Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

2/- DEC., 1945

ELECTRONICS

made it possible!

Hullo skipper, flares gone—and the aircraft climbs away setting course for base, its reconnaissance pictures safely locked in the automatic camera. For the white-hot brilliance of the bursting flares operated a tiny OSRAM photo cell which automatically actuated the camera mechanism, permanently recording the panorama below.

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Electronic Engineering

DECEMBER, 1945

Volume XVII. No. 214.

CONTENTS

PAGE


Weather Forecast . . .
High in the sky . . . above the clouds . . . soars a balloon . . . automatically sending by radio, data on the always topical weather.
The meteorological stations are regularly releasing these upper-atmosphere mobile transmitters to predict the future weather.
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Electronic Engineering

EDITOR
G. PARR.

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 43-44, SHOE LANE, LONDON, E.C.4

TELEPHONE
CENTRAL 7400

Monthly (published last day of preceding month) 2/- net. Subscription Rates: Post Paid to any part of the World—6 months, 13/-; 12 months, 26/-. Registered for Transmission by Canadian Magazine Post.

TELEGRAMS
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Notice Board

Completion of Volume

THIS issue completes Volume XVII of this Journal—from June, 1944, to December, 1945. The volume thus contains 18 issues instead of the customary 12, an arrangement made to enable subsequent volumes to coincide with the year.

The publishers regret that it is not yet possible to arrange for a standard uniform binding, but " self-binders " are recommended to keep the issues in good condition until a more permanent cover is available. These " self-binders " hold 24 copies which are slipped through strings in the spine to keep them in place, and can be obtained from the Circulation Dept., price 3s. 6d. post free.

Binding Covers for *Electronics and Short Wave World*, as this Journal was formerly called, can still be obtained, price 2s. 3d. post free.

Supply of Copies

Nearly all the stock of copies of *Electronic Engineering* is exhausted within a few days of issue. The paper restrictions still do not allow us to print sufficient copies to satisfy the demand.

Readers who see occasional copies but cannot obtain them regularly are invited to register their names with the Circulation Dept., to be placed on the priority list. They will be notified when further copies become available.

Regular readers who have any difficulty in obtaining their copies should write to the Circulation Dept. The name and address of their usual newsagent should be given in each case.

Back copies

Before applying for back copies, please inquire first whether they are available. This will save the staff time and trouble in returning money sent if the copies are not in stock.

Owing to the steady demand for back copies, any reader having clean copies for disposal should write to the Circulation Dept. giving particulars of month and year. A fair price will be paid for all copies in good condition accepted.

Monographs

Owing to paper difficulties, it is regretted that the issue of the *Electronic Engineering* Monographs has been unduly delayed.

The third Monograph is now in press, and will be issued shortly. It is entitled:

" The Electron Microscope "

by Dr. D. G. Gabor

and forms a valuable and authoritative account of the theory, present performance, and future possibilities of this instrument. The price is 4s. 6d. from all technical booksellers, or 4s. 9d. post free from the Circulation Dept.

Earlier Monographs in the series were:

Frequency Modulation
by K. R. Sturley, Ph.D.

(a few copies left)

and

Plastics in the Radio Industry
by E. G. Couzens, B.Sc., and W. G. Wearmouth, Ph.D.

Copies of these are still available, price 2s. 6d., or 2s. 8d. post free from the publishers. Address as below.

All inquiries regarding sale of copies or Monographs should be addressed to: The Circulation Department, Hulton Press, 43, Shoe Lane, London, E.C.4.

Demonstrating the Properties of Aerials

Instructional Equipment Used at the School of Signals

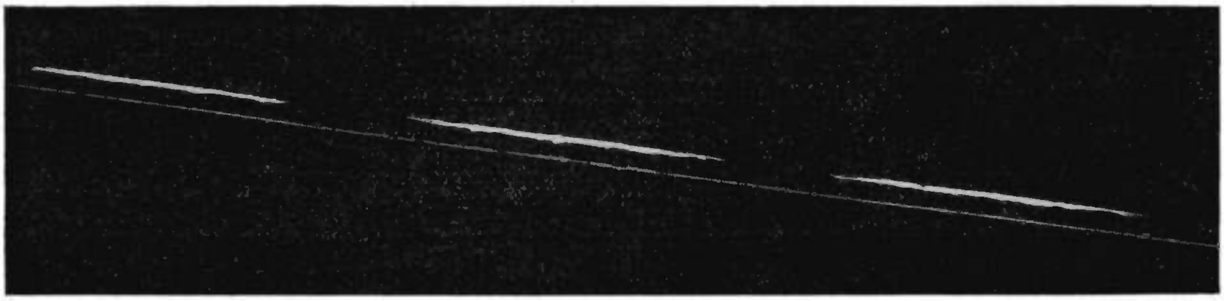
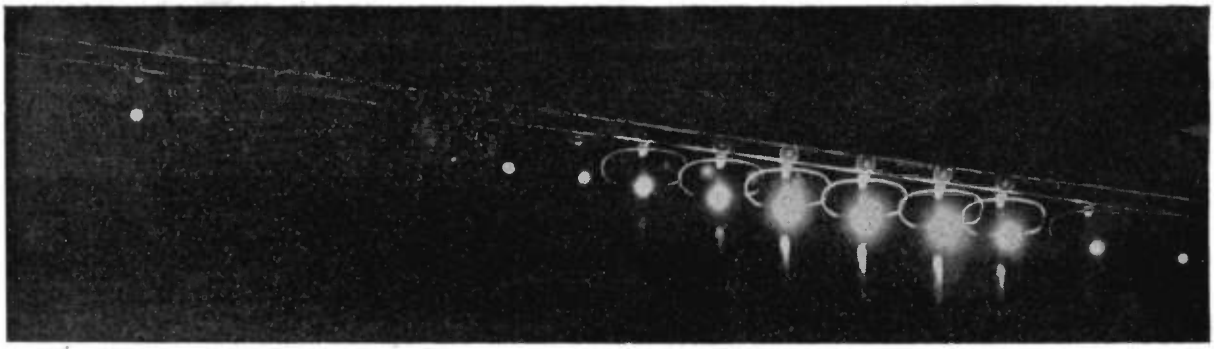


Fig. 3 (above). Standing wave of current on O.C. line. The trace is made by the traverse of the detector of Fig. 2B along the line.

Fig. 4 (below) Standing wave of current on O.C. line. A similar trace to that of Fig. 7 formed by successive images of the detector.



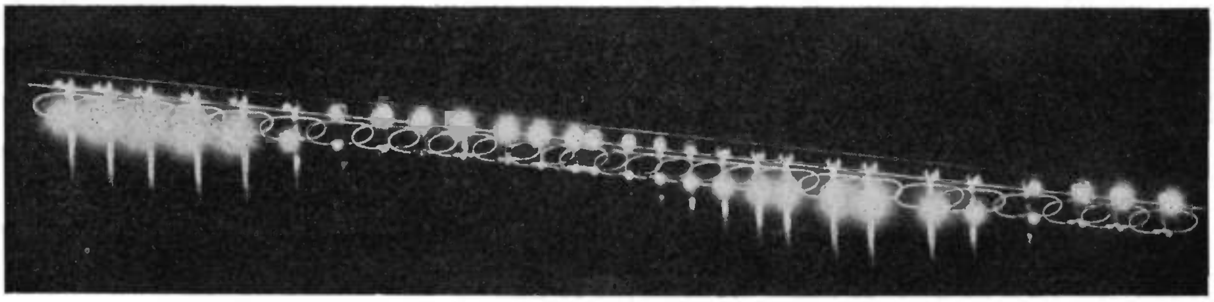
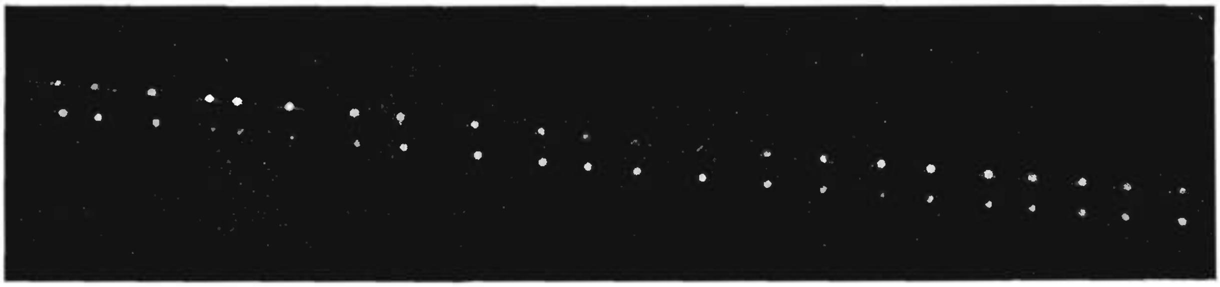


Fig. 5 (above). Current and voltage on O.C. line. The upper row of lights indicates voltage, the lower current, distribution. Successive images of the detector of Fig. 2C are shown.

Fig. 6 (below). Line terminated in 490 ohms. The termination approximates to the characteristic impedance: the variation of both current and voltage is less marked and the maxima are less intense. Same exposure as Fig. 5.



Introduction

THE performance of an Army radio sender in itself is decided in the main by the designer and in accordance with the specification laid down for it. The operator has little latitude in deciding the output power available from the P.A. The choice of aerial and the estimation of correct dimensions—and hence the far-end signal strength—depends, however, to a considerable extent on the officer or N.C.O. in charge of the station in the field. An understanding of the fundamentals of aerials is therefore essential for all wireless personnel in the Royal Corps of Signals. The layout described is designed by the Wireless Section of Signals Wing to demonstrate these fundamentals to students at the School of Signals.

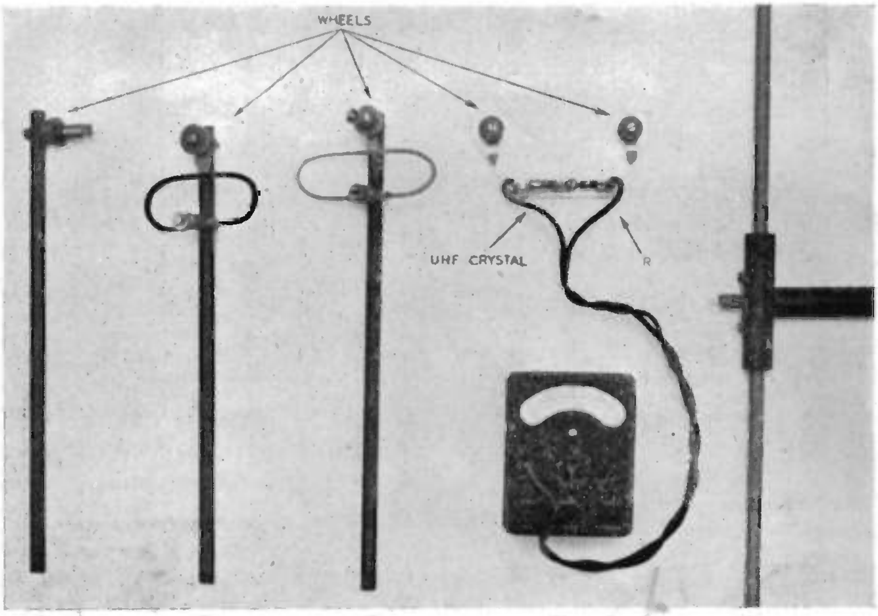
The technical standard of the demonstration is adjusted to suit the needs of the course under instruction and, although the principles illustrated are elementary, even the most advanced courses find this visual training a useful adjunct to lectures as a preliminary to practical work on full-scale aerials.

The basis of the demonstration is a V.H.F. oscillator and distribution system; the latter requires particular attention as radiation from sources other than that under investigation will falsify results. The auxiliary equipment falls under headings according to use—that for the visual summary of the principles of line transmission at radio-frequencies, a second set for the visual indication of radiation phenomena—polar diagrams, polarisation and the like—and thirdly, a set of typical aerials in miniature, showing their layout and current distribution.

Oscillator and Distribution System

The oscillator delivers approximately 45 watts at 150 Mc/s. It is of the push-pull resonant line type using two DET12's with tuned filament leads. The circuit diagram with values and operating conditions is given in Fig. 1. The frequency chosen represents the best compromise between the conflicting needs of a sufficiently visible physical layout and of obtaining aerial sizes suitable for the restricted space available. As it is, long-wire arrays such as rhombics are impracticably large.

The oscillator output is coupled by hairpins to three separate outlets. The first delivers the full output



A B C D E

Fig. 2. A and C have conducting contact wheels. D is used for measurement of standing wave ratio. E is the type of $\lambda/2$ receiving indicator used in many of the dems.

into a 70-ohm feeder running to a concentric socket and thence to either the transmission line or to any one aerial in the radiation section of the display. The other two outlets are intended to serve with much smaller amounts of power the parallel-connected feeders for the miniature aerials; these latter are very weakly coupled to the oscillator. One of these two outlets energises unbalanced aerials, the other being used for dipoles only.

All the miniature aerials are arranged for switching by relays operated either by push-buttons or by a dial. All the branch feeders are brought on to parallel lines running above the relay contacts and the lines

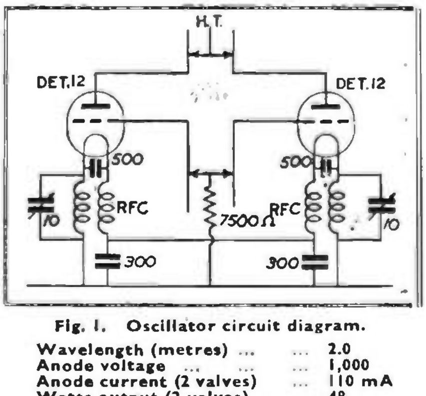


Fig. 1. Oscillator circuit diagram.

Wavelength (metres)	2.0
Anode voltage	1,000
Anode current (2 valves) ...	110 mA
Watts output (2 valves) ...	48
Anode efficiency	44%
Anode dissipation (per valve)	31 W

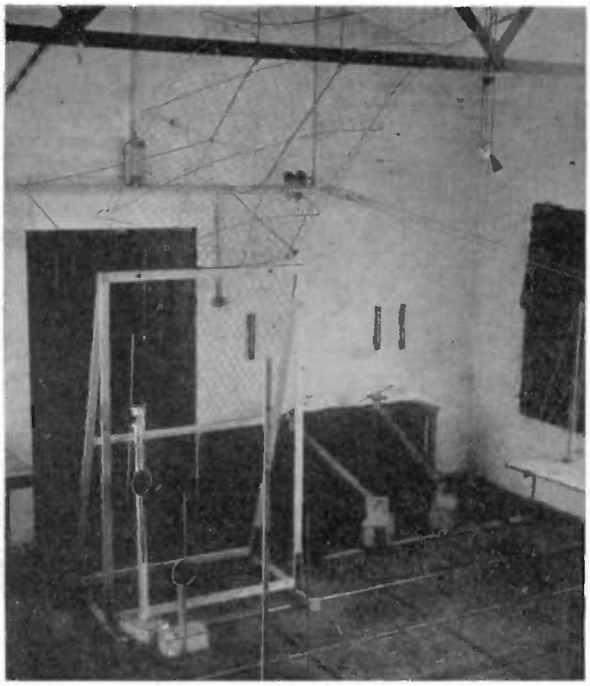
themselves are then paralleled on to the oscillator coupling link terminals.

The relays are P.O. 3,000 types, modified to carry phosphor-bronze contacts shorted together and making directly on to the transmission lines. The travel is about 0.3 in. The relays are normally held closed, shorting out their associated feeders. Since the shorting point is arranged to be a quarter-wavelength from the oscillator outlet terminals, the shorted and therefore inoperative feeders present a very high impedance to the oscillator and do not affect the feeder actually in operation. The shunting action of an open relay on a working feeder is slight.

Coupling to Miniature Aerials

For the miniature aerials further weakening of the coupling to the oscillator is required and, in addition, unbalanced aerials must be so fed that they do not seriously unbalance the capacity of the oscillator terminals to ground. If any feeder does become unbalanced then the quarter-wave sections between the terminals of the oscillator and the relays radiate excessively and disturb the results of the radiation section of the display. The unbalance may also affect the results obtained on the other miniature aerials when in use.

