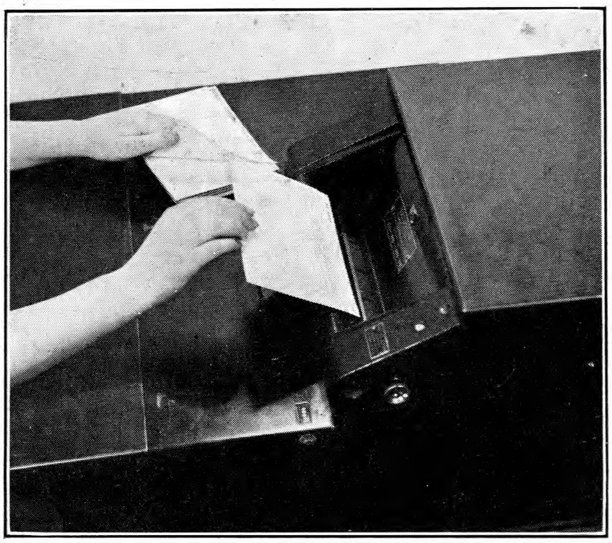


FIG. **3**.—FEEDING DOCUMENT INTO "RECORDAK."

Film.

A panchromatic film is used to reproduce colours, in monochrome, in their relative brightness as seen by the eye. The film is of the "safety" variety, being less inflammable than paper. It has an opaque backing, which enables loading operations to be carried out by ordinary room lighting away from windows or strong sunlight, a few turns being wound on the spool as a cover to prevent light reaching the undeveloped portions of the film. Exposed films are sent to Kodak, Ltd., for processing and, subject to suitable storage, will keep indefinitely without deterioration.

Three machines were put into service early in 1939, one being located in the London Telecommunications Region, the other two touring provincial centres throughout the country in specially fitted Morris vans, each staffed by an operator-driver.

Printing Apparatus.

The original conception of the Recordak system was to provide a duplicate record mainly for reference purposes, the film being passed through a viewer projecting a full size image on to a screen, or wall, enabling manuscript, or typed copies to be taken. The object of filming records, however, so far as the Post Office Engineering Department is concerned, is to replace those destroyed. To reconstruct records manually from the images shown on the screen of a viewer would be a long and laborious process, and would introduce the possibility of error. A more suitable method is to produce photographic enlargements of the films providing a facsimile of the original records.

Apparatus for enlarging Recordak films does not greatly differ from that employing the usual methods, except that the Recordak, having a fixed reduction factor and working on the moving document and moving film principle, produces film images varying in length according to size of document, so that a regular length of film or "frame" cannot be projected, for the image may often be larger than can be accommodated within the effective field of the projecting lens. Speed of output too is another consideration when replacing large quantities of lost records. Taking into consideration the foregoing facts, the conclusion was reached that the most suitable method of projecting films of this type was by employing the same principle of synchronous movement of image and object, as used when photographing the documents.

The Post Office Engineering Department sought to instal apparatus embodying this principle, but none was available for purchase at that time (1939). In consequence, an automatic contact-printing and processing machine, known as a Reprograph, made by the Williamson Manufacturing Co., Ltd., was obtained, and after some considerable experimental work, the Post Office Research Station evolved a modified, or P.O., Reprograph by means of which 16 mm. micro-films are projection-printed and processed continuously. Many thousands of reconstructed records have been produced successfully by this apparatus.

The Reprograph, however, is limited to a paper width of 7½ in., whereas the Recordak will photograph documents up to 8½ in. wide, therefore it is not possible to reproduce images occupying the full width of film to full size, and a projector of this type with variable magnification facilities would tend to become complicated out of proportion to its usefulness. Originally the bulk of records filmed were 8 in. by 5 in. cards, so a compromise of approximately 14 diameters magnification was agreed upon, using a paper the thickness of a postcard with a dull surface, enabling manuscript entries to be made in either ink or pencil; erasure of the pencil is also possible.

The projecting portion of the Reprograph consists of a condenser and a Leitz Elmar 3·5 lens, with a 100 W projector lamp, suitably housed, as light source, with a "gate" or mask accurately centred in the focal plane of the lens across which the film passes, the moving images being projected downwards on to the sensitised paper moving synchronously with the film (Fig. 4). A slit, placed widthwise, is

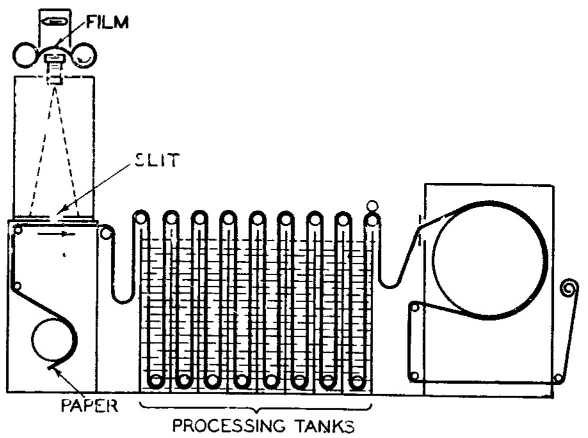


Fig. 4.—Operating Principle of "Reprograph."

situated immediately above the paper, the latter receiving the image in the form of a continuously moving narrow band. This slit, the width of which can be varied during running operations is also the means of exercising exposure control.

After exposure the paper passes into the processing section of the Reprograph, consisting of a series of eight stainless steel tanks, being carried up and down through the developing and fixing solutions and washing water by a number of "jockey" rollers. After the paper emerges from the last washing water the surplus moisture is removed by two rubber rollers, followed by a squeegee, it then passes on to a stainless steel drying drum, heated by three 2 kW heaters, the hot moisture-laden air being extracted from the drying chamber by a small fan, and finally the paper is spooled ready for cutting by hand. The rate of progression is about 200 ft. per hour, representing an output of 350 cards from 8 in. by 5 in. originals.

Linen Records.

The serious "Blitzes" of 1940 onwards made it evident that the Post Office ought to be in the position to replace, in the event of the originals being destroyed, certain linen records, e.g. local line plant, ordnance map records, and cable diagrams, most of which were of double elephant dimensions (40 in. by 26 in.). At the outset, schemes were put in hand for the provision of full sized duplicates, on sensitised tracing paper, but owing to numerous difficulties, the chief of which was the obtaining of suitable materials, it was decided to produce at Headquarters reduced film negatives which could readily be stored in a safe place, and be used as the starting point in the replacement of lost originals.

Reduced negatives of line originals must be clean cut, each line and figure being perfectly sharp, so as to produce enlargements free from "wooliness." Thus, although a magnification of 17 or even 23 diameters (as with the "Recordak" system) gives reasonably good results for manuscript or printed records, a magnification of 7 to 10 diameters is the largest practical enlargement consistent with good line resolution that can be made from negatives of line originals, excepting when working under laboratory or some special conditions.

For the production of suitable reduced line negatives a first-class lens must be employed. It should possess flatness of field, to ensure sharpness to extreme corners, be fully corrected for astigmatism, i.e. have the ability to bring both radial and tangential lines to needle-sharpness, and also be free from chromatic aberration, so that various colours of the solar spectrum can be brought to a common focus. Further, the lens should be of a fairly narrow angle, for with a lens where the angle of light rays with the optical axis is only 20°, the illumination falls to 78 per cent.[3] at the edges of the lens field as compared with 100 per cent. at the centre. It is important, too, that the camera and copyholder be of rigid construction, and methods of rapidly changing the sensitised material after each exposure, together with a means of positioning, quickly and accurately, the matter to be copied, are essential if a good ouput is to be obtained

As large numbers of linen records had to be dealt with at high speed it was necessary to instal apparatus

[3] Ilford Manual of Process Work.

giving a high output, and to produce negatives of prime quality. Several installations were available, but most were limited in output, or possessed other undesirable features, and eventually a copying unit made by S. R. Littlejohn & Co., Ltd., was installed.

Littlejohn Copying Camera.

The Littlejohn copying unit (Figs. **5** and **6**) comprises a camera, copyholder and lighting equipment, all mounted on a steel girder frame, suspended about 2 ins. above floor level by springs at the four corners to eliminate vibration. The end of the frame on which the camera is mounted extends into a darkroom allowing loading and unloading to be carried out in the correct "safelight." Sufficient film for 100 exposures, each $7\frac{1}{2}$ in. by $5\frac{1}{2}$ in., can be loaded at a time. The camera, constructed in metal, is equipped with a film winding motor operating automatically immediately after an exposure has been made, winding the exposed portion of the film, which is cut off by a guillotine operated by a cam on the film wind roller. The lens, a Cooke Process Anastigmatic series V.B. 280 mm. focus, is placed so as to protrude through an opening in the darkroom wall. Behind the lens is an electrically operated shutter, timed and operated from a control panel on the copyholder.

On the other end of the girder frame is a superstructure supporting four open type arc lamps (20 A 230 V A.C.), and the copyholder with control panel, which houses the shutter timing gear and arc lamp push button switches. The copyholder is a glass-fronted frame 42 in. by 32 in., with a sprung back, pivoted to enable it to be brought to the horizontal position for loading. By means of a counterbalance action the glass front is tilted upwards to allow for the insertion of the linen to be copied (Fig. **5**), whereupon it is closed, clamped, and returned to the upright position for the exposure to be made. The copyholder and arc lamps are mounted on a base with four wheels, enabling it to be moved along the girder frame to positions appropriate to the scale of reduction set out on graduations affixed to the girder frame. The camera is similarly adjusted to graduations on the base of camera. The reduction scale is from 1/7 to 1/3.