Balancing of the lines is achieved by using half-wave phasing loops; tapping-in the unbalanced feeder



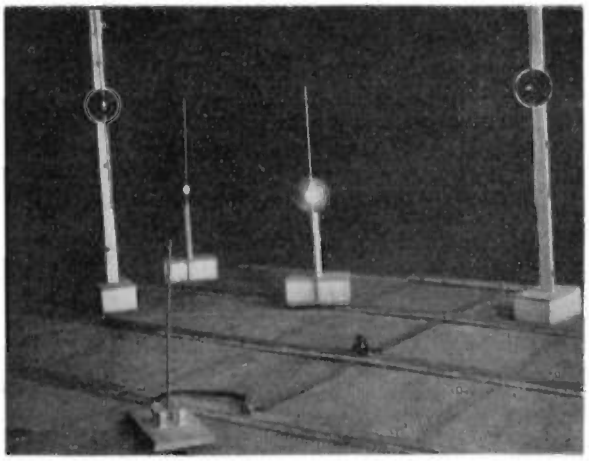
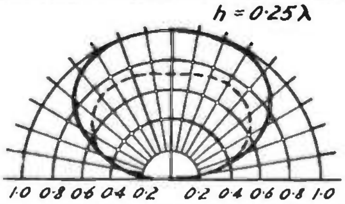
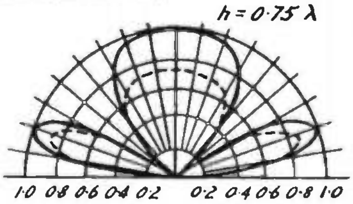
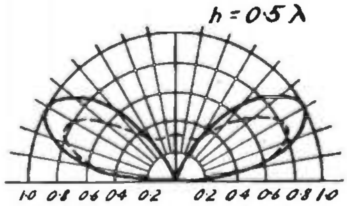


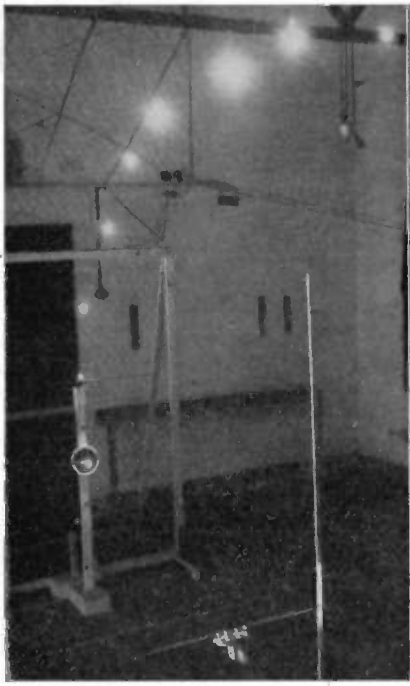
Fig. 8 (above). Vertical $\lambda/4$ radiator Increased ground-wave radiation indicated by increased brilliance of two lower indicators. Upper indicators show no increase of higher angle radiation.

Fig. 7 (left). Vertical $3\lambda/4$ rod. The low angle lobe is exciting pick-ups of both sides of the arc. The nearer pick-ups are out of focus and show as two bright circles on the right-hand side of the picture. Note the lack of ground-wave radiation indicated by the lowest white-ringed pick-up.









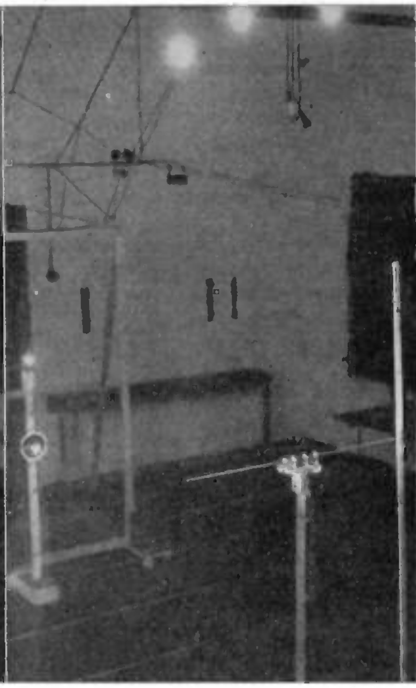


Fig. 9. Dipole $\lambda/4$ above ground. The pattern shows maximum radiation vertically upwards although it is only the lowest angles which show very little. The dotted curve above shows the predicted pattern for average ground.

Fig. 11. Dipole $3\lambda/4$ above ground. Further increase of height produces both high and low angle radiation. If the aerial is lower than $\lambda/4$, Fig. 9 applies always. Figs. 9 to 11 were taken by a 3-exposure method at equal times.

Fig. 10. Dipole $\lambda/2$ above ground. The radiation is now at a low angle with little upwards. A slight increase of brightness in the topmost lamps is discernible and is accounted for by the dotted curve above for imperfect ground.

down one of these loops gives control over the tightness of the coupling. Alternatively, an insulated wire twisted round both feeder legs and acting as a shunt capacity has also the required effect, weakening the coupling and assisting in unbalancing the line.

From the phasing loops, the aerials are fed by the appropriate feeder system—concentric for unbalanced aerials, twisted feeder or open-wire lines for the dipoles.

Transmission-Line Demonstrations

The 490-ohm transmission line is constructed of 300 lb./mile copper wire and fed by a tapped-in concentric at a point giving a compromise in mis-match between the feeder and the line when the latter is in either the open- or short-circuited condition.

Provision is made for the display of current and voltage distribution when the line is terminated in an open- or short-circuit, and also when it is more or less correctly terminated in a 490-ohm 25-watt resistance. Accurate termination is difficult at the frequency involved owing, among other things, to the lumped capacity of the binding wire at the end of the line.

The devices used for showing the nature of the distribution of current and voltage are respectively a loop-fed lamp (Fig. 2B) and a similar lamp making contact with the line through a wheel (Fig. 2A). The capacity to ground of the threaded portion of this latter lamp is sufficient to ensure satisfactory brightness. The pick-ups are used severally and in a combined form (Fig. 2C) to show the spatial relationship of the two standing waves, the inclination given to the transmission line traversing them under gravity from the termination to the feed point at the lower end.

The pick-ups are shown in Fig. 2, and their trace for the open-circuited and correctly terminated cases illustrated in Figs. 3, 4, and 5. Fig. 3 is the trace formed by the current pick-up traversing the line, the varying brightness of the track showing clearly the usual standing wave of current. Fig. 4 illustrates the same point in a different manner, successive images of the moving pick-up being shown. Again the varying amplitude of the line current is manifest in the variation of lamp brightness. The same process shows in Fig. 5 the combined voltage and current pick-up of Fig. 2C in action; the top row of lights is due to the voltage indicator, the lower row to the current variation. Note the clear indication of the $\lambda/4$ spatial separation of modes on each trace. Figs. 3-5 represent conditions on the open-circuited line. Maintaining the same exposure time and terminating the line in a resistor, the trace of Fig. 6 is obtained. Here the reduced variation of both current and voltage is evident. The match is evidently not perfect, but a substantial improvement in standing wave ratio is evident.

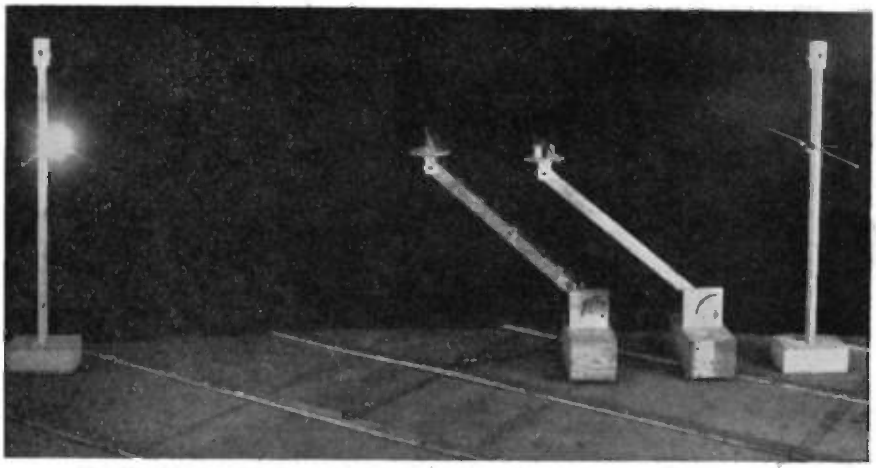


Fig. 12. Horizontal dipole. The receiving pick-ups show equal strengths.

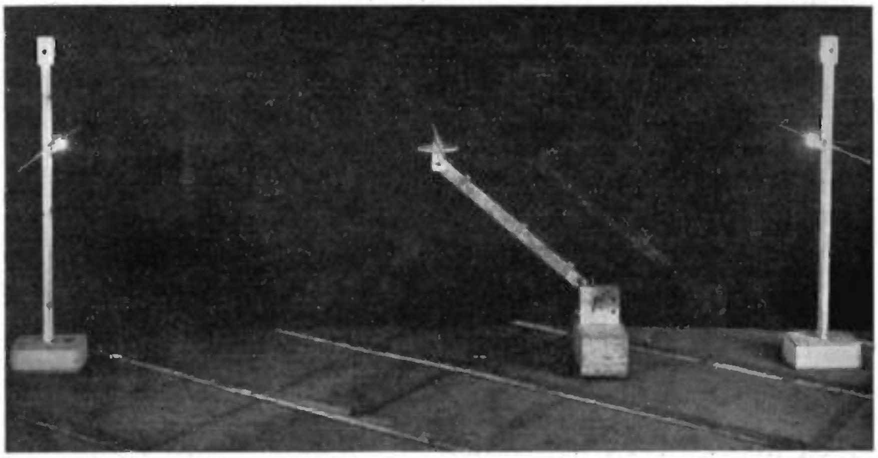


Fig. 13. Horizontal dipole with reflector. The parasitic reflector is made longer than the radiator, and placed $\lambda/4$ behind. The left-hand pick-up then shows the greater strength.

Measurement of V.H.F. Impedance

A further use for this line is in the practical determination of unknown impedances at V.H.F. The impedance is connected to the end of the line and the standing wave ratio on the line measured by using the loop-fed crystal detector of Fig. 2D. The application of the impedance circle diagram to these results follows the usual method and gives results agreeing well with those obtained by other means; a suitable correction for end-capacity is made.

Radiation Displays

Radiation displays are available for both vertical and horizontal radiators. In the former case, zenithal polar diagrams are indicated by the relative brightness of lamps inserted at the centres of a number of vertical half-wave receiving aerials; these are situated on a vertical semicircle with the radiator as centre, at equal intervals of arc (Fig. 7).

Similarly situated are a set of horizontal half-wave pick-ups, performing an identical function for the horizontal radiators (Fig. 9). Both sets are backed by a conducting mesh a quarter-wavelength behind them; the object of this mesh is to place the receiving aerials in the same relative positions relative to the standing wave

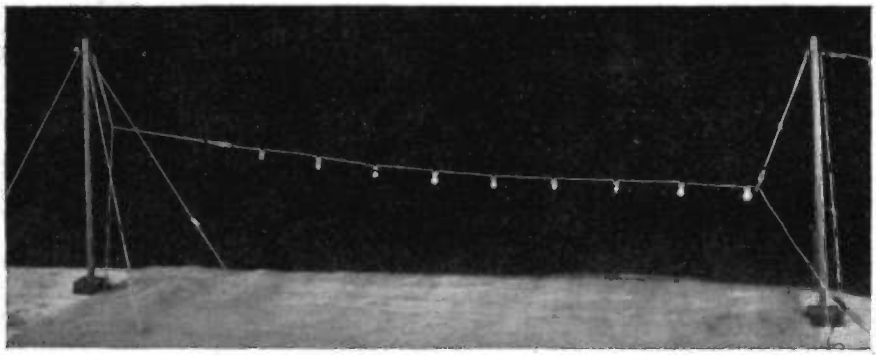


Fig. 15. Three-quarter wave end-fed. Note the minimum of current at the fourth lamp from the right, showing the presence of reflexion despite the lamps.

which exists in the space between the radiator and the mesh. In the absence of such a regular reflector, irregular reflexions from the roof and its associated trusses give a misleading result on the polar pattern indicators. The use of a mesh, placed as in Fig. 9, gives an answer little different from that obtained out-of-doors, for the amplitude of the maximum of the standing wave along any radius from the radiator depends on the intensity of radiation along that radius.

It should be noted that the various irregularities due to reflexion within the room are more evident with vertical polarisation than horizontal. Steel table legs and similar metallic objects are of the order of a half-wavelength and cause distortion of the field. The presence of an audience in such small confines may also affect results. Apart from this, it has already been noted that feeders must radiate as little as possible, as they also may give rise to an incorrect result which, while explicable, detracts from the genuineness of the demonstration.

The receiving aerials are within the induction field of the sending aerial. However, if uniformity of radial distance and of spacing along the semi-circle is maintained, any variation in brightness between the various lamps is due to the radiation field only.

The lamps used in the half-wave pick-ups are checked for uniformity by a substitution test before installation. They are rated for D.C. at 6 V, 60 mA. At the frequency used and at average intensity, they must be treated as a complex impedance when wired into an aerial, affecting the electrical length considerably.

Vertical Radiators

The vertical end-fed aerials are erected from a base section fed by a 70-ohm concentric. To minimise the destructive effect of any standing wave on this feeder it is run under the wire mesh which forms the earth level for the demonstration.

Variation of polar pattern with aerial length is demonstrable, it being important to show that vertical aerials longer than five-eighths wave are poor ground-wave radiators. Fig. 7 shows the result for the $\frac{3}{4}\lambda$ case. Note that the main lobe for such an aerial is correctly shown as above the horizontal with very little ground-wave.

Any lighting of the indicator lamps in the horizontal pick-ups is due to radiation from the feeder to the vertical aerial; this can be reduced to a minimum by keeping the feeder flat on the wire mesh floor.

A further simple point is illustrated in Fig. 8 where the relative brilliance of the receiving aerial lamps provides a clear indication of the effect of a capacity top in the form of a roof on the performance of a short vertical ground-wave radiator. The original aerial (a $\lambda/8$ vertical) gave a weak signal strength to all four vertical receiving dipoles. Doubling the height of the aerial raises the low-angle strength, as is indicated by the increased brightness of the lower pick-up lamps (Fig. 8).

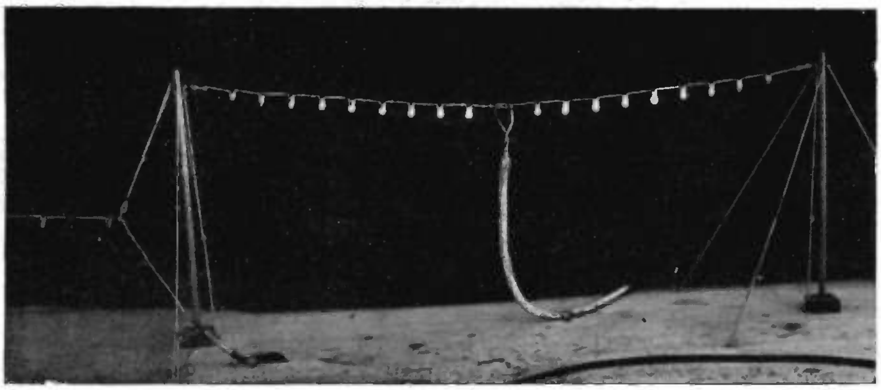
A horizontal top added to the $\lambda/8$ aerial results in much the same signal strength as with twice the height and no capacity top. Rotation of the top serves to show that the horizontal polar diagram is still a circle. Horizontal pick-ups above the rod are useful here to show that the amount of high-angle horizontally polarised "sky-wave" is small when the aerial is suitably dimensioned.

Horizontal Radiators

The types of horizontal aerial for which vertical directivity can be shown are the half-wave dipole and the so-called end-fed three-quarter wave. It is with the former that most of this work is carried out. The effect of height above the conducting floor screen on the vertical pattern is shown as before by the relative brightness of the lamps in, for this case, horizontal pick-ups. Three illustrations, Figs. 9-11, make the correspondence of the ideal pattern and that obtained in the lamps clear. In each case the ideal diagram is shown alongside the practical result and, making due allowance for the proximity of the receiving pick-ups to the radiator, the correspondence is satisfactory. It is clear to the student that for short-distance high-angle sky-wave his aerial must be low-slung. The pattern of Fig. 9 is the most useful for this short-distance working and holds so long as the aerial is not more than $\lambda/4$ above the water-table. The more usual properties—such as polarisation and the horizontal polar diagrams—of this aerial can clearly be demonstrated straightforwardly: they will not be dealt with in detail. One most successful result is, however, worthy of reference—that ob-

(*Concluded on p.* 835.)

Fig. 14. Wire T-aerial. Almost completely uniform current in the ground-wave radiator with very slight current indication at the centre of the roof only.



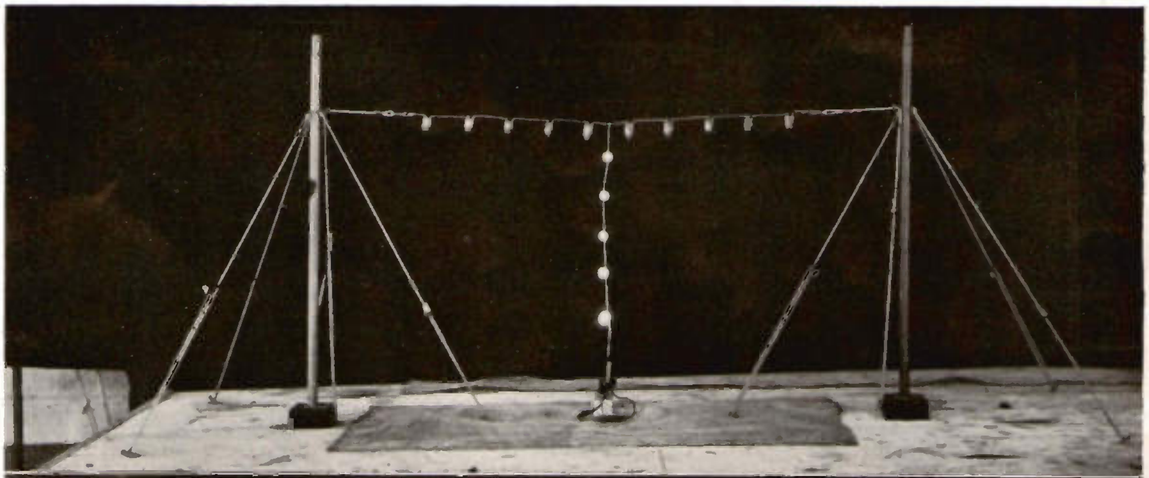


Fig. 16. Low dipole. Twisted feeder fed.

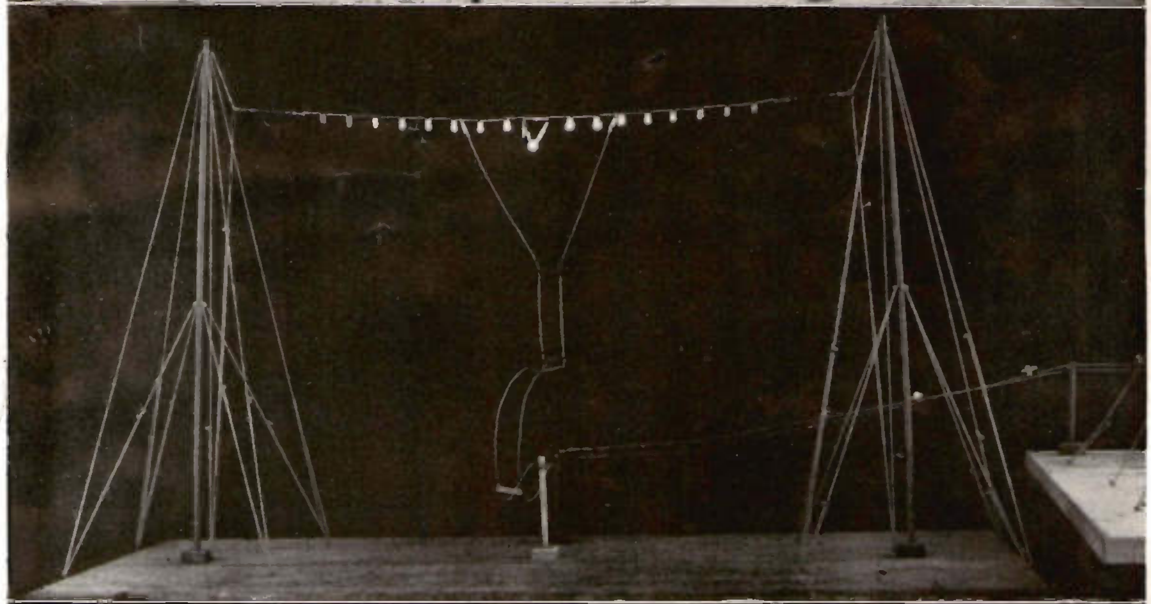


Fig. 17. High dipole. A resonant-stub is used for matching to an open-wire line. Standing-wave on this line is indicated by the three voltage-indicating lamps on the feeder, rear right

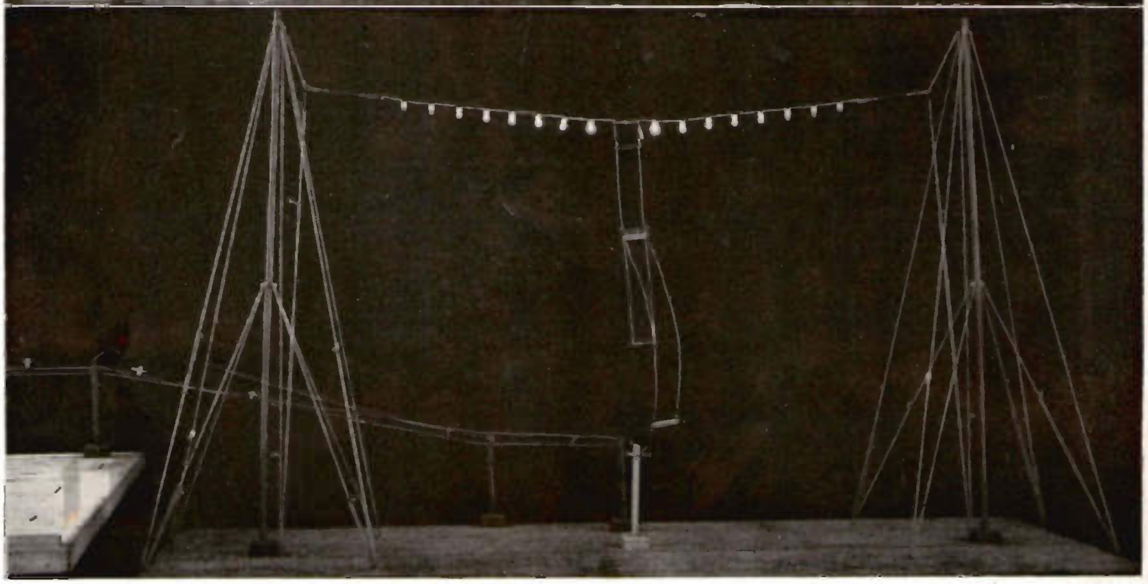
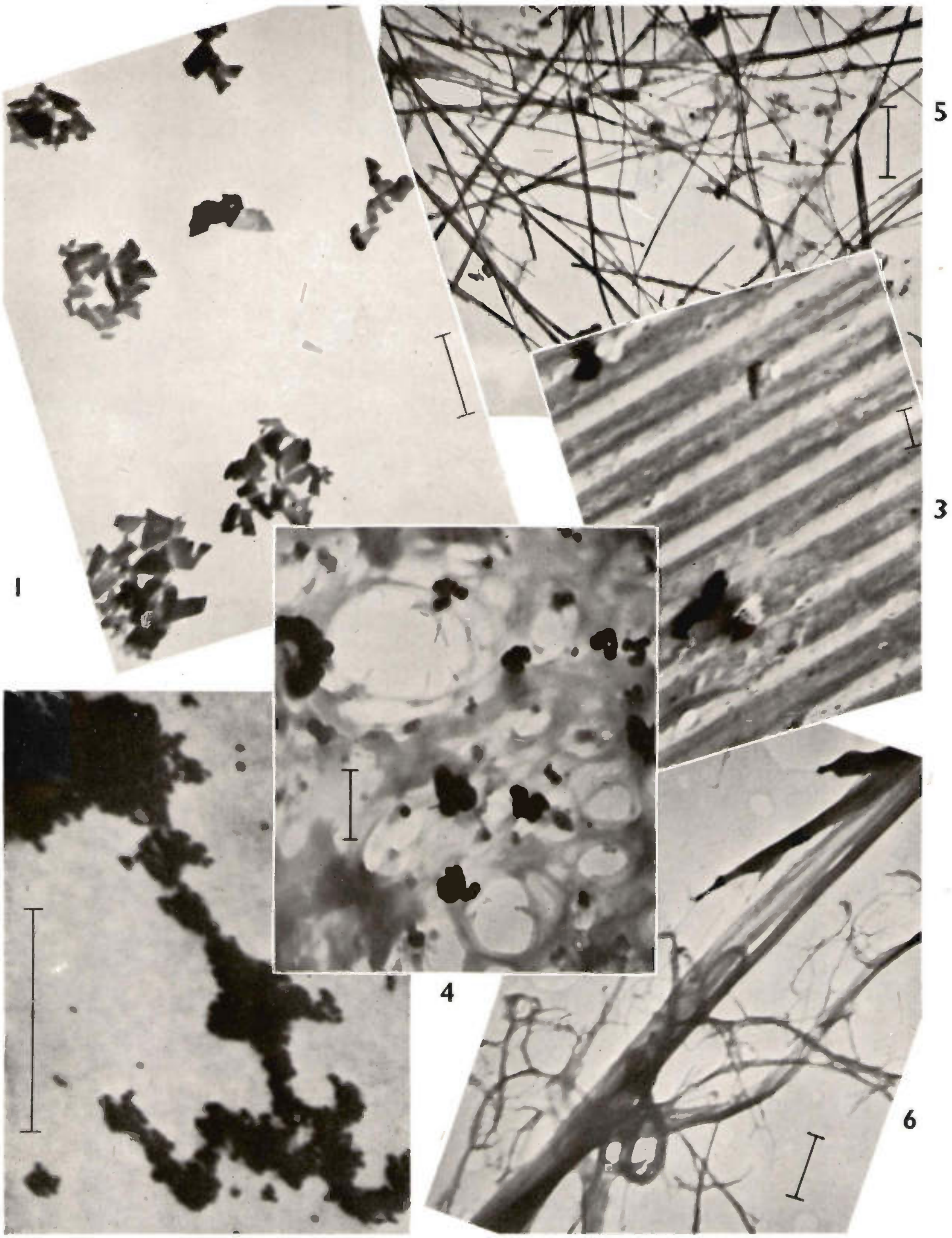


Fig. 18. Fed now by a delta-matching section. A standing-wave is present, as indicated by the unequal brightness of the indicator lamps, rear right.

Electron Micrograms

to illustrate points made by the author in the following article



The Preparation of Specimens for the Electron Microscope

By D. G. DRUMMOND, M.Sc., Ph.D., F.Inst.P.*

AT the beam velocities commonly employed in the electron microscope (30 to 60 kV) the probability of an inelastic rather than an elastic collision when an electron encounters an atom is low, so that we may expect the electron usually to undergo a slight deviation in direction with negligible change of speed, while the relatively massive atom remains almost unaffected. As a result of such elastic scattering the conical angle of a beam of electrons emerging from a given point of a specimen is greater than that of the incident beam by an amount which depends upon the intensity of scattering at the point in question. Statistically this is true even though each electron may have suffered multiple scattering.

Electron lenses, however, have very small apertures and the peripheral parts of the scattered cone are intercepted at the objective lens so that the wider the scattering the more the beam is weakened by passing the lens. The variations of intensity from point to point of the final image thus reproduce the variations of scattering power across the object. It will be seen that by this process an image of the object can be formed without any appreciable transfer of energy to the specimen.

As the thickness and density of the specimen increase, the number of atomic encounters which an electron makes in transit increases also and the chance that it will undergo an inelastic collision becomes appreciable. The kinetic energy then lost by the electron will ultimately appear as heat in the specimen which may be destroyed. Thus we have the paradox that minute and apparently fragile objects such as viruses can be successfully examined, while a relatively large and robust object such as a cotton hair is at once shrivelled up by the impact of the electron beam.

The electron scattering power of an object depends on two main factors:

i. The nature of the atoms present,

ii. The number of atoms per unit area of the specimen,
   Of which the latter breaks down into two component factors:

ii.a The density of the specimen,

ii.b Its thickness.

If the scattering is so little that the scattered cone falls entirely within the aperture of the objective lens then there can be no contrast in the image and, theoretically at least, there is a lower limit to the scattering power required to give useful results as well as the upper limit set by the incidence of excessive inelastic collisions.

In subjects of an organic nature the atoms present are all of similar scattering power (*i.e.*, Carbon, Oxygen, Nitrogen) and, since the mass densities of the materials are not greatly different, structures shown are attributable largely to differences in thickness, the range of thickness giving useful differentiation being roughly from 0.01μ to 0.1μ. The denser inorganic materials such as an iron oxide pigment or gold sol particles have heavier atoms present as well as a higher mass density and are opaque in much smaller thicknesses. Gold sol particles of only 0.02μ diameter show no sign of transparency to the beam. (Figs. 1 and 2.)

The beam should be obstructed as little as possible by material other than the specimen in its path since this will cause general scattering resulting in a fogged background and loss of contrast in the image and this has two practical consequences:

i. That the beam must operate in as high a vacuum as possible.

ii. That the support for the specimen must be extremely thin and of a low density.

The first operation in preparing a specimen is to make a thin film on which to support it. Commonly this is of nitrocellulose and is cast on a water surface from a drop of a dilute solution in amyl acetate. It should be of the order of 100 Å (0.01μ) in thickness if it is to have sufficient strength and yet be sufficiently transparent to the electron beam. It is itself supported on a small disk, $\frac{1}{8}$ in. in diameter, of a metal grid material of 200 mesh to the inch. The square holes in this are of about 60 to 70 μ side. This is near the upper limit of the size of hole which can be used, as the film will not readily withstand the beam if it is left unsupported over a larger area. The developed heat and charge cannot then leak away to the surrounding metal fast enough.[1]

The specimen itself is deposited on the film-covered grid by precipitation from the air or from liquid suspension or by other suitable means.

The easiest subjects to prepare are the smokes of some burning metals. If, for instance, magnesium ribbon is burnt in the air and a prepared grid is held in the white smoke a deposit of magnesium oxide is formed on the film which is seen in the electron microscope to consist of cubic crystals of various sizes down to 100 or 200 Å edge. A more controllable way of

* The British Cotton Industry Research Association.

Description of Electron Micrograms on opposite page

Fig. 1. Particles of an organic pigment containing no heavy atoms, dispersed in water with a wetting agent. Showing density varying with thickness.

Fig. 2. Gold sol. Showing a large aggregate with a few of the very small dense ultimate particles lying free on the supporting film.

Fig. 3. Positive replica of a metal diffraction grating. Made in formvar from a gelatine negative.

Fig. 4. Surface stripping from vulcanised rubber. The carbon-black filler particles (of relatively high mass density) are seen embedded in the less dense rubber.

Fig. 5. Fibrils from a rayon fibre broken up by a paper beating machine.

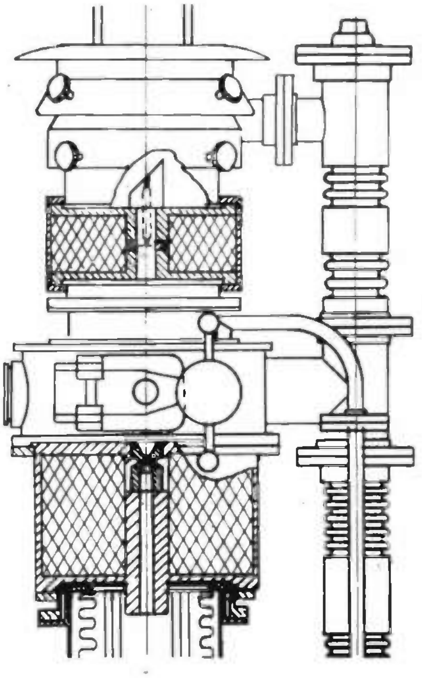
Fig. 6. Fibrils from a natural silk fibre macerated in a Waring Blendor.