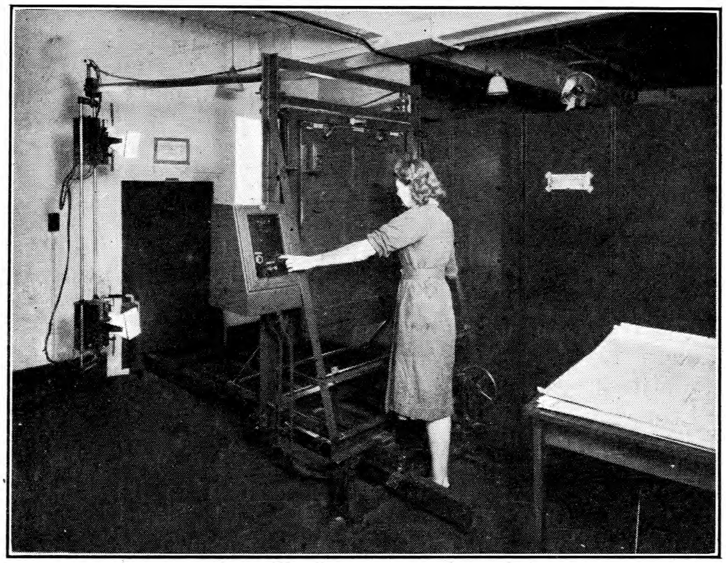


FIG. **6**.—OPERATING POSITION OF LITTLEJOHN COPYING CAMERA.

Camera Operation.

The linen to be copied is placed in the copyholder and the unit set for the required scale of reduction, the exposure time, determined by experience, is set by a knob and scale on the control panel, the arc lamps are switched on, and then, by pressing a button (Fig. **6**), the shutter opens for the predetermined period, and on closing the winding mechanism operates, the exposed portion of film is cut off, and the camera is reloaded ready for the next cycle of operations. A pilot lamp on the control panel is illuminated during the periods of exposure and film winding.

The explanatory diagram shown in Fig. **7** shows the principles of operation of the exposure control and film winding mechanism.

The camera shutter is opened upon depressing the "exposure" button by the operation of the solenoid SC. Simultaneously the electromagnet ZZ is energised. ZZ carries 3 contacts so mounted that at this stage only ZZ1 is actuated, thus closing the hold circuit of ZZ and SC. ZZ is also mechanically linked with a fibre sector cam (part of the exposure timing mechanism) and lifts it into contact with the drive spindle of a continuously running synchronous motor. The point of application of the drive to the periphery of the sector cam, and consequently the

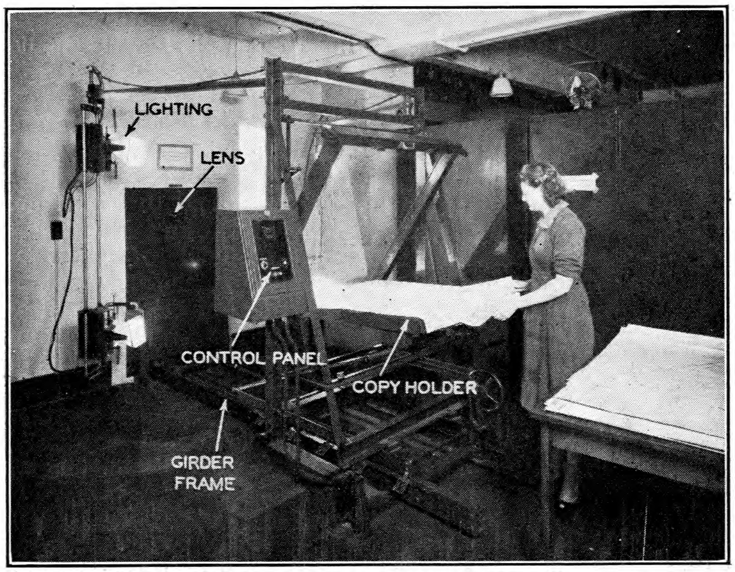


FIG. **5**.—LITTLEJOHN COPYING CAMERA.

duration of the exposure, can be regulated over a range of 0·25 secs. by a manually operated knob with scale.

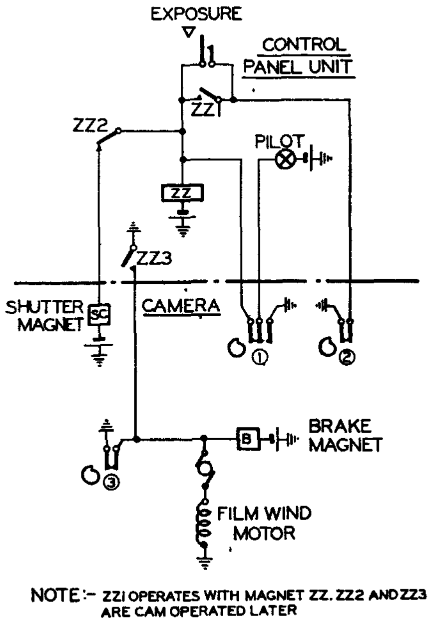


FIG. 7.—CIRCUIT SCHEMATIC OF EXPOSURE CONTROL FOR "LITTLEJOHN" COPYING CAMERA.

The cam slips at the termination of its arc of travel, and spring units ZZ2 and ZZ3 are operated. The former breaks the circuit of S3 and releases the shutter, and ZZ3 closes the circuit of the film wind motor and of the electromagnet B, which removes the friction brake from the motor shaft. The motor drives the film wind roller through a reduction gear, and also a fibre cam which controls the springsets numbered 1, 2 and 3 in the sketch. They operate in the following sequence :—

(1) Changes over the earth to a pilot lamp which "flicks" and thus indicates to the operator that the camera shutter is closed.

(3) Closes the hold circuit for the motor and magnet B against the release of magnet ZZ.

(2) Disconnects the locking circuit of magnet ZZ, which restores to normal.

At the end of one revolution of the cam, the contact units 1, 2 and 3 restore. The winding motor is rapidly brought to rest by a friction brake which is applied when magnet B releases and the pilot lamp is extinguished. The equipment is then ready for the next operation of the "exposure" button.

Processing of Film.

The lengths of exposed film are collected in a receptacle beneath the camera and removed for processing to an adjacent darkroom, without interfering with the working of the camera. Films are processed on usual commercial lines by time and temperature methods, being clipped in non-corrosive metal frames, which are fitted into racks each holding 20 frames. The racks are immersed, successively, in tanks containing developer, fixing solution and running water, the negatives being dried, after draining, by placing the racks in a hot air oven. The finished negatives are each enclosed in a transparent envelope $7\frac{1}{2}$ in. by 6 in., about 50 occupying one inch of filing space.

Enlarging.

The complementary part of the Littlejohn copying camera is the enlarging apparatus. This apparatus is constructed on similar lines to the camera, having a suspended girder frame on which the camera and paper holder are mounted with calibrations along the base to which the paper holder, mounted on wheels, can be set for the required scale of magnification. The camera, in metal, has a lens similar to that used for negative making and the illumination is by means of a 30 A open type arc lamp and a double plano-convex condenser.

In the event of original linens being destroyed, the negatives are projected to size and enlargement made on strong thin bromide paper, which can be used for making "dyeline" prints, or linens can be made by the true-to-scale (ordoverax) process,[4] thus replacing the destroyed originals.

Acknowledgement.

Thanks are due to the Engineer-in-Chief's Circuit Laboratory for the Littlejohn camera circuit diagram and operation notes.

[4] *P.O.E.E.J.*, Vol. 30, p. 325.

A New Standard Attenuation Equaliser

F. PYRAH.

U.D.C. 621.391 621.396.662.3

This article describes a new standard shunt type attenuation equaliser which, although designed primarily for use with the Amplifier No. 32 is suitable for use with any type of audio amplifier.

Introduction

PRIOR to the introduction of units amplifying in about 1933, all 4-wire repeaters used for the provision of trunk lines were provided with an attenuation equaliser for each direction of transmission. These equalisers, which were an integral part of the repeater, were of the grid-tuning type and were particularly suitable for the contemporary types of loading. The unit amplifying was introduced with the object of economically improving transmission over short trunk and junction circuits and for the lighter loading then being introduced, attenuation equalisers were not generally necessary for short distance circuits. Equalisers were therefore omitted from units amplifying and this omission was the main difference between a unit amplifying and a "main line repeater." Up to the present time, therefore, circuits requiring equalisation have generally been provided by means of repeaters with grid-tuning equalisers. Where this was impracticable, special equalisers—either constant impedance or shunt—have been used.

As described in a previous article[1] in this JOURNAL, the Amplifier No. 32 has now been adopted as the standard line amplifier for all types of audio circuit. This amplifier is a single stage amplifier using negative feed-back and does not include facilities for equalisation. When required, equalisers are fitted on the transformer and line corrector equipment, space having been left on this equipment for fitting an equaliser on every "receive" pair. To preserve a satisfactory layout of equipment it was necessary to limit the space available for the equaliser to that occupied by a 48 type line transformer, i.e. approximately 2 in. × 2½ in. As all existing equalisers were too large to be accommodated in this space it was necessary to introduce a new standard equaliser which has been given the title " Equaliser No. 9A."

Design of Equaliser.

The limitation in size was perhaps the chief requirement for the new equaliser but cost was also a very important factor in view of the likelihood that a very large number of equalisers would ultimately be used, especially on unloaded cables. The relative merits of fixed and variable equalisers were considered, and it was decided that, if a satisfactory design could be produced, a completely variable equaliser was most desirable.

The space and cost requirements of the new equaliser can only be met by using the minimum number of components. Two-terminal equalisers (series or shunt) have this attribute, and it was decided that a shunt type equaliser was preferable.

[1] *P.O.E.E.J.*, Vol. 34, p. 60.

To be completely variable an equaliser must be capable of being varied in respect of—

(*a*) The basic (or maximum) loss. This is usually required to occur at very low frequencies.

(*b*) The resonant frequency—at which the loss is a minimum.

(*c*) The "slope" or rate at which the loss decreases from the basic loss to the resonance loss (i.e. loss at resonance) with change of frequency.

The most obvious way in which these three variables may be provided is to use a variable resistor, variable inductor and variable condenser as shown in Fig. **1**.

In this form of equaliser the resistor controls the

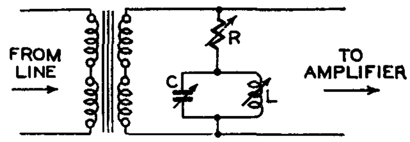


FIG. 1.—GENERAL FORM OF VARIABLE SHUNT EQUALISER.

basic loss, and the resonant frequency is determined by the product of the inductance and capacitance. The " slope " of the insertion loss curves, i.e. the rate at which the loss of the equaliser changes with frequency is dependent upon the ratio of the inductance to the capacitance. A variable resistor and variable inductor are indispensable, but it is possible to use a fixed condenser with the variable inductor to obtain the required variation of resonant frequency and to use the variable inductor as an auto-transformer to give the required variation of " slope." The arrangement is shown in Fig. **2**(*a*).

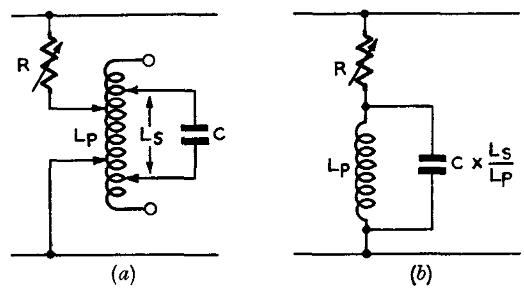


FIG. 2.—VARIABLE EQUALISER USING FIXED VALUE CONDENSER.

Assuming perfect coupling between the turns on the coil, it can be shown that the circuit given in Fig. **2**(*a*) is equivalent to that shown in Fig. **2**(*b*). It will be seen from Fig. **2**(*b*) that the product of the capacitance and inductance L_P equals CL_S so that when operating between non-reactive impedances, the resonant frequency is dependent only upon the capacitance and inductance L_S and is independent of the value of L_P. Thus the arrangement is more or less capable of adjustment in respect of resonance independently of "slope." Fig. **3** shows a typical loss-frequency curve for an equaliser to Fig. **1** or **2**,

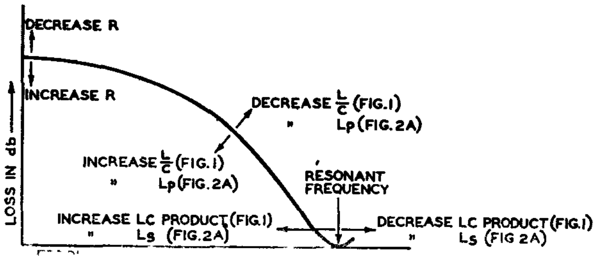


FIG. 3.—TYPICAL SHAPE OF EQUALISER LOSS—FREQUENCY CHARACTERISTIC SHOWING EFFECT OF VARIATION OF COMPONENT VALUES.

and indicates the effect of varying the values of the components. The degree to which these are independently variable depends upon the angle of the line impedance.

Previous designs of shunt type equalisers indicated that the maximum value of the inductor should be of the order of 50 millihenries. A value of 48 mH. was decided upon, although any value between about 45 mH. and 55 mH. would be satisfactory for general use on audio circuits. In considering the best method of arranging the taps on the inductor it was essential to provide a large number of inductance values with only a few tapping points because of the small space available on the equaliser case for connection tags. The arrangement adopted is shown in Fig. **4**.

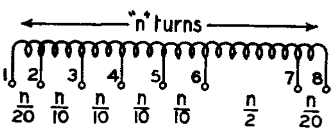


FIG. 4.—TURNS RATIOS OF INDUCTANCE FOR EQUALISER No. 9A.

This arrangement enables any fraction from 1/20th of the coil upwards to be selected in steps of 1/20th. In this way by means of 6 tapping points (8 tags) 20 inductance values were made available of which 16 would probably be useful. (It was not expected that it would be possible or necessary to use fractions of the coil below a quarter of the turns). The selection of a capacitance was governed by the range of frequencies to be covered by the equaliser and by the types of condenser which could be readily obtained. A condenser of **0·1** μF gives a useful range of resonances from **2·3** kc/s when across the full coil to **9·2** kc/s when across a quarter of the turns of the coil with **14** intermediate resonances. This was considered satisfactory for all present audio cables in use with the possible exception of those cables loaded with **136** mH. coils at **2·6** miles spacing. If equalisation of such cables is to be done by the standard equaliser an additional small condenser of suitable capacitance (**0·05** to **0·1** μF) could be used in parallel with the one in the equaliser to give a sufficiently low resonance if this was found necessary.

The circuit design was completed by using resistors of **5**, **10**, **20**, **40**, **80**, **160** and **320 Ω**. This gives a wide range of resistance values suitable for covering a 20 db. range of basic loss which is all that is normally required in practice. Table 1 gives the useful inductance values and resonant frequencies obtainable, and Table 2 gives the nominal values of resistance required for various values of basic loss.

TABLE 1

Inductor Tags	Inductance mH	Resonant frequency kc/s with 0·1 μF	Inductor Tags	Inductance mH	Resonant frequency with 0·1 μF
1–8	48·0	2·3	5–7	17·3	3·83
2–8	43·5	2·42	6–8	14·5	4·19
2–7	39·0	2·55	6–7	12·0	4·6
3–8	34·7	2·71	1–6	9·7	5·12
3–7	30·8	2·87	2–6	7·7	5·76
4–8	27·0	3·07	1–5	5·9	6·58
4–7	23·6	3·28	2–5	4·3	7·67
5–8	20·3	3·54	1–4	3·0	9·2

TABLE 2

Value of R	Basic Loss between 600Ω	Value of R	Basic Loss between 600Ω
630	3·5	85	13
510	4	75	14
385	5	65	15
300	6	55	16
240	7	50	17
200	8	45	17·5
165	9	40	18·5
140	10	35	19·5
115	11	30	21
100	12		

Fig. **5** shows the final schematic arrangement of the "Equaliser No. 9A."

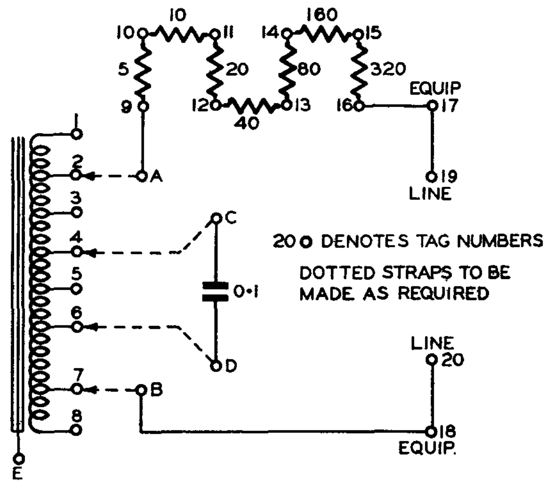


FIG. 5.—CONNECTIONS OF EQUALISER No. 9A.

By careful mechanical design of the components and using radiometal for the core material it was found possible to assemble the inductor, condenser and resistors in a case of dimensions 2 in. × 2½ in. × 4¼ in., which is suitable for mounting in the space allotted on the "Panel Transformer and Line

Corrector " used with Amplifier No. **32**. Fig. **6** shows the equaliser with cover removed.

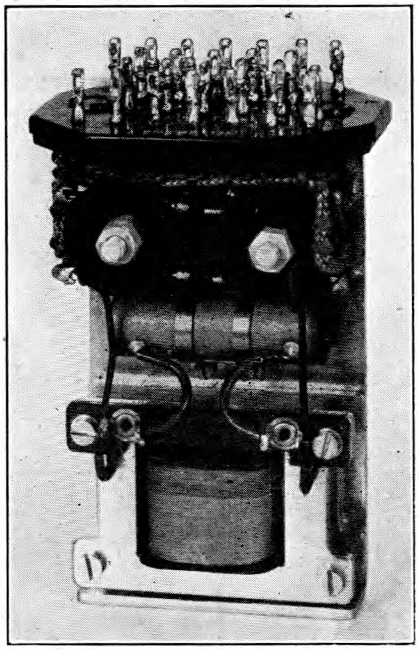


Fig. **6**.—Equaliser No. 9A with Cover removed.

Insertion Loss Characteristics.