The length indicated by |———| represents 1μ (*i.e.*, 0.001 mm.) in each figure.

making this deposit, and one which avoids all risk of burning the nitrocellulose film, is to catch the smoke in an inverted test tube and set this down over the grid until sufficient material has settled out. Zinc and lead oxides can be prepared in the same way, though greater heat is required to burn these metals. Such smokes are heavy and highly aggregated and settle out readily even though the ultimate particles are very small, but in atmospheric pollution and similar problems the air-borne particles concerned are light and do not fall easily in air. These must be deliberately precipitated if they are to be examined and two methods of doing this have been applied in electron microscopy. These are by thermal precipitation and by electrostatic precipitation. There is not the space here to describe the precipitators but one or two points deserve notice. The glass cover slips used in the standard thermal precipitator[2] to receive the dust deposit are replaced, for electron microscope work, by nitrocellulose-covered grids of nickel held in position by magnetic chucks and provision is made for adjusting their position accurately. The density of the dust trace is not uniform across its width and there may be slight size fractionation so that differing pictures are presented in areas which are only separated by an amount which, though not of practical consequence under the optical microscope, is apt to cause serious error at the greater magnifications and correspondingly more restricted fields of the electron microscope. No work appears to have been done to determine the minimum size of particle which can be conveniently collected in the thermal precipitator and whether this is below the resolving limit of the electron microscope. That there must be such a minimum size is clear since particles as small as air molecules move freely past the wire.

An electrostatic precipitator has also been designed[3] to throw the dust down directly on the electron microscope grids, but further investigation will be necessary to determine the efficiency of this instrument and whether it causes any fractionation.

In some cases specimens can be prepared by sublimation or evaporation onto the supporting film, either in air or in vacuo. Films of metals evaporated in vacuo onto a supporting nitrocellulose film have been examined.[4] The discontinuous nature



Outline drawing showing specimen chamber and two lenses of the R.C.A. electron microscope.

of these films in, for instance, copper or aluminium as shown by the electron microscope explains the anomalously high electrical resistance of these films. In some cases (*e.g.*, gold and chromium) it is possible to form continuous films, and this has given rise to a valuable development known as shadow-casting.[5, 6, 7] Some objects, such as virus particles, which are within the range of resolving power, nevertheless give such low contrast against their supporting film that they are not readily photographed in the electron microscope. If chromium or gold is evaporated onto such a specimen at an oblique angle in a vacuum then the metal atoms will pile up against the exposed side of the particles leaving a metal-free " shadow " on the supporting film at the opposite side. After such treatment the specimen shows much greater contrast and the pictures give a strong impression of relief; surface irregularities have been made very evident and, moreover, the heights of objects can be deduced from the lengths of their " shadows."

The investigation of the size and shape of small particles is a type of problem to which the electron microscope is particularly well adapted and there are many industrial fields in which information is required as to the nature of preformed particles rather than particles prepared *in situ* (such as the metal-oxide smokes). The main requirement and the main difficulty in these cases is to disperse the particles so that they are suitably displayed for observation. Such submicroscopic particles cling persistently together by adhesive forces which far transcend any other forces acting on them and the energy required to separate them may be considerable. The usual method of dispersion is to mill or " rub out " the powder in a suitable medium, one essential property of which must be a high viscosity so that high shearing forces are developed. For the electron microscope a further requirement is that the milling medium must be completely removable from the final mount. A drying oil such as linseed is apt to leave an insoluble residue of oxidised oil unless it has been specially treated and properly stored, but castor oil may safely be used. A dilution in benzene is made after dispersing the powder in the oil and a drop of this is placed on the grid. Once the particles have settled and adhered to the supporting film the residual castor oil can be easily washed away in benzene without disturbing them.

A highly successful milling medium for carbon blacks is crêpe rubber which, however, requires a roller mill to work it (Fig. 4). The rubber is subsequently dissolved and diluted in xylene which is also used for the final washing of the mounts. For rougher work the powder can be rubbed out in a viscous nitrocellulose dope afterwards diluted with amyl acetate and a film cast in which the particles are embedded. Some sharpness of the edges of the particles is lost by this method because of the irregularity of the film near the inclusions. More elaborate methods have also been described.[8] A high-frequency spark is said to be effective in dispersing submicroscopic particles,[9] but the present writer has no experience of this. The spark from an induction coil is not satisfactory.

The direct examination of the surface of a solid is not possible with the standard transmission type electron microscope, but the surface features can be impressed as a replica on one face of a thin film which can readily be studied.[10] The material of the replica and its method of preparation depend on the circumstances. Sometimes a thin film can be cast directly on the surface to be examined and then stripped away without undue distortion. Formvar (Polyvinyl formal) is a plastic which is tough enough to withstand this process in the case of surfaces which are not too deeply etched. It is applied from solution in dioxane and can be floated off again onto a water surface or removed by backing it with a layer of gelatine thick enough to be ripped off mechanically and which usually brings the formvar with it. The composite film is then floated, gelatine side down, on warm water until the gelatine is dissolved away. (Fig. 3.)

Alternatively, a double process may be used in which a substantially thick first, or negative, replica is made, coated with a thin film to form the second, or positive, replica and then washed away to leave the latter ready for mounting. Where both the positive and negative materials are applied from solution it is essential that each should be insoluble in the solvent used for the other and this severely limits the combinations available. Gelatine in water and formvar in dioxane form a workable pair but, of course, the wet gelatine cannot be used on a corrodible surface such as steel.

Another method is to make a negative in polystyrene which is moulded hot and under high pressure onto the surface.[11] This may sometimes be cracked away from the surface, or a metal specimen may be removed from the polystyrene by dissolving in acid. A positive film of silica is applied, by evaporation in vacuo, to the polystyrene which is then removed by immersion in ethyl bromide.

In an attempt to examine the surface of a vulcanised rubber using the gelatine formvar combination the writer has obtained, not a replica, but some of the actual surface of the rubber ripped up by the gelatine in a layer thin enough for electron microscope examination.

In attempting to examine organic or living material various difficulties of a rather different sort arise. One must always be alert for artefacts arising from the evacuation, and consequent extreme desiccation of the specimen, or from the electron bombardment. Bacteria, for instance, are probably killed by the electron beam though they frequently survive exposure to vacuum. It is difficult also to obtain many tissues in a thin enough layer to avoid gross damage by the electron beam. The fragile nature of the supporting film precludes the use, unmodified, of such a technique as making a "squash," while the cutting of sections down to 0.1μ or thinner is not possible by ordinary methods. New section cutting methods are being devised, such as to cut deliberately wedge-shaped sections and study the thin edge,[12] or to cut with a knife travelling at such a high speed that very thin sections are removed before distorting strains can develop through the material,[13] but little work of this nature has yet been published.[14]

Fibres are notoriously tough materials and difficult to cut and, as they are too thick for direct examination, have so far only been examined after breaking up into their constituent units by violent disintegration. This can be effected by pulping in a paper beater or by passing as a wet sludge through a colloid mill, or by treatment in a Waring Blendor,[15] but the method gives no information as to how the units are put together to form the fibre. (Figs. 5 and 6.)

In some work one may be interested, not in a representative sample of the material, but in a specific small area. This may arise in cytological work where, for instance, chromosome structure in a cell may be the subject. This involves the use of micromanipulative methods for mounting the desired feature near the centre of the grid and, moreover, placing it over an aperture and not over one of the bars of the grid (which occupy roughly three quarters of the total area). This means placing it within a specified square of 60μ side. To the optical microscopist this may not seem very difficult of attainment, but it must be remembered that the mount is not a solid glass slide but an extremely tenuous film which will be broken by any attempt to slide the specimen into place or to lift it to readjust its position. Methods are being developed, however, and one of these is to put the object on the nitrocellulose film while it is still floating on a water surface and to bring the grid up from below, adjusting its position under a low-power optical microscope just before making contact with the underside of the film.

The more general requirements and methods of preparation of the specimens for the electron microscope have been described here and some of the divergences from optical microscope practice indicated. There are many more specialised devices, designed to overcome various disabilities of the electron microscope. Such include staining of tissues with heavy metal compounds to improve contrast,[16, 17] an enclosed cell to enable moist material to be examined,[18, 19] the use of supporting films of silica or alumina with a heated stage for the study of effects at high temperatures,[20, 21, 22] but these have been little used as yet and can only be given this passing reference in a general article.

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Electronics at the R.A.E. Exhibition

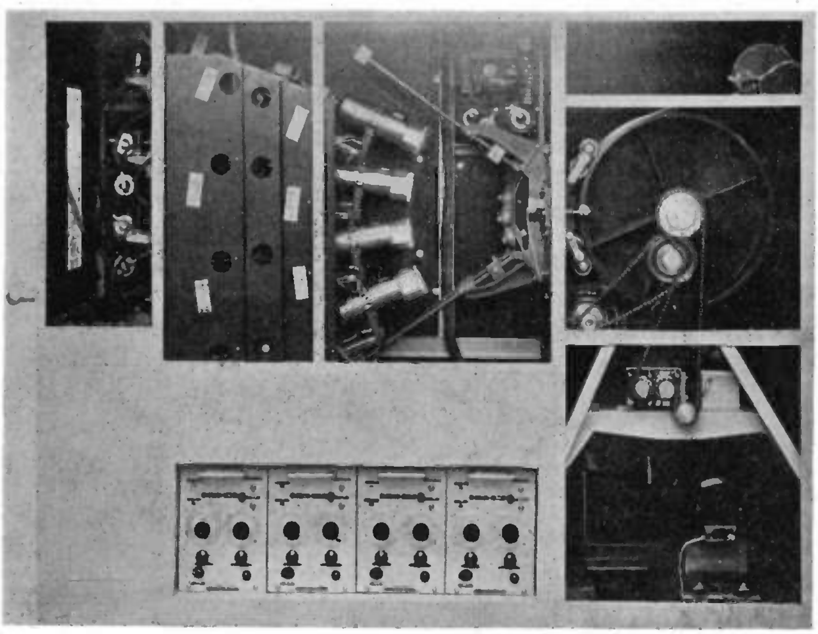
An exhibition of instruments used for ground and flight tests of aircraft and their component parts was held at the Royal Aircraft Establishment, Farnborough, from October 1 to 6. The exhibits included many items developed and manufactured by the aircraft and instrument firms, and by the R.A.E. and other Ministry of Aircraft Production experimental establishments, together with some instruments of which the development had been carried out jointly by the Establishment and instrument manufacturers.

Some idea of the rapid strides that have recently been made in the application of electronic methods of measurement to aeronautical engineering is obtained when it is observed that, of the total of nearly 200 exhibits, approximately half comprised electronic instruments, the remainder being either electrical or mechanical.

MOST of the aircraft constructor's problems demand for their solution accurate measurements of vibration frequencies and amplitudes, varying accelerations and static and dynamic strains in the structure. The attainment of high speeds, necessitating powerful engines having many cylinders, has raised the frequencies of many of the phenomena under investigation far above the limit imposed by the inertia of mechanical systems. Such frequencies may be recorded by the electronic method—the conversion of the mechanical effect into a proportionate change in an electrical quantity, for example, voltage, resistance, inductance or capacity—by a suitable "pick-up" unit and subsequent conversion of this change to a proportionate voltage variation, if it is not already such, which, after voltage or power amplification, is applied to the deflector plates of a cathode-ray tube or to a vibration galvanometer, a permanent record being obtained by photographic or other means on an accurately known time scale. Other important advantages of the electronic method are the high sensitivity obtainable and the comparative ease with which "multi-channel" recording may be effected, enabling phased records of several simultaneous phenomena to be obtained on the same time-scale.

It is worthy of note that, although the instruments on show were designed for aeronautical work, in most cases they may be applied directly to problems in other fields of engineering and, in some cases, to physiological measurements.

Space does not permit every relevant exhibit to be described in detail, but brief descriptions of some of the most interesting instruments are included.



Four-channel electronic recorder for ground use (rear view), showing the chain drive system for the camera drum, and the four resistance bridges, any or all of which may be interchanged with the capacity pre-circuits, in their stowed position.

Pick-Up Units

The first link in the electronic chain, the "pick-up" for conversion of the mechanical effect into a proportionate electrical change, necessitates careful electrical and mechanical design, and if its response is unsatisfactory the records from it will be inaccurate, no matter how efficient the remainder of the electronic system. It is no exaggeration to say that the accuracy obtainable at present is decided more by the pick-up than by the electronic circuits and recording system.

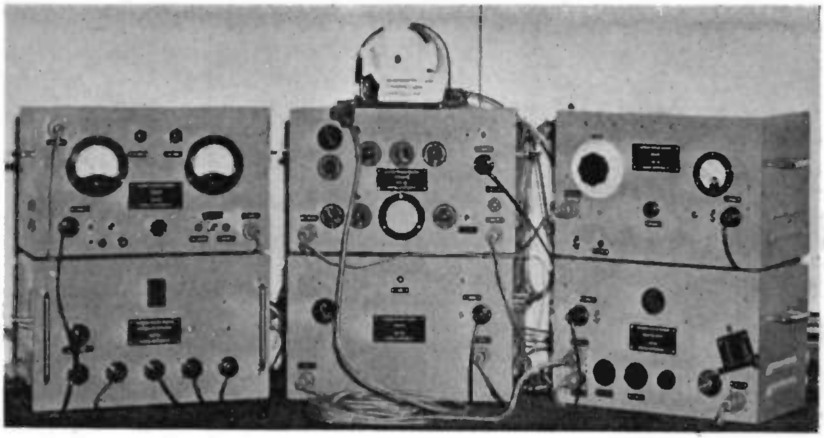
It needed but a glance at the exhibition to see how little challenged is the wire resistance strain gauge for both static and dynamic strain measurement. The orthodox type, of which several varieties were shown, consists of a "grid" of resistance wire of about 0.001 in. diameter, wound to and fro, and cemented to a paper support. This is stuck to the test surface, strains in which produce corresponding resistance changes in the wire, due to its changes in dimensions. The gauge is connected as one of the arms of a Wheatstone bridge, to which either D.C. or A.C. is applied. The temperature sensitivity of the gauge is almost nullified by the connexion in the adjacent arm of a similar unstrained gauge subjected to the same temperature variations. An interesting new development by Rolls-Royce is their Type R.R.3 gauge, in which the resistance wire is woven into a silk tape, lengths of which are cut to obtain any desired resistance. This type allows the adhesive to set more quickly.