A two-terminal equaliser has insertion loss characteristics which are dependent upon the impedances between which the equaliser is connected. The impedance of lines varies with frequency and in a manner which is dependent upon the primary line constants—resistance, capacitance, inductance and leakance. This makes it impracticable to plot curves of equaliser insertion loss which can be used with any degree of accuracy for the equalisation of circuits. Curves of insertion losses usually measured between **600 Ω** impedances are, however, useful for showing the effect of varying the value or setting of any of the components. Fig. **7** shows typical curves obtained on an Equaliser No. **9A**. It should be noted that the letters L_{AB} have been used to denote the value of inductance between the A and B connections, i.e. L_P of Fig. **2***a*. These curves show that when measured between **600 Ω** non-reactive impedances the resonant frequency is dependent only upon the value of the inductance across which the condenser is connected.

Method of Use of Equaliser.

The method of use of the equaliser is an essentially practical one—more usually termed "trial and error," and is as follows:

(*a*) First measure the loss of the circuit to be equalised over the required frequency range. The adjustment of the equaliser is done mainly at three frequencies which are determined from the unequalised insertion loss characteristic of the circuit. These frequencies are—

(i) f_1 — the frequency at which the loss of the circuit is a minimum.

(ii) f_3—the highest frequency it is desired to transmit over the circuit. For loaded cables this is usually about **·75** of the cable cut-off frequency.

(iii) f_2 — the frequency at which the loss is the average of the loss at f_1 and f_3.

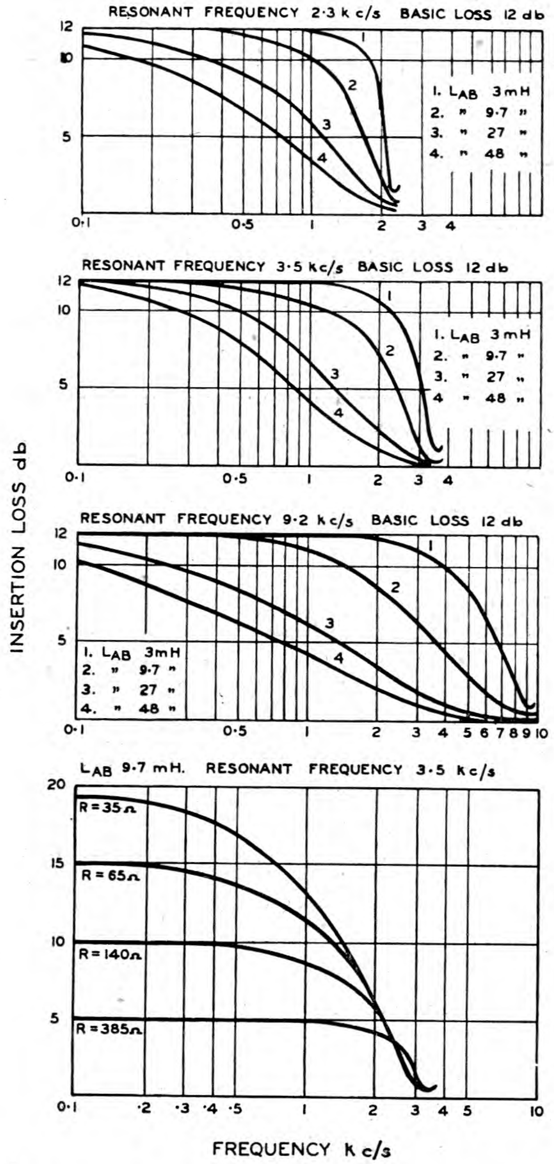


Fig. 7.—Typical Loss-Frequency Characteristics of Equaliser No. 9A (measured between 600Ω Impedances).

(*b*) Connect the equaliser to the circuit and with AB (see Fig. **5**) connected to tags **1** and **6** and CD connected to give resonance at least four steps above f_3; adjust the resistance so that the loss of the circuit—including the equaliser—measured at f_1 is between **0·5** db. and **1** db. more than the unequalised loss at f_3.

(*c*) Measure the loss of the circuit including equaliser at f_2 and adjust the A and B connections so that the loss is between **1·0** db. and

1·5 db. more than the unequalised loss at f_3. The loss at f_2 is decreased by increasing L_{AB}, i.e. the value of the inductance between the AB connections.

(*d*) Measure the loss at f_3 and reduce the resonant frequency by adjustment of the C and D connections so that the loss equals that at f_1. The nominal resonant frequency of the equaliser after the adjustment has been done correctly will never be less than f_3.

(*e*) A complete transmission loss-frequency test should then be made and if necessary slight readjustments made to the resistance, AB setting or CD setting to give a satisfactory equalised characteristic—usually ± 0·5 db.

Fig. **8** shows the characteristics obtained on an unloaded circuit at the end of each successive step described above.

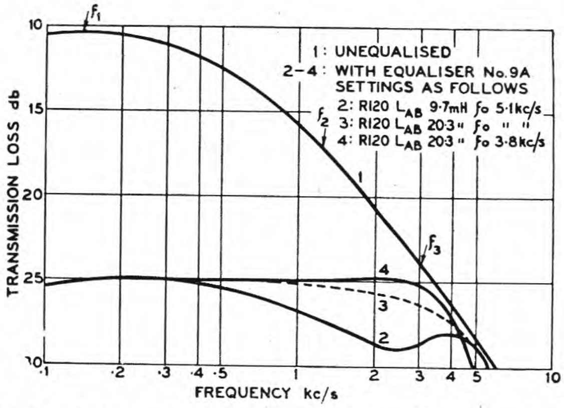


FIG. **8**.—EQUALISATION OF 16·5 MILES OF 40 LB. UNLOADED PHANTOM CIRCUIT.

Switchbox.

Although the Equaliser No. **9A** is completely variable it will be realised that the adjustment of the connections necessary during the setting-up of the equaliser can sometimes be laborious, particularly in view of the fact that the top of the case holds **25** tags. These tags are so close together that, in making test connections extreme care is necessary to avoid short-circuits. A switchbox—illustrated in Fig. **9**—has therefore been designed to simplify the setting-up of an equaliser. This switchbox, which measures **8½** in. × **5½** in. × **4¾** in., accommodates two radial switches, two toggle switches, a set of resistances connected to U-links and a special jack. By plugging the equaliser tags into the special jack the required connections can be set up on the two radial switches, one of which selects, in conjunction with a toggle switch, the required value of inductance for the AB connections. The other radial switch also in conjunction with a toggle switch enables the required resonant frequency to be selected. Variation of resistance is obtained by the test links.

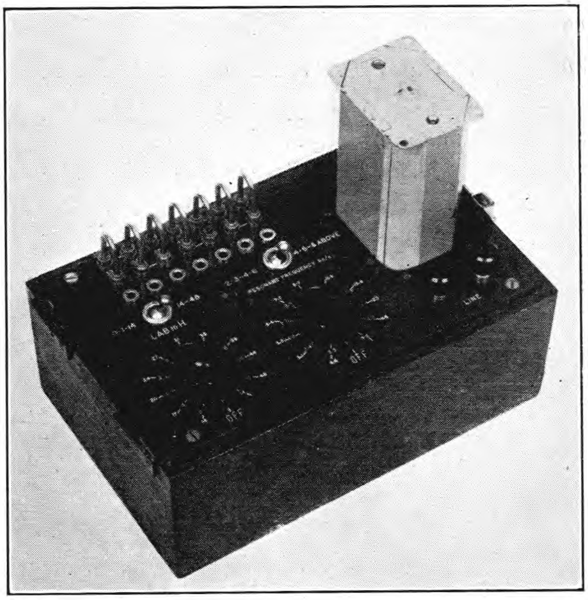


FIG. **9**.—SWITCHBOX FOR SETTING EQUALISER CONNECTIONS.

The tester enables the setting required on an equaliser for a particular circuit to be readily found, after which the equaliser is detached from the switchbox and used in the circuit concerned. It was not considered advisable to incorporate an Equaliser No. **9A** as an integral part of the tester, because, due to war-time restrictions a capacitance tolerance of up to ± **10** % had to be accepted. This means that the performance of the equalisers will probably vary to such an extent as to require different settings to produce the same insertion loss characteristics.

Conclusion.

Although designed primarily for use with the Amplifier No. **32** the Equaliser No. **9A** is likely to have a very useful field on all existing types of audio amplifiers or repeaters. Hitherto shunt equalisers have been fitted only on definite instructions from the E.-in-C. The new equaliser will probably be produced relatively cheaply, and there would appear to be no reason why equalisation should not be undertaken by repeater station staff provided instructions are given regarding the frequency response requirements for various classes or types of circuit.

Notes and Comments

Roll of Honour

The Board of Editors deeply regrets to have to record the deaths of the following members of the Engineering Department :—

While serving with the Armed Forces, including Home Guard.

Bedford Telephone Area ..	Fletcher, J. S. ..	Skilled Workman, Class I ..	Sergeant, Royal Air Force
Belfast Telephone Area ..	Haldane, R. ..	Labourer..	Gunner, Royal Artillery
Birmingham Telephone Area	Martin, C. F. ..	Unestablished Skilled Workman	Sergeant Navigator, Royal Air Force
Birmingham Telephone Area	Shelvington, W. H. A.	Unestablished Skilled Workman	Sergeant, Royal Air Force
Bournemouth Telephone Area	Downey, R. J. ..	Skilled Workman, Class II ..	Corporal, Corps of Military Police
Bradford Telephone Area..	Lumb, H. J. ..	Skilled Workman, Class II ..	Flying Officer, Royal Air Force
Brighton Telephone Area ..	Collier, A.	Skilled Workman, Class II ..	Acting Lance Bombardier, Royal Artillery
Brighton Telephone Area ..	Laker, W. J. ..	Labourer..	Sergeant, Royal Air Force
Brighton Telephone Area ..	Rudd, L. A. ..	Skilled Workman, Class II ..	Gunner, Royal Artillery
Bristol Telephone Area ..	Godfrey, R. S. T. ..	Skilled Workman, Class II ..	Lance Sergeant, Royal Corps of Signals
Engineering Department ..	Ellis, C. P.	Skilled Workman, Class I ..	Pilot Officer, Royal Air Force
Engineering Department ..	Maxwell, H. B. ..	Clerical Officer	Sergeant, Royal Air Force
Exeter Telephone Area ..	Mappin H.	Unestablished Skilled Workman	Flying Officer, Royal Air Force
Leeds Telephone Area ..	Holdsworth, B. ..	Unestablished Skilled Workman	Flight Sergeant, Royal Air Force
Liverpool Telephone Area..	Brade, F. V. ..	Skilled Workman, Class II ..	Flight Sergeant, Royal Air Force
London Telecommunications Region	Bolsworth, J. H. ..	Youth-in-Training	Leading Aircraftman, Royal Air Force
London Telecommunications Region	Burbridge, L. E. W.	Unestablished Skilled Workman	Midshipman, Royal Navy
London Telecommunications Region	Cloke, H.	Skilled Workman, Class II ..	Signalman, Royal Corps of Signals
London Telecommunications Region	Doe, J. H.	Skilled Workman, Class II ..	Major, Auxiliary Military Pioneer Corps
London Telecommunications Region	Eyles, C. T. ..	Labourer..	Sergeant, Queen's Royal Regiment (West Surrey)
London Telecommunications Region	Grove, E. G. ..	Unestablished Skilled Workman	Flying Officer, Royal Air Force
London Telecommunications Region	Kessock-Phillip, H. E.	Skilled Workman, Class II ..	Flying Officer, Royal Air Force
London Telecommunications Region	Palmer, T. H. E. ..	Labourer..	Aircraftman, Class II, Royal Air Force
London Telecommunications Region	Patrick, A. G. ..	Skilled Workman, Class II ..	Lance Corporal, Royal Corps of Signals
London Telecommunications Region	Simmonds, H. R. ..	Unestablished Skilled Workman	Flight Sergeant, Royal Air Force
London Telecommunications Region	Smith, W. T. ..	Skilled Workman, Class II ..	Lance Sergeant, Royal West Kent Regiment
London Telecommunications Region	Tolleth, J. A. ..	Skilled Workman, Class II ..	Sergeant, Scots Guards
London Telecommunications Region	Ware, W. H. ..	Labourer..	Private, Dorsetshire Regiment
London Telecommunications Region	Williams, C. ..	Skilled Workman, Class II ..	Corporal, Royal Corps of Signals
London Telecommunications Region	Williamson, J. F. R.	Skilled Workman, Class II ..	Signalman, Royal Corps of Signals

Manchester Telephone Area	Biddulph, S. ..	Skilled Workman, Class II ..	Sergeant Observer, Royal Air Force
Manchester Telephone Area	Hadfield, J. H. ..	Unestablished Skilled Workman	Sergeant, Royal Corps of Signals
Manchester Telephone Area	Sherwin, R. D. ..	Unestablished Skilled Workman	Private, Manchester Regiment
Nottingham Telephone Area	Rumsey, W. P. ..	Skilled Workman, Class II ..	Flight Sergeant, Royal Air Force
Oxford Telephone Area ..	Welford, W. B. ..	Unestablished Skilled Workman	Private, Oxford and Bucks Light Infantry
Reading Telephone Area ..	Penfold, D. J. ..	Unestablished Skilled Workman	Sergeant, Royal Air Force
Swansea Telephone Area ..	Bates, J. H. ..	Skilled Workman, Class I ..	Company Quartermaster Sergeant, Royal Corps of Signals
Swansea Telephone Area ..	Water, T. W. ..	Inspector	Sergeant Navigator, Royal Air Force

Recent Awards

The Board of Editors has learnt with great pleasure of the honours recently conferred on the following members of the Engineering Department :—

While serving with the Armed Forces, including Home Guard.

Belfast Telephone Area ..	Brannen, R. ..	Skilled Workman, Class II	Company Sergeant Major, Sherwood Foresters	Mentioned in Despatches
Bournemouth Telephone Area	Clater, J. W. ..	Skilled Workman, Class II	Captain, Royal Corps of Signals	Mentioned in Despatches
Brighton Telephone Area ..	Hope, G. W. ..	Draughtsman, Class II	Company Quartermaster Sergeant, Royal Corps of Signals	British Empire Medal
Lincoln Telephone Area ..	Wilkes, W. D. G.	Skilled Workman, Class II	Flight Sergeant, Royal Air Force	Distinguished Flying Medal
London Telecommunications Region	Davis, C. V. ..	Skilled Workman, Class I	Company Sergeant Major, Royal Corps of Signals	Mentioned in Despatches
London Telecommunications Region	Lawrence, W. S.	Skilled Workman, Class II	Regimental Quartermaster Sergeant, Royal Corps of Signals	British Empire Medal
London Telecommunications	Ware, E. T. ..	Unestablished Skilled Workman	Flight Lieutenant, Royal Air Force	Distinguished Flying Cross

New Year's Honours

The Board of Editors offers its sincere congratulations to the following members of the Engineering Staff who have been honoured by H.M. the King in the New Year's Honours List.

Bradford Telephone Area	Downward, F. ..	Draughtsman, Class I	British Empire Medal
Engineering Department	Nancarrow, F. E.	Staff Engineer ..	Officer of the Order of the British Empire
Engineering Department	Parker, P. N. ..	Inspector	British Empire Medal
London Telecommunications Region	Merrill, W. V. ..	Skilled Workman, Class I	British Empire Medal
London Telecommunications Region	Walton, W. R...	Assistant Engineer	Member of the Order of the British Empire
Northern Ireland Region	McCrossan, A. ..	Inspector	British Empire Medal

Regional Notes

Scottish Region

COAXIAL CABLE FAULT.

An interesting fault occurred recently on a coaxial cable route, which consists of "go" and "return" cables, each with a coaxial tube + 26 pr. P.C.Q.T. audio pairs. Subaqueous cables are used for a distance of 0·6 naut, and on January 24th, 1944, the "go" cable of this subaqueous section was crushed by a vessel going aground, the coaxial tube being short-circuited, but the audio pairs still remaining intact.

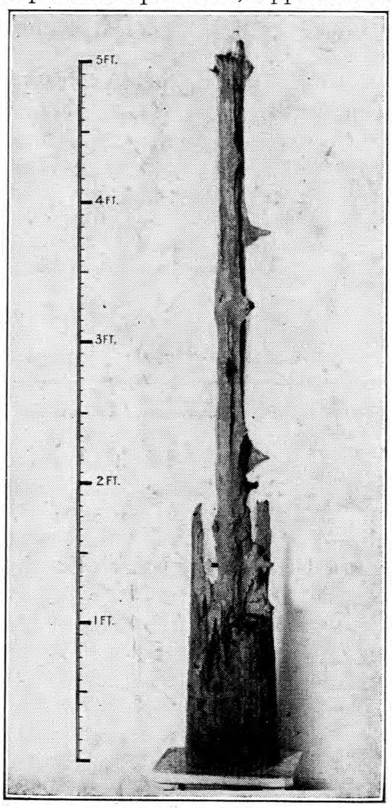
On the occasion of a previous fault a spare cable had been laid in this section and this was tested and the tube transferred. Before the spare cable could be brought into use, however, the vessel causing the trouble was refloated and in the process the spare cable was dragged slightly, the tube being pulled at two joints and thus disconnected.

It was decided to attempt the restoration of the coaxial system by disconnecting the outer tube of the original "go" cable at each side of the section and substituting a bunched audio pair, replacing the coaxial tube by the existing inner conductor and an audio pair. It was realised that this method would introduce serious extra attenuation, especially at the higher frequencies. The method was, however, tried, and it was found that the extra attenuation introduced could be compensated by the addition of group amplifiers. An additional gain of the order of 45-50 db. was provided in this manner. This enabled the system to be lined up to the initial figures, and satisfactory working continued until the repair of the subaqueous cables on February 2nd, 1944.

Home Counties Region

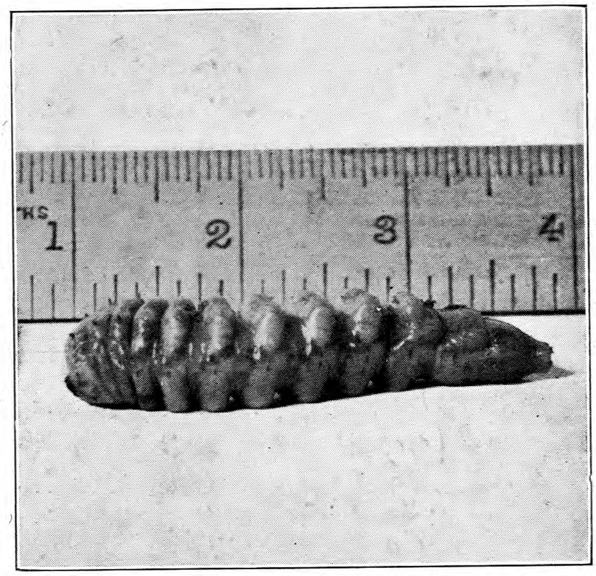
A NEW ENEMY

The accompanying photographs show the condition of 5 feet of a 26 ft. light pole dug out after it had collapsed at Spixworth, approximately 5 miles north of Norwich, November, 1943, and a larva of the beetle responsible for the damage. About 20 of the grubs were found in the decayed portion of the pole from the ground level to base; the attack had also extended for 2 ft. above ground level, but no sign of the damage underneath was discernible on the outer surface.