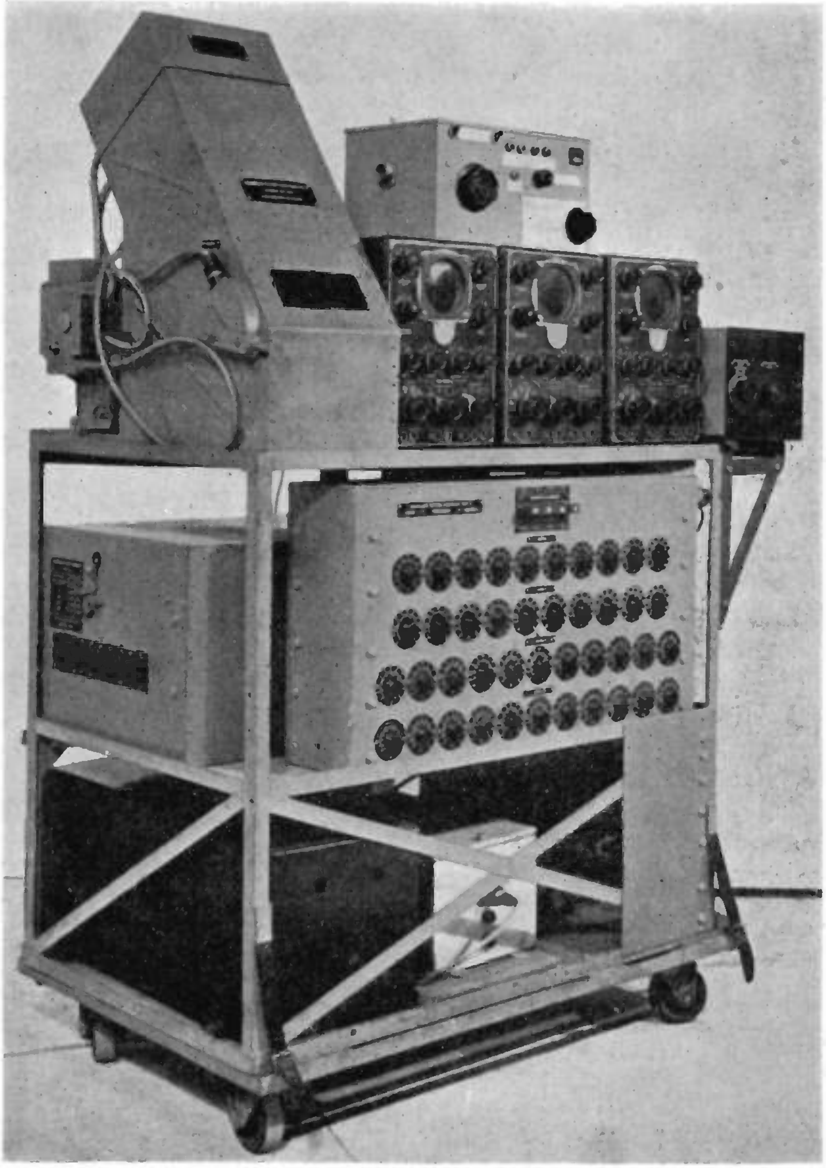
For linear vibration measurement four main types were displayed. The de Havilland piezo-electric gauge generates a voltage proportional to the amplitude of vibration applied to a "bender" bimorph crystal. An electro-magnetic generator type developed jointly by the Cambridge Instrument Co. and the R.A.E., and consisting of a low-frequency mechanical system seismic in the working range of 10 c/s. and upwards, produces a voltage by relative movement of a coil and magnet. This voltage is proportional to the rate of change of amplitude, and amplitude response is obtained by electrical integration. Eddy-current damping is provided by winding the coil on a metallic former, oil damping being unsuitable for flight testing owing to the large temperature variations. The piezo-electric and e.m. generator types have the advantage of giving a voltage change directly. Two types requiring the application of a carrier voltage were also shown —an R.A.E. eddy-current pick-up suitable for use when a fixed support is available, in which the vibrating metallic member under investigation has eddy-currents induced in it, thus changing the effective inductance of the pick-up, and a Bristol Aeroplane Co. variable inductance type. The change in carrier voltage produced is in both cases proportional to the amplitude of vibration, so that integration is not required.

For torsional vibration a capacity type was shown. One set of plates connected rigidly to one end of the shaft consists of longitudinal serrations on the inside of a cylinder, which under torsion of the shaft, move with respect to similar serrations on the outside of a second cylinder of smaller diameter than the first and coaxial with it and connected rigidly to the other end of the shaft, the twist of which changes the effective plate area and hence the capacity. Another torsional unit is such that a phase difference is produced between signals developed in two coils by the teeth of two steel wheels, one at each end of the rotating shaft. This phase difference varies with the twist, and hence the torque, in the shaft.

For pressure determinations the pressure is applied to one side of a diaphragm which forms the top plate of a condenser and produces proportionate capacity changes. Water-cooled units for use in the cylinders of reciprocating engines were shown, together with low-pressure button types.

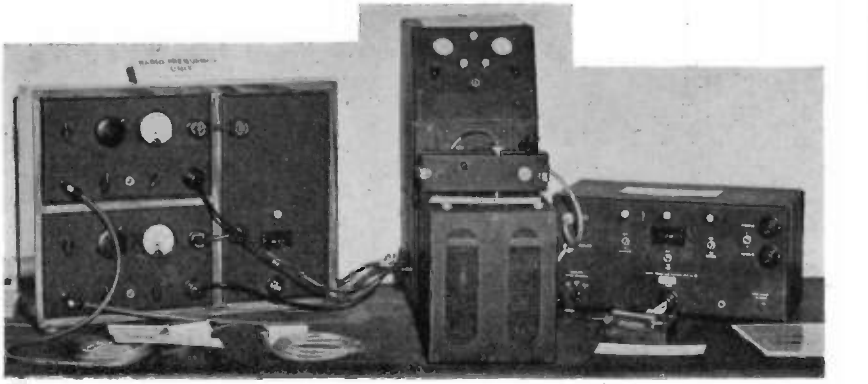
Three types of accelerometer were





(Top right). Wind tunnel pressure recorder, showing the six units into which the equipment is divided. At top (centre) is a motor-driven interrupter for an air jet impinging on the pick-up.

(Lower right). Resonance testing equipment, showing the camera at top left, with three Mullard E.800 oscillographs to its right. The tubes of the oscillographs are grouped together in the camera. The panel at the front carries the potentiometers for spot positioning.



Bristol vibration recorder. This two-channel equipment is for use with the Bristol variable inductance vibration pick-up. The pre-circuit and amplifier unit is at the left, the cathode-ray tube assembly in the centre, with the 35-mm. continuous-feed camera in front of it, and the time-marking unit at the right.

displayed. One, developed by R.A.E., consists of a mass spring-loaded against the diaphragm of a capacity pressure pick-up, and another of a duralumin tube, which forms the spring, having a mass attached to one end, the strain in the spring being determined by means of a wire resistance strain gauge. Both these types have natural frequencies of about 2,000 c/s. for a range of 0-100 g. A variable reluctance accelerometer contains two coils in the arms of an A.C. bridge, the ratio of the fluxes through the coils varying with the position of the laminated soft iron mass which is supported between them on cantilever springs. The accelerometer is very light and compact, and incorporates oil damping.

Single-Channel Recording Equipment

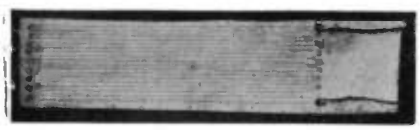
Despite the growing need for "multi-channel" recording instruments, there are many investigations in which measurements taken at a single pick-up position are sufficient. It is also advisable that those inexperienced in the operation of more complex instruments should learn the technique with simple single-channel apparatus, before proceeding to multi-channel recording. Two exhibits, aptly described as "the beginner's resistance unit recording equipment" and "the beginner's capacity unit recording equipment," were shown as examples of how the novice's initial needs can be met. The first comprised a Wheatstone bridge circuit, for use with wire resistance strain gauges, a Mullard Type E.800 oscillograph and a 70 mm. continuous-feed camera, and the second a pre-circuit employing an amplitude-modulated radio-frequency carrier for conversion of changes in pick-up capacity to voltage variations, the rectified output being applied to a similar oscillograph and photographically recorded on 16 mm. film.

A single-channel recorder, in console form, adaptable for use with either resistance or capacity pick-ups, was also shown.

Multi-Channel Recording Equipment

The increasing importance of records showing the phase relationships between phenomena occurring simultaneously at several points of a structure was shown by the large proportion of multi-channel electronic instruments exhibited, the number of channels ranging from two to sixteen.

Two exhibits in this class were particularly interesting, and detailed descriptions will, it is hoped, be given in future articles. They were a six-channel cathode-ray oscillograph recorder developed jointly by R.A.E. and Cinema-Television, Ltd., as standard equipment for use during ground tests, and a sixteen-channel recorder, using vibration galvanometers for recording and cathode-ray tubes as monitors, built into a mobile recording van and exhibited by de Havilland, by whom it is used for strain measurements on propellers.



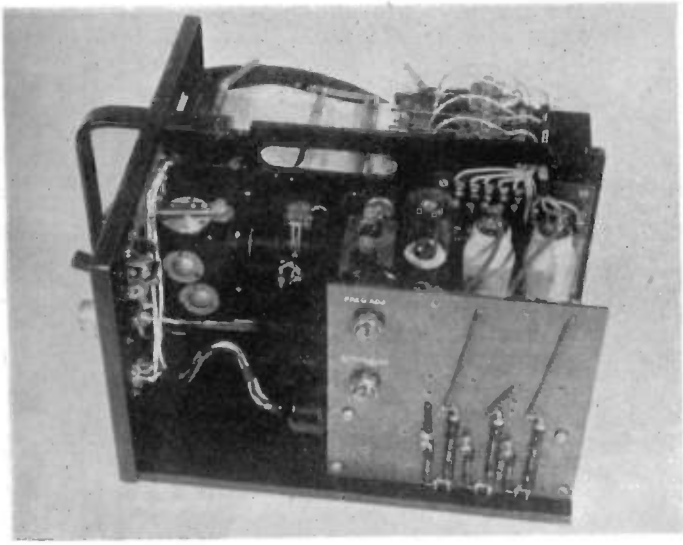
Wire resistance gauge (approximately full size). The wire is Nichrome 0.0006 in. dia., heavier leads being attached for connexion to the cable from the recording equipment. This type is wound on a paper support and the resistance is 2,000 ohms.

Also shown was a four-channel electronic recorder for ground tests, on which much of the design of the six-channel standard equipment is based. It incorporates four magnetically focused cathode-ray tubes, deflection being electrostatic. The deflector plates of each tube are connected to a direct-coupled paraphase amplifier. Interchangeable pre-circuits for use with either variable-capacity pick-ups or wire resistance strain gauges are provided. The recording paper is driven through an eight-speed gearbox by an electric motor, and the camera may be used either as a drum type taking records about 5 feet long, or as a continuous feed type, in which case records of any predetermined length up to a hundred feet may be obtained. Narrow straight line timing marks at intervals of ten milliseconds are applied photographically across the whole width of the 6-inch paper, which is driven at speeds from 6 to 350 inches per second.

A four-channel recorder was exhibited in which four moving-coil vibration galvanometers, fitted with light metallic pointers connected to an induction coil, record on spark-sensitive paper. This method has the advantage that the record is available for examination immediately it is made. A 2,000 c/s. A.C. energised bridge is used as the pre-circuit for both variable resistance and capacity methods, the out-of-balance voltage being amplified, rectified and applied to the galvanometers. Frequencies from zero to 70 c/s. may be recorded.

Methods of converting a single-channel oscillograph system for multi-channel work were demonstrated. These included a two-channel electronic switch, the beam being switched from channel to channel at frequencies up to 100,000 per second, and a four-channel 100 per second mechanical switch for low-frequency work.

A separate exhibit showed various methods of producing time-pulses of known frequency and applying them photographically to oscillograph records. The pulse generators included clockwork-operated contacts, vibrating reeds and a valve-maintained tuning fork, and the light-sources the Cinema-Television Type T.N.1 helium-nitrogen lamp for flashes of a few micro-seconds' duration, a small hot-cathode mercury vapour lamp for longer flashes at intervals up to 10 milliseconds and a filament "pea"-lamp for longer intervals.



Four-channel pen recorder (internal view), showing amplifiers and power supplies housed in separate assemblies.

—*By courtesy of Messrs. Henry Hughes, Ltd.*

Special Electronic Instruments

All the instruments so far described may be termed general in their application, but several exhibits were designed for use in specialised investigations.

Perhaps the most interesting of these is the resonance testing equipment, for investigation of resonances in aircraft structures when they are forced into vibration under ground conditions by a mechanical vibrator. Several electro-magnetic generator pick-up units are attached in line, at suitable positions, to the structure under test, and are connected in rapid succession, by means of a motor-driven selector switch, to the Y-amplifier of a cathode-ray oscillograph. Another bank of contacts on the switch applies pre-adjusted potentials to the X-plates of the same oscillograph, these potentials being proportional to the distances of the pick-ups from a fixed reference point in the same line as the pick-ups. By a suitable synchronising system a steady trace is obtained on the tube, the envelope being an instantaneous scale diagram of the surface at the section through the pick-up positions, and from this the nodes and antinodes may be found. Three channels are provided for simultaneous recording of the modes of vibration of, for example, one wing, the fuselage and a tail-plane, the three tubes being photographed by a still camera.

Further examples of the use of a mechanically driven selector switch for rapid "scanning" of a number of pick-up units for successive connexions to the input of a single amplifier are the multi-point rapid temperature recording equipment, the principle of which is similar to that of the resonance testing equipment, but the record gives the variation of temperature along, for example, an exhaust pipe, as measured by a series of thermo-couples, and a number of multi-way static strain recorders. In these the indications of a hundred or more wire resistance strain gauges are recorded at speeds up to 80 readings per minute on moving paper by means of an inked pen.

Space does not permit more than a brief reference to the remaining exhibits. They include a wind-tunnel pressure recorder, utilising inductive pick-up units whose amplified output may be applied to either a cathode-ray tube for photographic recording or to a frequency analyser for determination of the frequency components of fluctuating pressures. Detonation meters included one by Napier, Ltd., which uses a magnetostrictive pick-up, and another by the Bristol Aeroplane Co., in which the vibration transmitted via the engine cylinder wall is used to operate three magic eye indicators, one responding to heavy, the second to medium, and the third to light, detonation. A radio rate-of-descent meter operates from the ground reflexion of a high-frequency signal, and shows the vertical velocity of an aircraft at low altitudes. Other Napier exhibits were an aeration meter, in which the capacity of a condenser connected in one arm of a Schering bridge varies with the degree of aeration of the dielectric, which is the engine lubricating oil under test, and an ignition tester which shows the sparking of the plugs in an aircraft engine as a series of pulses on a cathode-ray tube. From the relative amplitudes of the pulses, faults in the ignition system may be diagnosed.

The purpose of the exhibition was to stimulate interest in the important field of aeronautical test measuring instruments, and it is felt that the organisers completely succeeded in attaining this aim.

Research in the U.S.S.R.

In a recent paper,[1] Gerald Oster, of the M.I.T. Laboratory for Insulation Research, gives some account of the important contributions to electrical research made by Soviet scientists over the past decade.

Items of electronic interest are the development of a stable infra-red-sensitive cell of 10,000 μA/L sensitivity, new industrial insulators such as aluminium oxide glazes, and unique high-voltage generators.[2] Original work has also been done on piezo-electric crystals of the Rochelle salt type and the theory of piezo-electricity has been carried further by Kobeko and Kurtchatov.[3]

Physicists in the U.S.S.R. have also carried out detailed studies of the nature of thermionic and photo-electric emission[4] and have developed a large ionic current source, the gasomagnetron,[5] which produces more ionic current than is available from "canal rays."

The gap in the spectrum between micro-waves and heat waves was bridged many years ago by Glogoleva-Arkadiev, who was able to produce E-M waves from the micro region down to hundredths of a millimetre by means of a "mass radiator."[6] This method consists in interposing in a spark gap a paste of fine metal particles mixed with heavy oil. The wavelength is determined by the dimensions of the particles and is monochromatic if they are of uniform size.

Experiments in propagation have also been carried out by Mandelstam and Papalexi.[7]

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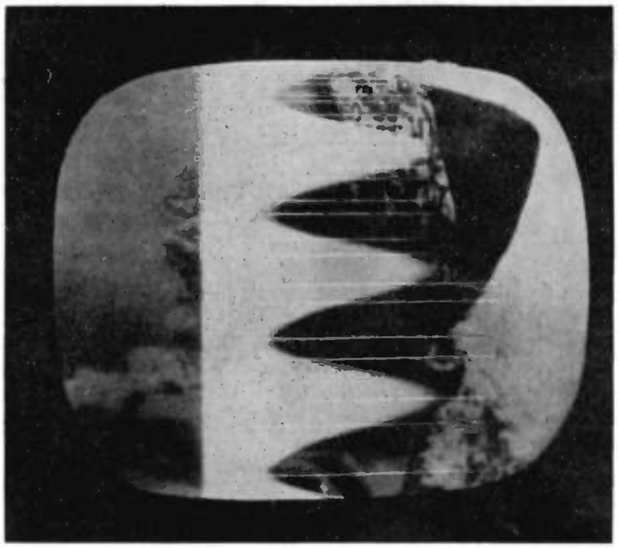


The Pye "Videosonic" Television System

On October 31, 1945, a demonstration was given to the Press of a television system developed in the laboratories of Pye Radio, Ltd., Cambridge. Full technical details of the system will be given in a paper to be read before the Radio Section, I.E.E., in January next, but in the meantime we are publishing the statement made by **Mr. D. I. Lawson,** head of the Technical Development Section. The illustrations above show a picture taken from the television receiver and the waveform of the sound pulses during the flyback periods.

Introduction

I WANT to tell you this afternoon about a new television system which my team have been developing during the past six months. This system enables the sound and vision programmes to be welded together over a single transmission, and this advance is comparable to the improvement in the motion pictures whereby the sound track is carried on the same film as the picture rather than on a separate gramophone record.

The Old System

In order to describe how this has been brought about it is necessary to recall how the pre-war transmission was effected.

If we look at a picture the entire scene is perceived at once. If this picture is to be transmitted it is necessary to break it up and transmit the component parts in an ordered sequence (Fig. 1). The pre-war television picture was broken up into 405 lines and 25 pictures were transmitted per second. Typical lines are shown as AB, CD, EF, and the tonal value along the line is expressed as the height of the waveform. During the periods BC, DE, etc., the electron beam in the television camera is returning to start another line. The time required to scan a line is 90 millionths of a second and 10 millionths of a second are allowed for the spot to return along the paths BC, DE, etc. This means that for one-tenth of the time the vision transmitter is idle. In the Pye system this idle period is made use of to transmit the sound programme. This is done by inserting a pulse in these periods the width of which varies according to the sound to be transmitted. At their widest the pulses are 5 millionths of a second and they narrow down to one millionth of a second at the sound troughs. They have a mean width of 3 millionths of a second. If there are enough of these sound snapshots per second the original sound programme can be reconstructed. There are in this case 10,125 of these snapshots per second. (Fig. 2.)

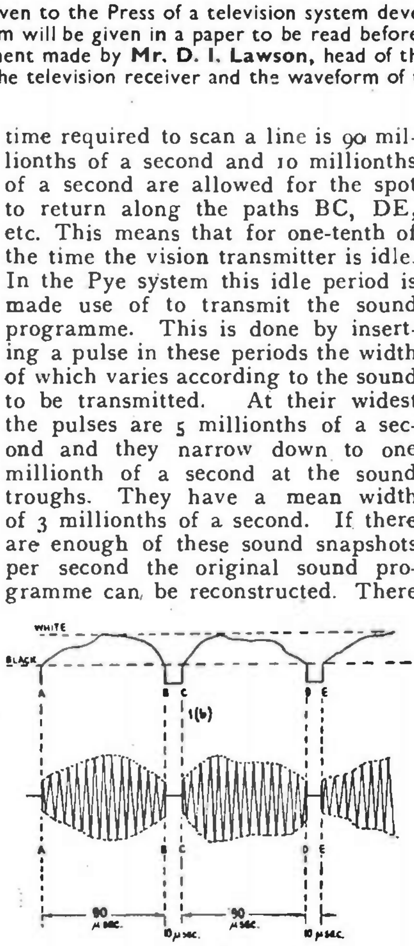


Fig. 1.

The recovery of the sound programme in the receiver is a simple affair. Firstly, the sound is separated from the vision and then the sound pulses are passed into a filter and the output from the filter made to operate a loudspeaker.

The advantages of the system are:

1. The sound transmitter can be dispensed with, but even more important, the television set can be considerably simplified. This it has been estimated would represent a saving of £30,000,000 to the country, when television transmitters have been installed in all the main centres.

2. The received sound signal is more free from noise and is therefore clearer than the pre-war sound transmissions. Calculations lead us to believe that this improvement would be the same as increasing the transmitter power 100 times.

3. One difficulty encountered with the pre-war sets was that of separating out the vision and sound signals and routing them to their respective receivers. This disappears when the sound transmitter is dispensed with.

4. No separate frequency allocation need be made for the sound channel.

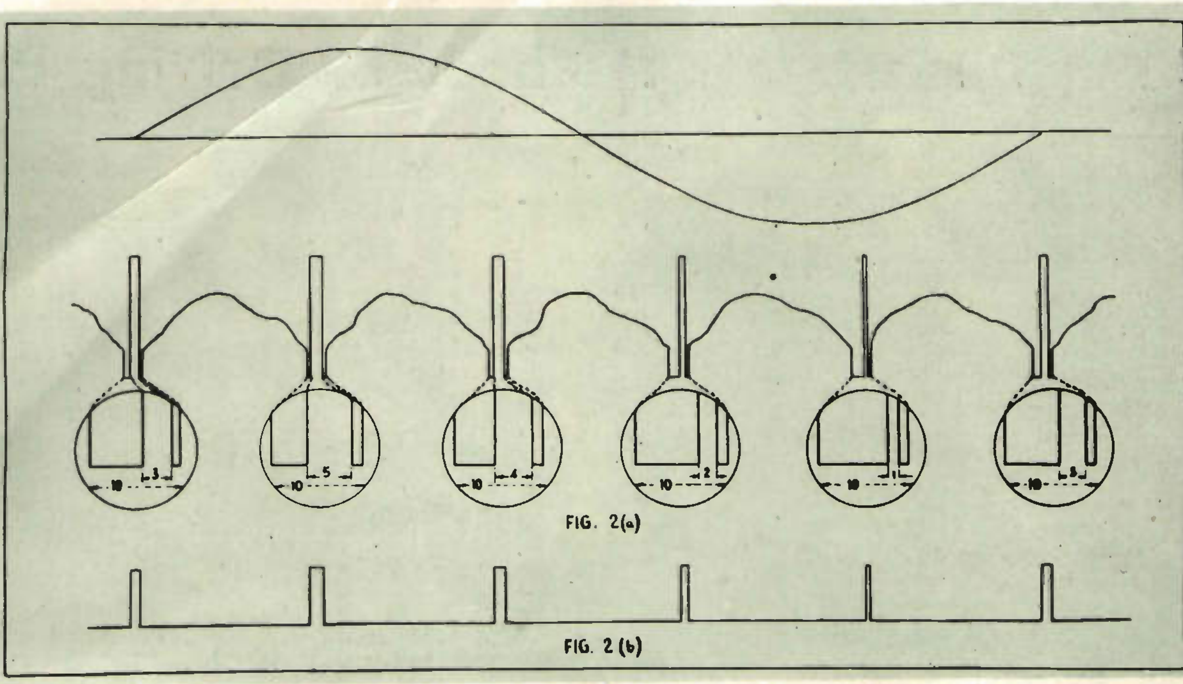


Fig. 2. Diagram showing method of inserting sound pulse in the flyback periods BC, DE. The width of the pulse varies with the sound to be transmitted; this is shown as a sine wave in the diagram. In the receiver the sound pulse waveform is separated from the vision waveform, leaving the train of pulses shown at the bottom of the diagram, and these are passed through a low pass filter to the loudspeaker.

5. The steady height of the sound signals would enable engineers to make receivers to compensate for fluctuations in signal strength.

6. The television receiving aerial is made more efficient since it need only cater for the vision band of frequencies.

7. The aerial problems caused by interference between the vision station disappear when the sound is incorporated in the vision transmission.

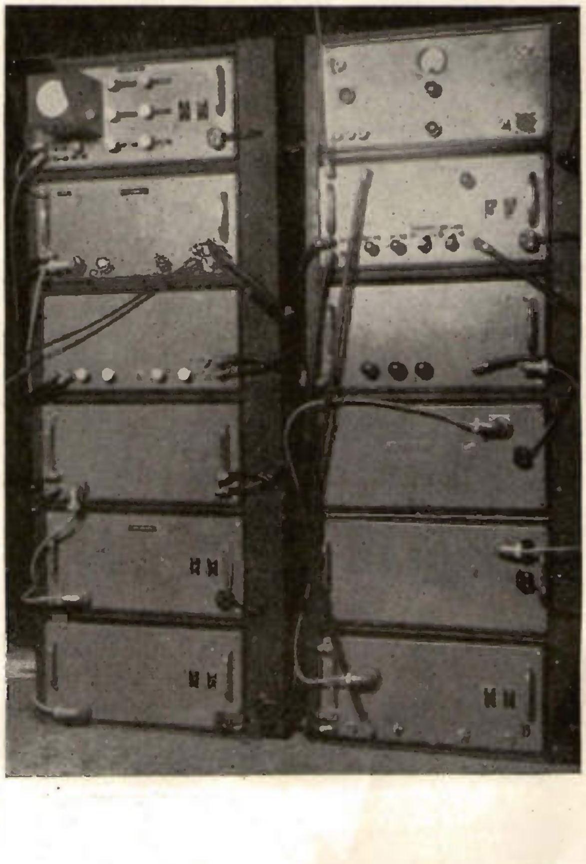
What of the Future ?

The fidelity of the sound programme would increase with the number of sound snapshots per second. This would increase with the number of lines transmitted per picture; that is, with the definition of the system. We know, for instance, that a picture of a thousand lines would give 25,000 sound snapshots per second, and it is doubtful whether anything would be gained by going beyond this figure. This system also holds further possibilities. Increasing the definition increases the amount of space in the idle periods I spoke of before, and on a high definition system it would be possible to insert two sound pulses carrying different programmes into the spaces BC, DE. This would allow sound from two microphones in the studio to be received on separate loudspeakers at the receiver, thus giving stereophonic sound.

With regard to colour television, we may vary the height of the pulses to select the various colour sequences at the receiver.

I hope I have said enough to show you that this system has not only great advantages which commend it for use on present television systems, but that it holds out great possibilities for future development.

In conclusion, I must tell you that none of the apparatus you are seeing to-day was built more than three months ago and of the equipment less than one-half was in existence ten days ago. This indicates how quickly a job of this kind can be brought to a successful conclusion if tackled with enthusiasm and energy.



The sound waveform generator and mixer units. The function of these racks is to produce pulses at the correct instant having a width dependent on the audio waveform to be transmitted, and then to mix these pulses into the vision waveform. These two racks would take the place of the sound transmitter at the television station.

Methods of Driving Push-

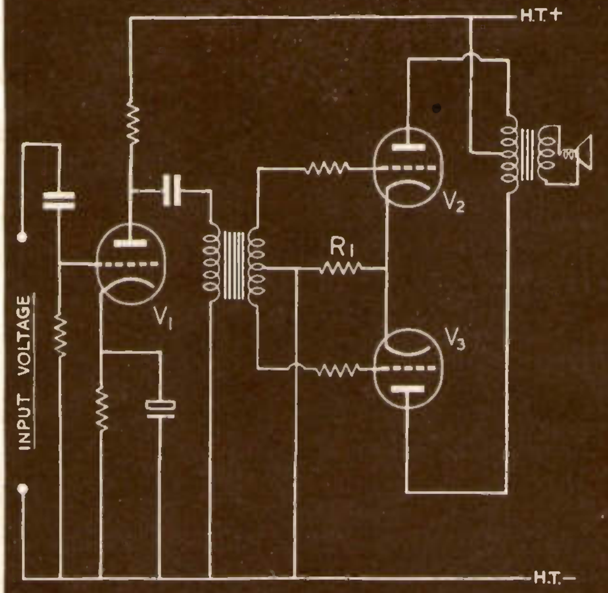


Fig. 1.

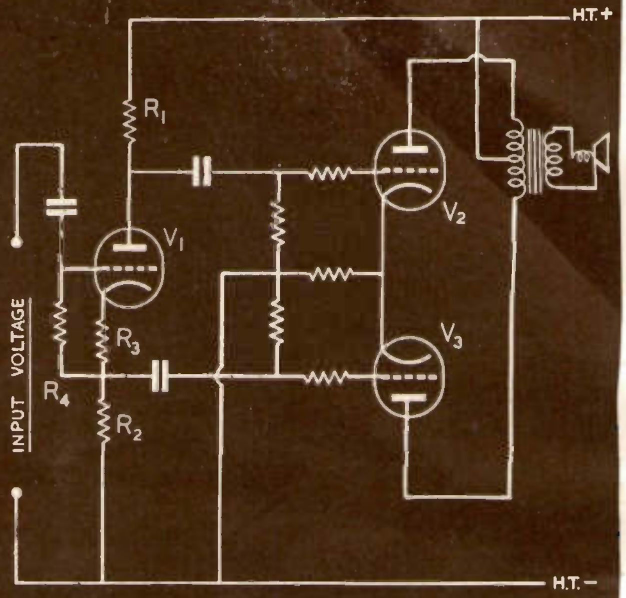


Fig. 2.

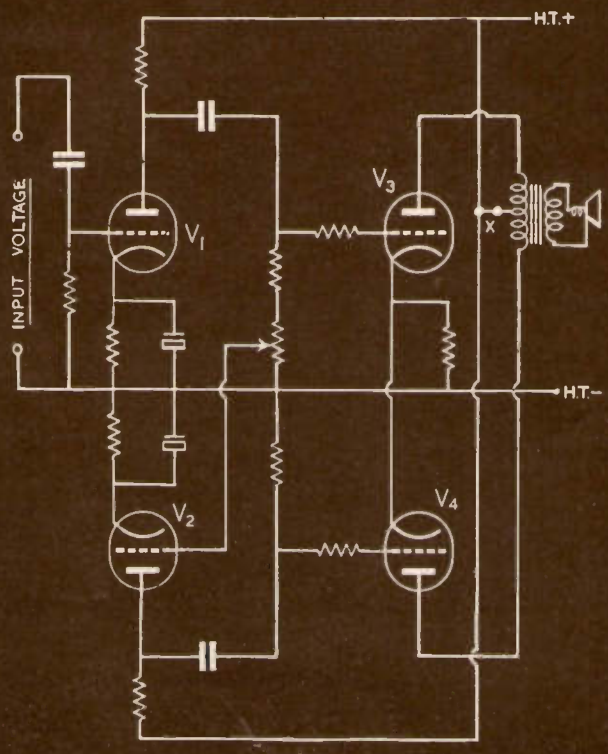


Fig. 3.

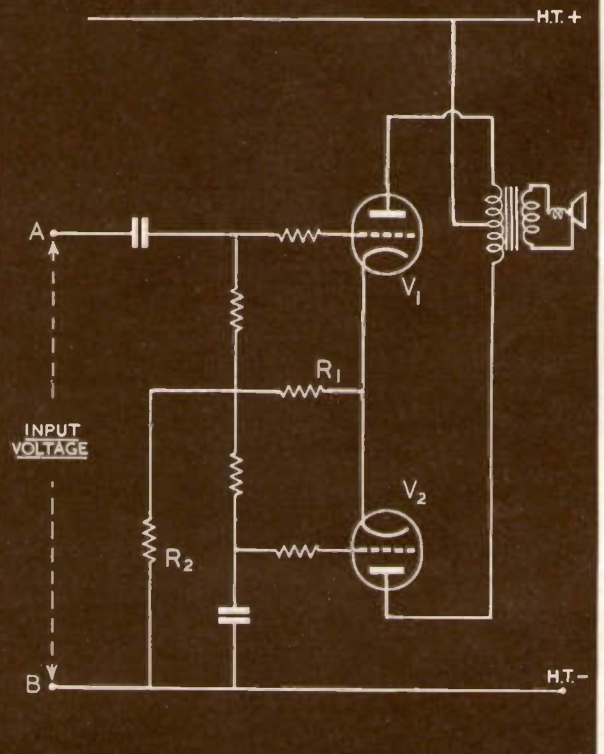


Fig. 4.

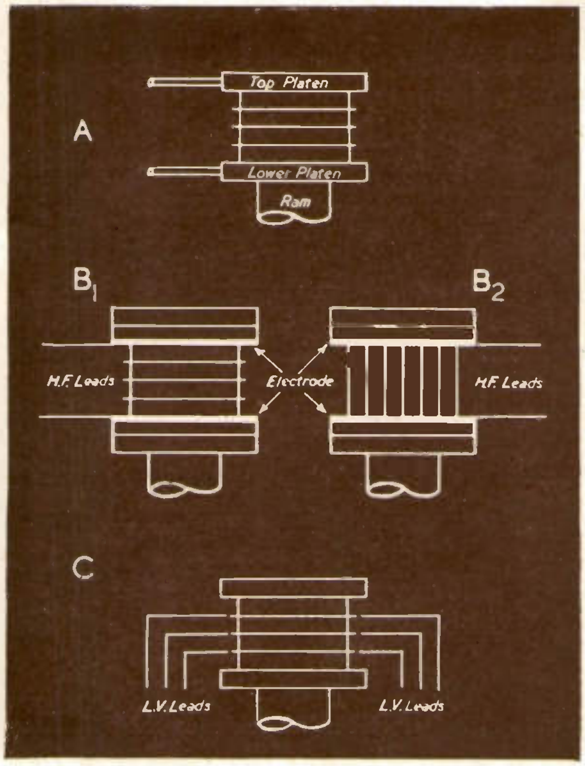


Fig. 2. Typical methods of heating laminated plastics.