The larva is that of the Beetle Prionus Cariarius and is not very common in this country; it has, however, been found recently attacking oak trees in the woods near Spixworth. It is learned from the Curator at Norwich Museum that eggs are laid by the beetle under the bark of the oak, and the grubs, when developed, feed on the woody tissue of the tree. The cycle from the egg to beetle is completed in approximately 3 years, but development in the less sappy wood of a pole may extend to 5 or 6 years.

The photograph shows a female specimen and final development would have been reached some time in the Spring of 1944. It may be of interest to record that this larva has been retained by the Curator.



This is not the first case of its kind discovered in the Norwich Area; an isolated specimen was found in a stayguard at the end of February, 1943. In this case the grub was full fed and due to pupate and would probably have emerged as a perfect beetle in the following May or June. The grub in this instance had bored a hole for about 5 feet along the stayguard.

The pole was a creosoted Scots pine dated 1925.

G. B. B.

South-Western Region

REMOVAL OF A UNIT AUTOMATIC EXCHANGE

Owing to the extension of an air field it became necessary for the Post Office to abandon a building housing a U.A.X. 12 with 5 units and to shift the exchange to a new site. Owing to the extreme difficulty in obtaining labour for this work, which had to be done at short notice, the possibility of making the transfer without breaking down the multiple was given careful consideration and it was finally decided to attempt to move the 5 units en bloc.

Two large baulks of timber—12 in. by 4 in.—were placed along the length of the units, which were raised upon the timber so that the latter acted as two long skids. These were bolted to two cross timbers, one on either end, by ½ in. bolts recessed into the skids. The angle irons at the base of the units were held in position on the skids by large rose-headed nails driven down on either side and close to the angle irons. To obviate the possibility of the units flexing at the top, a complete "chimney breast" unit (No. 6) was utilised with lengths of steel wire to hold the tops of the units together.

After the preliminary work had been done and the circuits had been transferred to a mobile U.A.X. unit adjacent to the new site, the wall of the old building was knocked out, a 3 ton lorry with a power driven winch was backed into position, and by means of the winch and rollers the 5 units mounted on their skids were drawn up into the body of the lorry.

In the new building arrangements had been made with the contractor to leave the doorway a foot or so higher than the final size so that the units could be passed in through the doorway on their skids. Owing to the level of the ground on which the new building was built, the skids from the 3 ton lorry to the entrance to the new building were practically horizontal and it was an easy matter, therefore, using rollers, to manhandle the 5 units on their cradle into the correct position.

The whole operation was successfully carried out in three hours, including the work of placing and removing the skids, transferring to the 3 ton lorry and unloading, and placing in final position. Not a single disconnection was proved in the multiple and it is estimated that about 200 manhours were saved through not having to re-terminate the multiple.

W. & B.C. Region

TRUNK CIRCUITS ON STAR QUAD PHANTOMS

Recent developments in this Region created demands for long distance circuits at short notice. These circuits were required over a link which for 65 miles was already worked to its full capacity of physical circuits. The cables on this link were of the star quad type. To provide the service needed until such time as an additional cable could be laid, Headquarters decided to experiment with the setting up of ten circuits on the phantoms of existing circuits.

The 65 miles of route was divided into five amplifier station sections. The amplifier equipment at each station consisted of an emergency repeater bay, a back board accommodating transformers, equalisers, etc., and a small main frame. Suitable accommodation was found at Post Offices and on non-official premises along the route except in one case, where a plot of ground was rented near the cable track and a battery hut erected and the equipment installed in the hut.

The electric power mains were available at each amplifier station site with one exception. Here, only a 22 kV supply was in the locality. The Power Company concerned, however, provided from this the 230 volts needed within three weeks of the official request.

The frequency/attenuation characteristics of the unloaded phantoms were such that equalisation had to be used as, of course, was expected. Because of the large amount of basic loss inserted by the equalisers a balance had to be struck between the output level of the link and the frequency range over which it was possible to equalise. With an output level of + 7 db., it was, found that it was only possible to equalise over the range 0 –2,600 c/s. To raise the output to + 10 db. the range 0 – 2,200 c/s only could be equalised.

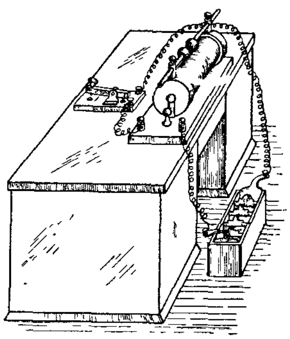
The crosstalk side-to-phantom in the worst cases was judged to be approximately 40-45 db., and similar results were obtained in the worst cases in the phantom-to-side direction.

The whole work, including the necessary circuit rearrangements to clear the wanted phantoms of the side circuit signalling facilities, was planned and completed in six weeks, and since being set up the circuits have worked satisfactorily. S. J. M.

Meeting of Sir William Preece and Signor Marconi

The following notes regarding the first meeting of Mr. Preece (later Sir William Preece), Engineer-in-Chief of the Post Office, and Signor Marconi, were received from Mr. P. R. Mullis, who has recently retired from the service.

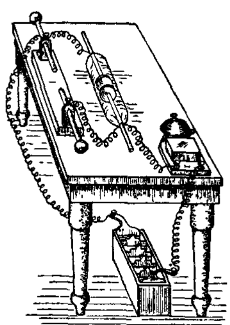
" One morning in the year 1896 Mr. Probert (the Electric Light Superintendent) brought into Mr. Preece's room a young dark looking foreigner, who was introduced as Signor Guglielmo Marconi. Signor Marconi had with him two large leather bags, the contents of which were placed on the table, and seemed to consist of a number of brass knobs fitted to rods, a large spark coil and some odd terminals, but, most fascinating of all, a rather large-sized tubular bottle from which extruded two rods, terminating inside the bottle on two bright discs very close together and between which could be seen some bright filings or metal particles.



CHIEF'S TABLE WITH KEY, SPARKING COIL & BRASS BALLS IN ANTENNA CIRCUIT (SENDING)

A key, some batteries and the spark coil were joined in series, and two of the rods fitted with the brass balls were passed through the large outer terminals of the spark coil. The curious glass tube (now spoken of as the coherer) was placed on a small table, and was joined in series with some batteries and a bell. Two of the rods fitted with balls were also included in this circuit. A general impression of the apparatus is given in the sketches.

After one or two preliminary adjustments to the connections and brass balls by Signor Marconi, the key was depressed, and immediately the bell on the adjacent table commenced and continued to ring. Marconi then went over to the glass tube and gave this a few sharp taps, when the bell ceased ringing. Again the key was depressed, and again the bell rang, and continued to do so until the tube was shaken.



SMALL ADJACENT TABLE, WITH BRASS BALLS IN ANTENNA CIRCUIT, COHERER & BELL (RECEIVING CIRCUIT)

I knew by the Chief's quiet manner and smile that something unusual had been effected.

The following day, and rest of the week, were given over to further experimenting, which included putting a leather pad on the hammer of a heavier bell after short-circuiting the contact pillar so that in action it automatically was brought into contact with the coherer and " de-cohered " it. It was but a short stage from this, and by successive steps that a complete Morse system of signalling was built up."