A—Heated platens.

B_1—Material H.F. heated, normal to glue lines.

B_2—Material H.F. heated, parallel to glue lines.

C—Low voltage heating, utilising conductive glue lines.

it is usually necessary to use some other technique.

Loss Factor

It is difficult to heat insulating materials having a very low loss factor. The practical lower limit is between 0.005 and 0.01. Materials like pure polystyrene, quartz, etc., have values much lower and are therefore hard to heat dielectrically as it is difficult to transfer the power.

Frequency and Energy

As the amount of energy introduced into the material is proportional to the frequency, it is desirable to use as high a frequency as possible. The frequency employed, however, is limited by various factors of which the following are examples :

The length of the load, which may be such as to produce standing waves giving rise to unequal heating. The area of load may be so large and the capacitive reactance so low as to make tuning of the load extremely difficult, if not impossible. Currents involved may also reach magnitudes difficult to handle.

The power required is given by the formula :

$$W = \frac{1.41\ A.f.E^2.e'' \times 10^{-12}}{d}$$

W = watts.
A = area of electrode in sq. in.
d = thickness of material in in.
f = frequency in c/s.
E = r.m.s. applied voltage.
e'' = loss factor of material = e' tan δ.

If A and d are in cms., the factor 1.41 becomes 0.551.

It is sometimes possible to scan the material, thus reducing electrode area to values permitting convenient adjustments and frequencies sufficiently high to produce desired rate of heating. It is also sometimes possible to stack the material, thus increasing the thickness and reducing the capacity of the load.

Voltage

It is necessary to choose an operating voltage which will not flash over in air between the edges of the electrodes and also one which will not puncture the material under treatment. The R.F. puncture voltage is generally much lower than that at 60 c/s. It is desirable to keep the values to 2,000 volts maximum per inch for porous materials and 5,000 volts maximum per inch for other materials.

Heating of Plastics

Fig. 2 shows three main methods of heating laminated plastics during manufacture and illustrates the difference between H.F. heating and other forms of heating. The same general arrangements apply to non-laminated plastics, *i.e.*, mouldings, but in this case there are no glue lines in the make-up. With arrangement A the press platens are heated so that the material under treatment can be heated by conduction. As the material is usually a bad conductor of heat the process is slow and the rate of heating is not uniform throughout. For example, it may take several hours to heat up a 6 in. by 6 in. by 2½ in. moulding preform, as compared with 3 minutes by H.F. With arrangements B_1 and B_2 the veneers and glue lines are heated internally and so work can be done in seconds or minutes, depending upon the H.F. power available, the nature of the material being handled, its shape and the desired final product. With arrangement C, heat is concentrated principally in conductive glue lines and low voltages at mains frequency, or low voltage D.C., can be used. This method is extremely ingenious, appears at first glance perhaps to be simpler than it actually is, does not require special shielding and seems to present a challenge to H.F. heating. It is quoted here so that the H.F. case can be considered with due regard to any advantages which older methods may possess (*see* Tego Wiro Brochure, Theodor Goldschmitt, Essen, and "The Gallay Process").

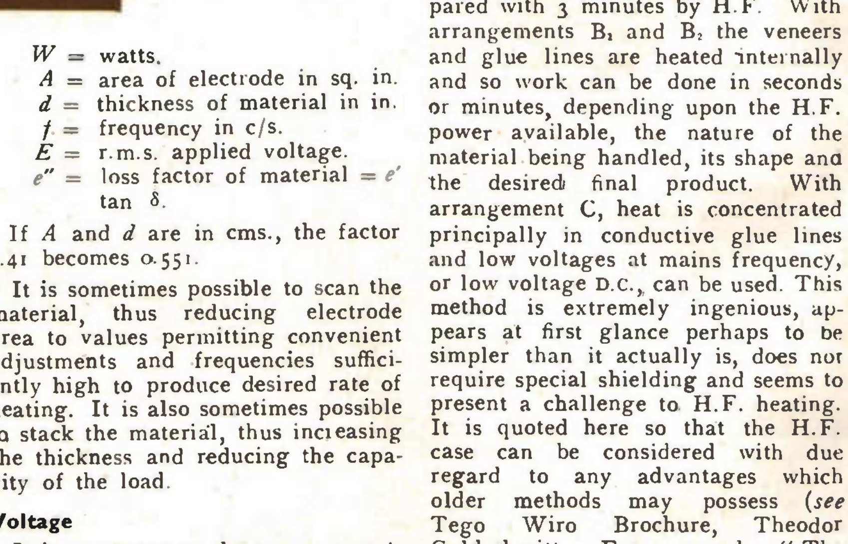


Fig. 3. Positive type compression moulding.
—"*Electronics,*" *Sept., 1943, p. 102.*

H.F. Heating in Heatronic Moulding

By A. E. L. JERVIS

THE employment of H.F. heating for raising the temperature of thermo-setting moulding preforms is of fairly recent origin. One of the earliest references to "Heatronic Moulding" is contained in an article by V. E. Meharg in the March, 1943, issue of *Modern Plastics*. Although exception has been taken in certain quarters to the word "heatronic" it is certainly most expressive and conveys in pithy form the idea of electronically produced heat.

In the moulding of thermo-setting plastics it is first of all necessary to soften the powder or pellets by applying heat to them and then, when the final shape has been imparted by the mould, further heating is necessary in order to "cure" or set the article in a hard state ready for use. For convenience of handling, the powder can be pressed into a cake or preform. This preform can then be partially softened in an oven adjacent to the press. In the case of H.F. heating the oven is replaced by a cabinet containing electrodes, between which the preform is placed.* (*See Electronic Engineering*, August, 1945, p. 626, Fig. 5.) Two of the drawbacks associated with oven preheating are, firstly, that the process is slow because it takes time for the heat to penetrate to the centre of the preform by conduction from the outside and, secondly, there is a danger of the preform becoming "baked" on the outside before the inside is softened. Heating of preforms by H.F. currents is preferable to the standard method of oven preheating because the heat is generated internally and uniformly. The process is thus very speedy and there is no danger of the preforms being under-heated on the inside and over-heated on the outside as just mentioned. In fact, with H.F. heating the temperature of the inside is raised a little more quickly than the outside because heat is conducted away from the top and bottom surfaces by the metal electrodes and from the remaining surfaces by radiation.

* It is, of course, possible to apply H.F. heating to moulding powders in low loss ceramic containers.

Advantages Claimed by H.F. Preheating

So far as the user is concerned there are at least three advantages in H.F. preheating. First, as a result of more uniform heating, the final article is more homogeneous and of better quality. Secondly, larger and more complicated shapes can be produced resulting in the elimination of other components, and thirdly, there is every reason to suppose that prices will be lower.

So far as the manufacturer is concerned, there are many advantages. High frequency produces results not possible with other forms of heating. The preheating takes less time and thicker sections can be handled. As softening is more uniform, mould closing times are less and lower moulding pressures can be used. As the plasticity of the preform is improved, the material "flows" better and there is less risk of damage to insets. There are thus fewer rejects. Impact-resisting moulding compositions can be moulded as readily as general purpose materials. More work can be done on fewer and lighter presses, and as a result, labour and overheads are reduced and there is a saving in floor space. Stresses on the moulds are reduced and the moulds should last longer. Output is increased. As the heat is generated inside the material itself, it is more "localised" than other forms of heating and in this respect is cleaner and more efficient. Various advantages are shown diagrammatically in Fig. 1.

Limitations of H.F. Heating

Some of the limitations of H.F. heating have been recently discussed by Carl Madsen of the Westinghouse Corporation. Not all the limitations mentioned apply to Heatronic Moulding; H.F. laminating of timber, for example, presents special difficulties. Before listing these limitations, Madsen draws attention to the various advantages implicit in H.F. heating, which have already been mentioned. Fortunately, the advantages frequently outweigh any price disadvantage, and the method becomes attractive when materials cannot readily be heated by other methods. It is pointed out, however, that H.F. dielectric heating cannot be used with all materials, *i.e.*, it is only applicable to materials normally considered as poor conductors of electricity (insulators), and if the electrical resistivity falls below 1,000 ohms/cm³

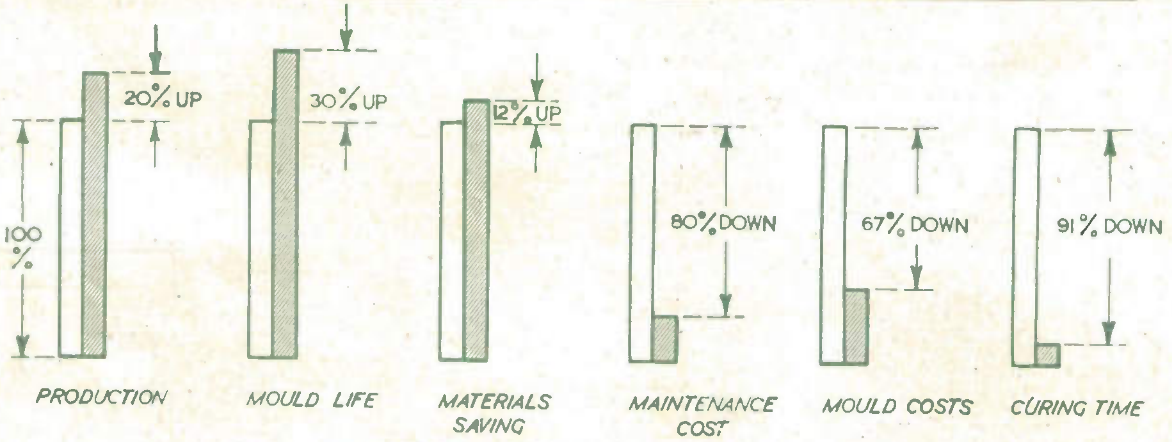


Fig. 1. Effect of H.F. heating on moulded plastics.
—*Westinghouse Ad. ("Electronics," Sept., 1945, p. 88.)*

Pull Amplifiers—A Reference Chart

DIAGRAMS of a number of circuits are given opposite which are used for supplying two alternating signals of equal amplitude but opposite polarity suitable for driving valves in push-pull.

Transformer Method

One of the most used circuits, shown in Fig. 1, employs a transformer with a centre-tapped secondary winding for this purpose. The output valves V_2 and V_3 are shown here (and in all the other diagrams) with a common automatic bias resistance (which need not be by-passed by a condenser since, ideally, the alternating components of the anode currents of V_2 and V_3 are equal and there will hence be no alternating component in the P.D. across it). Alternatively, of course, V_2 and V_3 could have individual grid-bias circuits. By adjustment of the grid-bias voltages any differences in the D.C. components of the anode currents of V_2 and V_3 can be eliminated, thus preventing any steady magnetisation of the core of the output transformer. By connecting potentiometers across the two halves of the secondary winding so that the amplitude of the signal inputs to V_2 and V_3 can be controlled, it is possible to correct for any difference in stage gain in the output valves. Although triode output valves are indicated in all the diagrams this is merely for the sake of clarity; pentodes or tetrodes are more likely to be used to-day with, no doubt, some form of voltage feed-back to reduce distortion.

Triode Phase Splitter

A triode valve is used as a phase splitter in Fig. 2. Its load consists of R_1 and R_2, two equal resistances, one in the anode, the other in the cathode lead of the valve. R_3 is the grid-bias resistance and R_4 the grid leak. The input is applied, if the preceding valve is R.C. coupled, between grid and H.T. –, as shown, so that the valve operates with considerable current feed-back (about 50 per cent.). In these circumstances the gain of the valve cannot exceed 2; it is, in fact, usually about 1.8, so that if each of the output valves requires an input of, say, 9 volts peak value, V_1 will require an input of 10 volts peak value. There is no point in providing a by-pass condenser for R_3; so much current feed-back is already present, due to R_2, that the additional amount, due to R_3, will make practically no difference to the performance of this stage and so a by-pass condenser is an unnecessary luxury.

Paraphase Method

Fig. 3 depends for its operation on the fact that the grid-cathode and anode-cathode signals in an R.C. coupled valve are 180° out of phase. V_1 is coupled to V_3 and V_2 to V_4 in the usual way, but the input of V_2 is derived from the output of V_1 so that the alternating output signals of V_3 and V_4 are 180° out of phase. A potential divider between V_1 and V_2 enables the amplitude of the signals fed to V_3 and V_4 to be made equal. Clearly this potential divider must provide a step-down ratio equal to the stage gain of V_1 and V_2 (these being similar valves). Balance is best achieved empirically by making the potential divider variable, as shown, and adjusting it until 'phones inserted in the circuit at point X give minimum signal.

"Out-of-Balance" Method

A most interesting circuit is shown in Fig. 4 in which the necessary phase reversal is achieved in the output stage itself without using a centre-tapped transformer or additional valve. To appreciate the method of operation, first imagine V_2 and all its grid circuit components removed. V_1 then performs as a normal output valve with current feed-back provided by R_1 and R_2. Signal P.D.s are developed across R_1 and R_2 and these are used to drive V_2 which is connected up so that its alternating output current is opposite in phase to that of V_1. This necessitates bonding of the two cathodes, R_1 being a common bias resistance, and joining the grid of V_2 to earth (by a condenser to permit correct bias to be applied *via* the grid leak). R_2 now carries the currents of V_1 and V_2, but these adjust themselves so that there is a slight difference between their A.C. components, sufficient in fact to develop the input voltage for V_2 across R_2. If R_2 is made 1,000 ohms this difference in anode currents is only about 10 per cent. if V_1 and V_2 are pentodes of the PEN 45 type—and this causes very little distortion and little loss of output power. R_2 will need to dissipate safely about 6 watts. The input voltage necessary across *AB* will be about twice that for one valve. An H.T. supply higher than normal will be necessary to make up for the volts lost across R_2. Care should be taken to avoid exceeding the safe heater-cathode insulation rating of V_1 and V_2.

Alternatively, the triode phase splitter could be transformer coupled from the preceding valves, the secondary connexions being made to the grid and to the junction of R_2 and R_3. R_3 should now be by-passed with a 50 μF condenser and R_4 can be omitted. A phase-splitter valve used in this way can give a very useful voltage gain. It should be possible, for example, to obtain 15 volts on the grid of each output valve from a 1-volt input to the grid of the phase splitter, this corresponding to an overall stage gain from the phase splitter of 30 times.

All push-pull circuits, particularly symmetrical ones, have a tendency towards parasitic oscillation and, to give protection against this possibility, it is advisable to include resistances ("grid stoppers") in the grid circuits of the output valves. These may profitably be as high as 50,000 ohms in the case of pentode or tetrode output valves. Any "top cut" caused by the inclusion of these can be overcome by the use of negative feed-back.

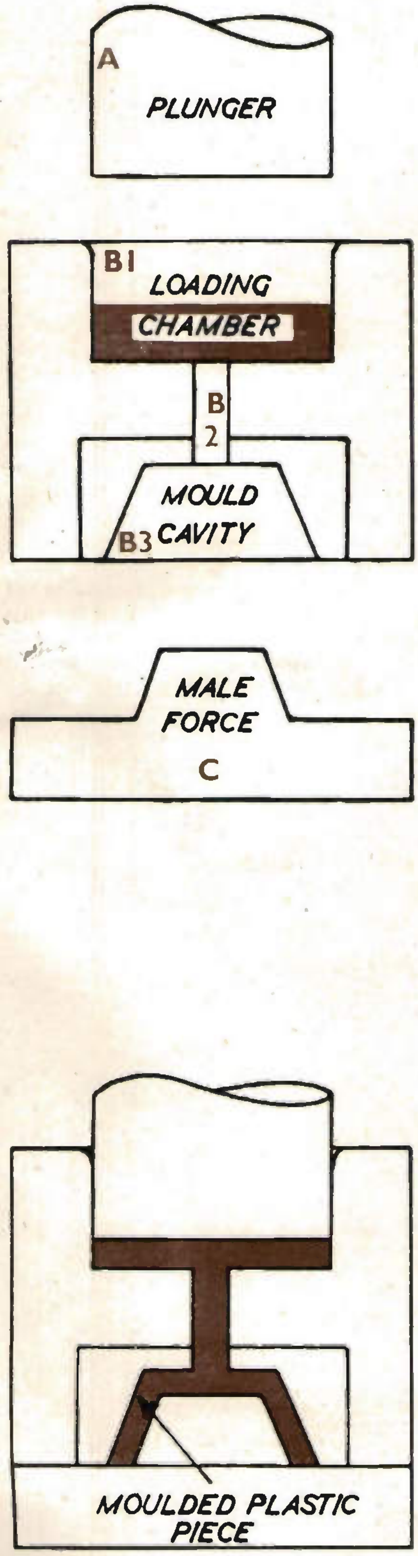


Fig. 4. A simple type of single cavity transfer mould.