Staff Changes

Promotions

Name	Region	Date
C.R.E. to Deputy R.D.		
Semple, L. G.	H.C. Reg. to N.E. Reg.	1.1.44
Deputy C.R.E. to C.R.E.		
Hudson, W. E.	H.C. Reg.	1.1.44
Reg. Engr. to Dep. C.R.E.		
Tolley, L. L.	H.C. Reg.	1.1.44
Exec. Engr. to A.S.E.		
Jackman, A. J.	E.-in-C.O.	11.12.43
Gould, E. F. H.	E.-in-C.O.	11.12.43
Bryden, J. E. Z.**	N.E. Reg. to H.C. Reg.	1.2.44
Blake, D. E.	W. & B.C. Reg. to H.C. Reg.	1.2.44
Area Engr. to T.M.		
Knowers, A. D. V.	H.C. Reg.	1.1.44
Towers, R.	N.E. Reg.	1.1.44
Asst. Engr. to Exec. Engr.		
Smith, G. E.	L.T. Reg. to Scot. Reg.	1.1.44
Turner, H. A.**	E.-in-C.O.	20.2.44
Smithers, F. A.	N.E. Reg.	23.1.44
Swain, E. C.	E.-in-C.O.	21.12.43
Adam, S. A. F.	N.E. Reg.	4.1.44
Sheppard, J. A.**	E.-in-C.O.	21.12.43
Floyd, C. F.	E.-in-C.O.	12.2.44
Fairweather, A.	E.-in-C.O.	21.12.43
Sulston, W. J.	Scot. Reg. to E.-in-C.O.	20.2.44
Asst. Engr. to Senior Physicist		
Josephs, H. J.	E.-in-C.O.	18.12.43
Chief Insp. to Asst. Engr.		
Wells, H. G.	L.T.R.	25.1.44
Hobsbaum, J.	N.E. Reg.	30.1.44
Knights, G. A.	H.C. Reg.	9.1.44
Biggers, P. S. S.	Scot. Reg.	20.2.44
Morgan, L. O.	L.T.R.	13.12.43
Wiltshire, R. E.	S.W. Reg.	13.2.44
Winter, F.**	H.C. Reg. to L.T.R.	13.12.43
Worth, W. B.	L.T.R.	13.12.43
Deacon, T. A. F.	E.-in-C.O.	13.12.43
Hall, A. W.	N.W. Reg.	13.12.43
Adams, W. R.	N.W. Reg. to E.-in-C.O.	13.12.43
Clark, R. J.	Mid. Reg.	16.1.44
Pierson, J. H.	N. Ire. Reg.	17.12.43
German, A. G.	E.-in-C.O.	6.1.44
Masters, E. J.	H.C. Reg.	20.2.44
Surman, W. L.	Mid. Reg. to E.-in-C.O.	16.1.44
Newson, F. W.	E.-in-C.O.	4.2.44
Britton, A. D.	H.C. Reg.	6.1.44
Endicott, A. H.	W. & B.C. Reg. to E. in-C.O.	20.1.44
Heron, K. M.	E.-in-C.O.	4.2.44
Birss, R. R.	E.-in-C.O.	4.2.44
Chief Insp. to Chief Insp. with Allce.		
Morris, G.	N.W. Reg.	1.1.44
Thompson, J.	N.W. Reg.	30.10.43
Preston, I. G.	Mid. Reg.	1.1.44
Insp. to Chief Insp.		
Fegan, G. R. F.	S.W. Reg.	6.2.44
Moores, H. J.	N.W. Reg.	13.12.43
Jordan, T.	N.E. Reg.	5.12.43
Hornsby, G.	L.T.R.	1.1.44
Nokes, H. R.	L.T.R.	1.2.44
Blunt, C. E.	L.T.R.	16.11.43
Theobald, H. A.	L.T.R.	13.12.43
Waterhouse, L. R.	N.E. Reg. to N.W. Reg.	13.2.44
Crook, F.	L.T.R.	25.1.44
Thompson, S.	E.in.C.O. to H.C. Reg.	6.2.44
Dootson, G. W.	L.T.R. to H.C. Reg.	16.1.44
Jago, R. T.	L.T.R. to H.C. Reg.	6.2.44
Roberts, W. E. C.	S.W. Reg.	13.2.44
Peach, R. S.	E.-in-C.O.	19.1.44
Tinsley, W. S.	E.-in-C.O.	1.2.44
Young, A.	Scot. Reg.	26.2.43
Kilgour, C. E.	Scot. Reg.	16.12.43
Eastwood, D.	N.W. Reg. to E.in-C.O.	13.2.44
Mitchell, S. C.	S.W. Reg.	13.2.44
Pratten, L. W.	S.W. Reg. to E.in-C.O.	13.2.44
Cameron, J. W.	Scot. Reg.	6.11.43
Honeybone, A. J.†	Test Section (Ldn.)	11.10.43
Harris, H. B.	Test Section (Ldn.)	11.10.43
Chilver, L. W. J.	E.-in-C.O.	9.11.41
Richards, H. B.	E.-in-C.O.	1.1.44
Insp. to A.T.S.		
Goodger, J. F.	L.P. Reg. to Scot. Reg.	14.7.43
S.W.1 to Insp.		
Day. W. J.	Test Section (Ldn.)	29.8.43
Foott, W. E.	Test Section (Ldn.)	5.9.43
Butler, L. H.	Test Section (Ldn.)	18.9.43
Cooley, S. J.	E.-in-C.O.	28.10.43
Dawson, G. H.	E.-in-C.O.	1.1.44
Ratcliff, D. J.	E.-in-C.O.	9.1.44
Shaw, M. L.	E.-in-C.O.	12.1.44
Gould, B. B.	E.-in-C.O.	16.1.44
Holmes, T. E.	E.-in-C.O.	9.1.44
Elliott, R. L.†	E.-in-C.O.	9.1.44
Millson, H. W.**	E.-in-C.O.	9.1.44
Setchfield, W. F.**	E.-in-C.O.	9.1.44
Hillier, F. C.	E.-in-C.O.	9.1.44
Gorton, B. D.†	E.-in-C.O.	9.1.44
Lamont, K.**	E.-in-C.O.	9.1.44
Brown, B. F.	E.-in-C.O.	9.1.44
Wood, R. A.	E.-in-C.O.	9.1.44
Lockwood, C. W.	Test Section (Ldn.)	6.9.43
Langford, C. C.	Test Section (Ldn.)	21.9.43
Second Engr. to Chief Engr.		
Fisher, H. C.	H.M.T.S.	1.1.44
Third Engr. to Second Engr.		
Jones, T. L.	H.M.T.S.	7.2.44
Fourth Eng. to Third Engr.		
Johnston, J. H.	H.M.T.S.	7.2.44
Fifth Engr. to Fourth Engr.		
Andrew, J. A.	H.M.T.S.	7.2.44

Retirements

Name	Region	Date
Dep. E.-in-C.		
Ridd, P. J.	E.-in-C.O.	31.12.43
Asst. Engr.		
Mitchell, T. A.	E.-in-C.O.	31.12.43
Stiles, O. S.	E.-in-C.O.	31.12.43
Wade, A. H.	N.E. Reg.	31.12.43
Lampard, F. P.	E.-in.C.O.	31.1.44
Chief Insp. with allce.		
Attenborough, F. C.	Mid. Reg.	31.12.43
Tansley, R.	N.W. Reg.	31.12.43
Chief Insp.		
Hayton, E.	S.W. Reg.	31.12.43
Fisher, F. C.	L.T.R.	31.12.43
Faithfull, F. E.	H.C. Reg.	31.12.43
Trickett, A. W. R.	L.T.R.	31.1.44

Name	Region	Date
Insp.		
Peverett, E. A.	H.C. Reg.	28.7.43
Courtis, F. J.	Mid. Reg.	18.9.43
Hoy, H. H.	N.W. Reg.	20.10.43
Marshall, F. E.	N.E.R.	31.10.43
Rickard, S. G.	W. & B.C. Reg.	31.10.43
Burgher, H.	Scot. Reg.	12.11.43
Everett, J. W.	L.T.R.	31.12.43
Greenland, G. A.	Mid. Reg.	31.12.43
Mellish, A.	Scot. Reg.	31.12.43
Rees, H. W.	Mid. Reg.	31.12.43
Mason, F. G.	Mid. Reg.	31.12.43
Tagholm, C. F.	W. & B.C. Reg.	31.12.43
Blacon, W. J.	N.W. Reg.	31.12.43
Haseley, S. H.	H.C. Reg.	31.12.43
Reeves, H.	Mid. Reg.	9.2.44
Chuter, A.	S.W. Reg.	29.2.44
Chief Engr.		
Dunlop, A.	H.M.T.S.	31.12.43
Senior Draughtsman		
F. L. Knight	L.T.R.	31.12.43
Draughtsman Class I		
Heggie, T.	Scot. Reg.	30.1.44

Transfers

Name	Region	Date
Reg. Engr.		
Palmer, W. T.	Mid. Reg. to H.C. Reg.	28.11.43
Stratton, J.	E.-in-C.O. to Mid Reg.	9.12.43
Exec. Engr.		
Charles, F. N.	N.E. Reg. to H.C. Reg.	5.12.43
Smith, D.	N.E. Reg. to E.-in-C.O.	13.2.44
Asst. Engr.		
Rimes, R. E.	E.-in-C.O. to N.E. Reg.	29.11.43

Name	Region	Date
Prob. Asst. Engr.		
Holmes, M. F.	Test Section (Ldn.) to E.-in-C.O.	1.1.44
Jemmeson, A. E.	Scot. Reg. to E.-in-C.O.	1.1.44
Insp.		
Penfold, F. L.	H.C. Reg. to L.T.R.	16.10.43
Cross, R. J.	S.W. Reg. to H.C. Reg.	1.11.43
Stooke, G. H.	Mid. Reg. to E.-in-C.O.	1.1.44
Bowen, R. F. R.	N.E. Reg. to E.-in-C.O.	2.1.44

Deaths

Name	Region	Date
Draughtsman Class I		
Whitton, J.	N.E. Reg.	14.12.43
Tech. Asst.		
Wilkinson, R. H.	N.E. Reg.	19.2.44
Chief Insp.		
Johnston, A. N.	Scot. Reg.	2.12.43
Gilpin, A.	S.W. Reg.	18.12.43
Insp.		
Russell, D. H.	W. & B.C. Reg.	3.5 43
Lillie, R.	Scot. Reg.	13.5.43
Willard, R.	H.C. Reg.	11.7.43
Archer, E.	Mid. Reg.	30.8.43

Name	Region	Date
Insp. (continued)		
Williams, H. S.‡	N.W. Reg.	20.9.43
Hilton, H.	N.W. Reg.	4.10.43
Stockton, A.	W. & B.C. Reg.	5.10.43
Smellie, D. M.	Scot. Reg.	16.10.43
Brackenborough, L. W. E.	L.T.R.	15.12.43
Oliver, J. E.	L.T.R.	4.1.44
Waters, T. W.‡	W. & B.C. Reg.	7.1.44
Gallagher, L. J.	L.T.R.	18.1.44
Worthington, D. C.	E.-in-C.O.	25.1.44
Donkeyman		
Roberts, C.	H.M.T.S.	30.1.44

CLERICAL GRADES

Promotions

Name	Region	Date
C.O. to E.O.		
Taylor, W. G.	E.-in-C.O.	18.1.44
Ellis, A. E. (Miss)**	E.-in-C.O.	18.2.44

Name	Region	Date
C.O. to E.O. (continued)		
Chandler, D. M. (Miss)	E.-in-C.O.	18.2.44

** Promoted in absentia. † On loan to another Government Department. ‡ Killed on Active Service.

Book Reviews

"Plastics in the Radio Industry," E. G. Couzens, B.Sc., A.R.C.S., and W. G. Wearmouth, Ph.D. 57 pp. 22 ill. Hulton Press, Ltd. 2s. 6d.

The booklet is one of a series of technical monographs which are being issued by the publishers of "Electronic Engineering" and which are intended to provide in a compact form information otherwise only obtainable from a number of books and periodicals. An outline is given of the nature, structure and manufacture of the various types of plastics, one thermo-plastic material (Xylonite) and one thermo-setting material (phenol-formaldehyde) being treated in rather greater detail. Tables of the physical and electrical properties of various plastics are given and there is also a useful table which shows the trade name, maker, type, basic colour and forms in which marketed of various commercial plastics. A chapter is devoted to the methods of manipulation of plastics, including cementing and moulding. One appendix gives a list of solvents and cements for use with various plastics and another gives a list of books and articles in periodicals dealing with the subject. This booklet forms a useful introduction to the subject of plastics and is a good half-crown's worth.

R. L. B.

"Electrical Technology for Telecommunications." W. H. Date, B.Sc., A.M.I.E.E. 160 pp. 115 ill. Longmans, Green & Co. 5s.

The diversion of the energies of engineers to more war-like pursuits, coupled with the shortage of paper, have made the appearance of new engineering text-books something of a rarity. One therefore expects to find the few that are published books of exceptional merit. It is perhaps this high standard unconsciously set and heightened by the ultra-modern cover of Mr. Date's book, that leads to a certain sense of disappointment, for inside there is much the same material as in other electrical technology text-books presented in much the same manner.. But there is a difference, for Mr. Date has deliberately set out to make the book readable to the beginner, by assuming the minimum of knowledge on the part of his readers and by the absence of mathematical proofs for many of the statements made. In this respect his book will appeal to a large section of students, although those slightly more advanced may not be content to take, without proof, the various formulæ given.

As regards the thorny problem of the order in which the subject should be taught, Mr. Date commences with D.C., introduces magnetism with the magnetic effect of a current, followed by elementary A.C. theory, and finishes with chapters on the transformer, instruments and cells. This order suffers from the disadvantage that the student learns little of the instruments he uses in the laboratory until late in his second year. Static electricity is almost completely omitted, and in this respect the book does not fulfil the author's claim to cover the City and Guilds examinations in Technical Electricity. Other omissions are the megger (although the dynamometer principle is explained) and Kirchoff's laws.

The book cannot be considered as a comprehensive treatment of the subject, but as an introduction for the new recruit it can be confidently recommended.

H. L.

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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: HEAdquarters 1234. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

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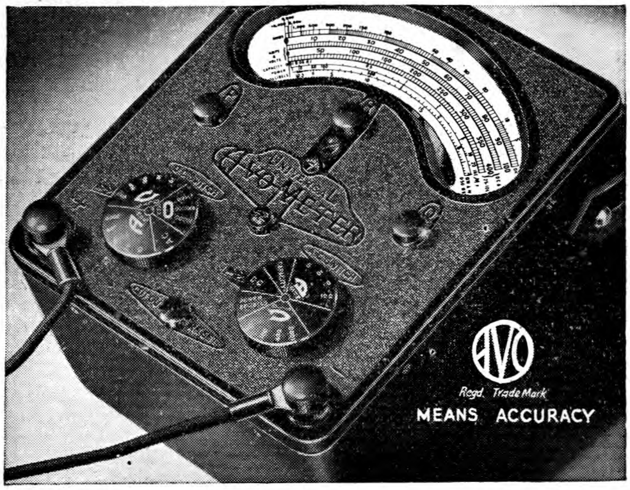

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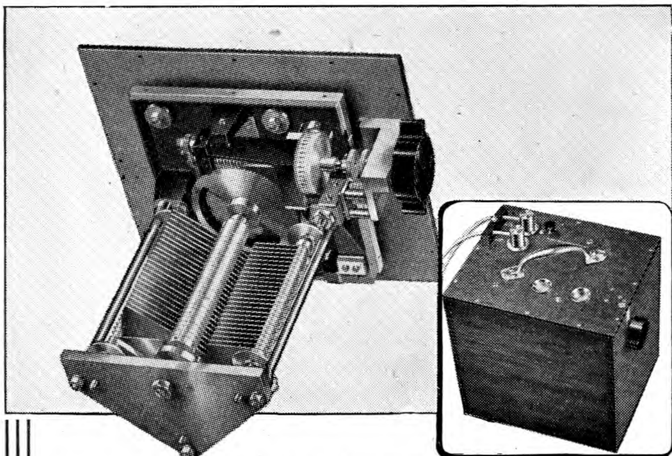

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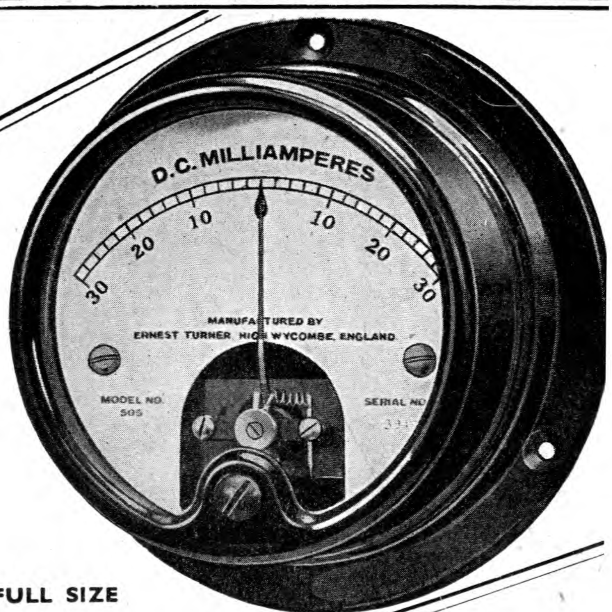

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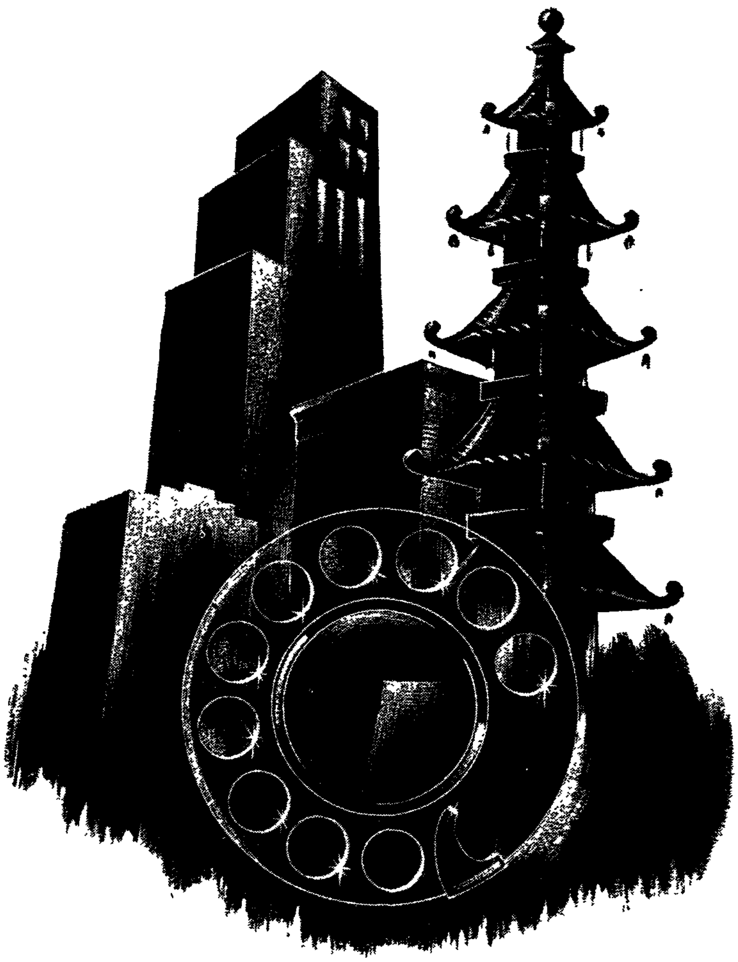

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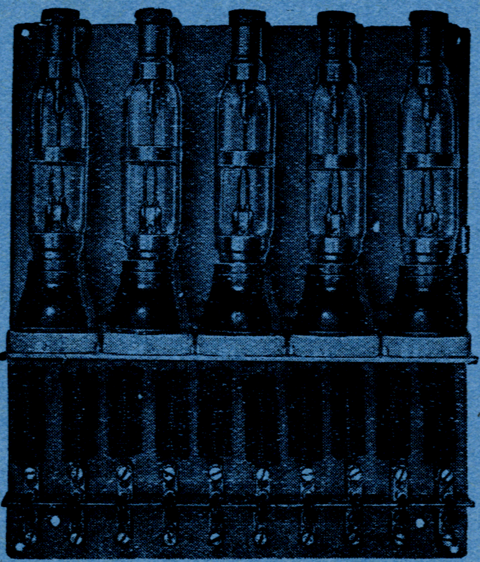

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