—"*Plastics and Resins Industry*," *January, 1944.*

Standard Methods of Moulding

In order to appreciate fully the advantages of H.F. heating of preforms it is necessary to consider the usual methods of moulding. Two examples are given:

(a) Positive type compression moulding (Fig. 3).

(b) Transfer moulding (Fig. 4).

Compression Moulding

The mould consists of two heated parts: upper and lower. The preform is partially softened by heat in an oven adjacent to the press, the temperature of the oven and the time the preform is left in the oven being regulated so that the outside is not baked hard in an endeavour to soften the preform right through to the centre. Because of this, when the preform is placed in the mould it has not attained uniform and maximum plasticity; in fact, it is still relatively hard. Considerable effort is therefore needed to close the mould and squeeze the material into its final shape while it is further heated up. During this operation light inserts and even hardened steel core pins may snap off.

Transfer Moulding

Fig. 4 represents a simple type of single cavity transfer mould in three sections:

(A) Plunger attached to head of press.

(B) Centre section which contains:

1. Loading chamber or "pot."
2. "Sprue" through which material is transferred.
3. Mould cavity.

(C) The "male force."

In the top half of the figure the three sections are shown separated, and in the bottom half the mould is shown closed, with a moulded plastic piece in position.

Operation of Transfer Moulding

1. The preheated material is loaded into the chamber or "pot" (B1). 2. Mechanical pressure is applied to the transfer plunger A which telescopes into the chamber (B1) and transfers the material forcibly through sprue (B2) into mould cavity (B3). When the pressure is first applied the material may not be completely softened. However, it soon softens and it absorbs more heat as it flows through the sprue into the closed cavity of the mould. It then reaches maximum plasticity and tends to flow around inserts, cores and other

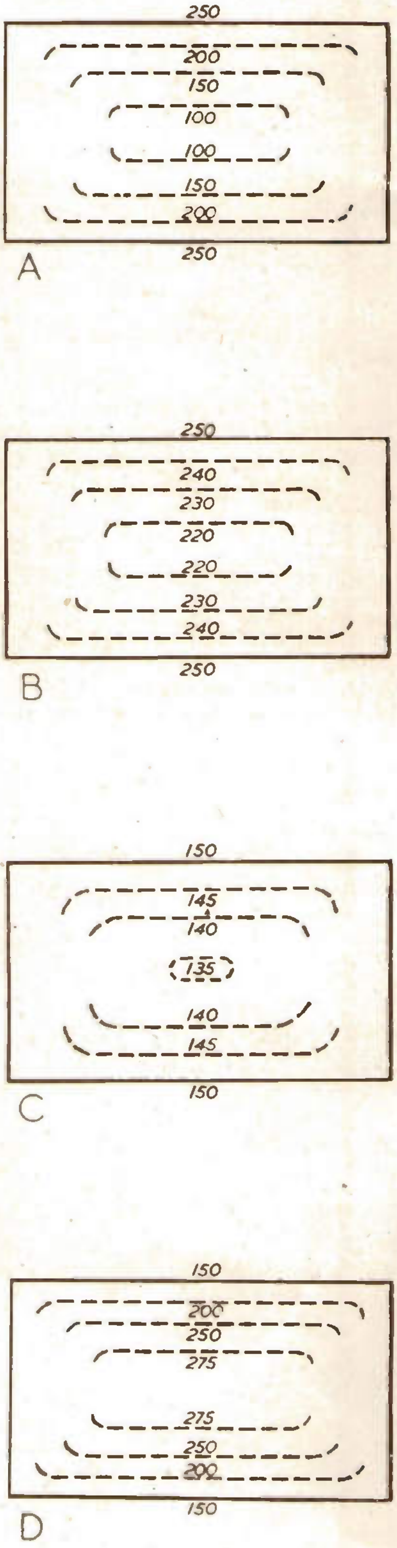


Fig. 5. Preform Isotherms.

—"*Electronics*," *Sept., 1943, p. 102.*

obstructions. When the cavity is completely filled full pressure can be applied. The action of the press must be timed so that the cavity is filled before the moulding material sets.

Transfer moulding is valuable in cases where components cannot be made by the simple compression moulding method described elsewhere. Other advantages claimed for standard transfer moulding are :

1. Material is more uniformly heated than is the case with standard compression moulding, and so the quality is better.

2. Arising out of the above, irregular sections can be manipulated with less danger of over-curing the thin parts and under-curing the thick parts.

3. Density is more uniform and dimensions are more stable.

4. The system can be used where stiff-flowing high strength materials have to be handled.

Heat Distribution in Preforms by Oven and H.F. Preheating

Because the normal type of preform is a poor conductor of heat, oven preheating is not ideal. Fig. 5 shows the isotherms for oven heating against H.F. heating, the preforms A and B being oven preheated at 250° F., A for 5 minutes and B for 30 minutes.

In the case of A the innermost part of the preform reached a temperature of something under 100° F. In order to raise this value to a really useful figure the oven preheating at 250° F. was carried on for 30 minutes, in the case of B, until an innermost temperature of something under 220° F. was attained. Unfortunately, the 30-minute duration is far too long for the outside of the preform which has set hard.

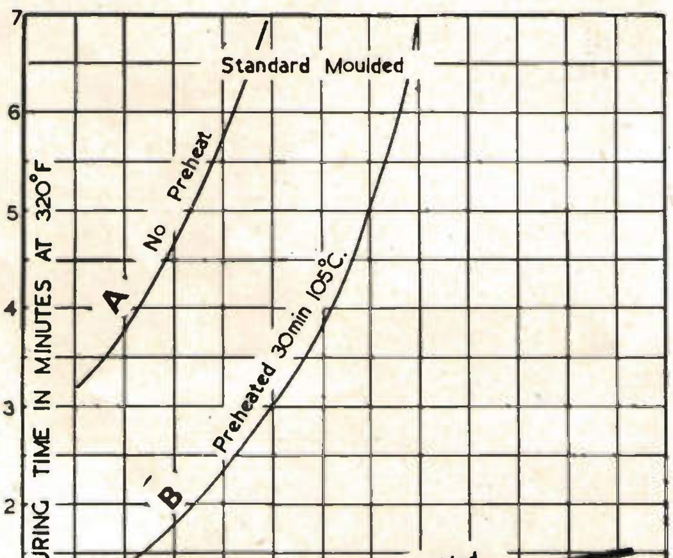
As a compromise, the arrangement shown at C was adopted, *i.e.*, oven preheating at 150° F. for 30 minutes in order to produce an innermost temperature of approximately 135° F. It is interesting to compare H.F.-heated preform D with oven-heated preform C. In each case the surface temperature is the same, but in the case of D the innermost temperature has reached a value in excess of 275° F. in 40 seconds. J. P. Taylor points out that the fact that the outer surface temperature is lower than the inside temperature is no great disadvantage, because when the preforms are placed in the mould they take up heat from the hot mould and the tendency is for the temperature to equalise throughout the preform.

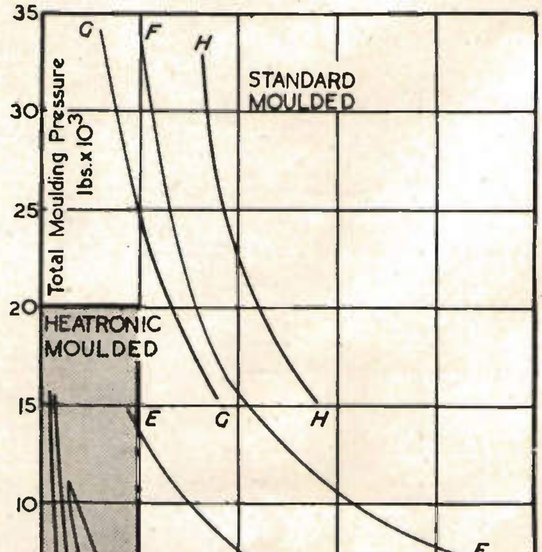
Electrodes and Housings

The H.F. electrodes are usually mounted in a special chamber attached to the generator housing. Before access can be gained, a door has to be lifted vertically and the supply is immediately cut off. On some models, the "oven" door is operated by a foot pedal, and on others a lid shrouding the preform lifts automatically at the end of the heating cycle. As an indication of the attention to detail, it is interesting to record that at least one design has fluorescent lighting installed in the heating chamber. In cases where moisture condensation is unusually severe, warm air from the generator may be "bled" into the cage. The escape of gases from preforms is facilitated by the provision of perforations in the hood, and in some cases the electrodes themselves are perforated. Circular sheet metal electrodes are already available in various diameters up to

Fig. 6 (left). Curing time for mouldings—a comparison of H.F. and standard heating.
—"Modern Plastics," 1943, p. 88.

Fig. 7 (right). Mould closing times/Moulding pressures.
E—Wood flour filled phenolic moulding material, soft flow.
F—Wood flour filled phenolic moulding material, stiff flow.
G—Urea moulding material, cellulose filled.
H—Fabric base phenolic moulding material.
—V. E. Meharg.





WE KNOW–
we made most of them!

There is no exaggeration in the story that appeared in the National Press recently that over 13,000 types of condensers were produced for the fighting Services during the war—in fact, our records show an even greater variety. We know this, since most of them were made in our main and dispersal factories as well as in out-working units which we organised.

Reference was also made in the Press to the manufacture of condenser parts by disabled ex-Servicemen, and we are proud to have been associated with this valuable means of obtaining extra production.

We make no complaint about the varied types and sizes of condensers we had to make—our skill and organisation were fitted for the work and we regarded it as our duty in the national interest. It also became part of our duty to make available generally our technical knowledge and manufacturing technique; if this helped in the final victory that has now been achieved, we are amply rewarded.

Now we shall be getting back into peace-time harness again and our Condenser service, which we claim to be the most comprehensive in the country, will once again be at the disposal of our customers. Our job is to make the kind of condenser YOU require.

TCC CAPACITORS

THE TELEGRAPH CONDENSER CO., LTD.
RADIO DIVISION

NORTH ACTON · LONDON · W·3 *TELEPHONE:* ACORN 0061 and including 15 in., which gives some idea of the size of preforms capable of being handled by H.F. heating.

A British made equipment of this type was illustrated in the August issue of *Electronic Engineering*, page 633.

Dimensions of H.F. Heating Units

Various references have recently appeared with regard to the size of H.F. generators. It goes without saying that it is desirable to keep the equipment as compact and light as possible, particularly where it is introduced into existing installations where most of the space may already be occupied. To illustrate the progress in this direction an example is quoted of a 2.5 kW model, dimensions 36 in. high, 26 in. wide and 22 in. deep, capable of heating 1 lb. of various types of moulding materials from ambient temperature to 240° F. in 37 to 49 seconds. The dimensions given approximate to those quoted for a 1 kW generator only a short time back (*Modern Plastics*, May, 1945, p. 57—Airtronics 2.5 kW, Model DE).

Table 1 gives typical dimensions, weight, and cost of British equipment recently exhibited (Rediffusion, Ltd.).

Cost of H.F. Heating

Most authorities seem agreed that H.F. energy is not a cheap source of electrical energy, but as H.F. heating can claim to do what has hitherto been considered as impossible, its cost is not the deciding factor. Actual costs are not readily available and one is all the more grateful to J. P. Taylor for publishing Fig. 8 as a basis for discussion (American prices). J. E. Oram in *Electrical Review* (June, 1944) points out that

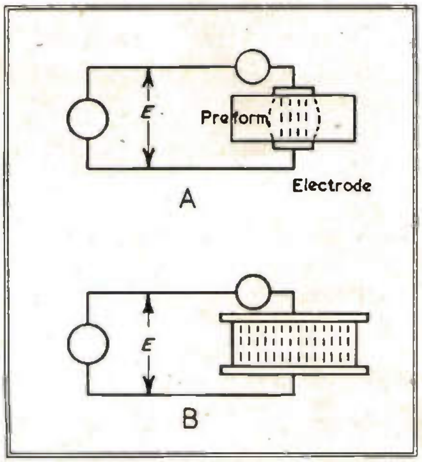


Fig. 9. Parallel plate electrodes—incorrect and correct.
—"Modern Plastics," May, 1943.

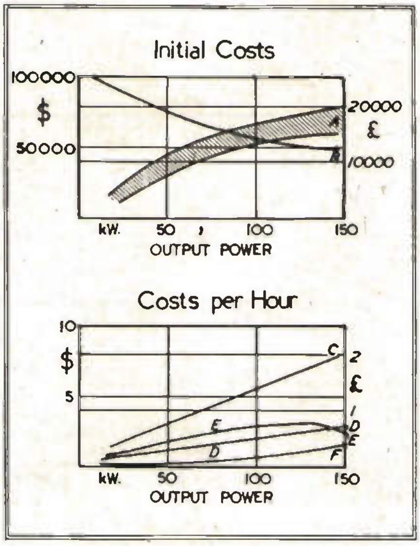


Fig. 8. Prices for H.F. apparatus.
A—Initial equipment cost.
B—Cost per kW.
C—Overall cost.
D—Power cost.
E—Depreciation.
F—Tube cost.

British prices are in certain cases two to three times as cheap. Carl Madsen has recently stated that the overall cost of H.F. energy works out at 0.025 to 0.04 dollar per kWh (say 1½d. to 2½d. per kWh).

Operating Costs per Hour

For an output power of 150 kW, the following operating costs are given.*

	$	s.
Tube cost	2	10
Power cost	3	15
Depreciation	3	15
Total overall cost	8	40

For an output power of only 25 kW the corresponding costs are approximately:

	$	s. d.
Tube cost	¼	1 3
Power cost	½	2 6
Depreciation	1	5 0
Total overall cost	1¾	8 9

* J. P. Taylor, *Trans. A.S.M.E.*, April, 1943.

Cost Summation

From J. P. Taylor's curves the following overall costs are typical:

Output Power (kW)	Dollars, per hour	Shillings, per hour
10	1	5
50	3	15
100	6	30
150	8	40

From the above, price per kWh varies between 5 and 10 cents, say 3d. to 6d. One British figure which covers valve replacement but no other depreciation is quoted at 1½d. This can easily be misleading as depreciation of the whole equipment should be included.

Initial Costs

From J. P. Taylor's curves the following are typical initial costs of H.F. Heating equipment:

kW Rating (output)	$	£
10	10,000	2,500
50	30 to 40,000	7 to 10,000
100	50 to 65,000	12 to 16,000
150	60 to 80,000	15 to 20,000

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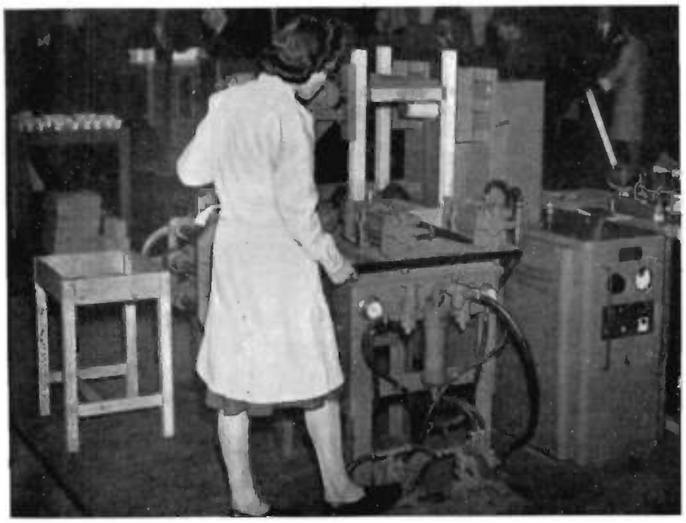
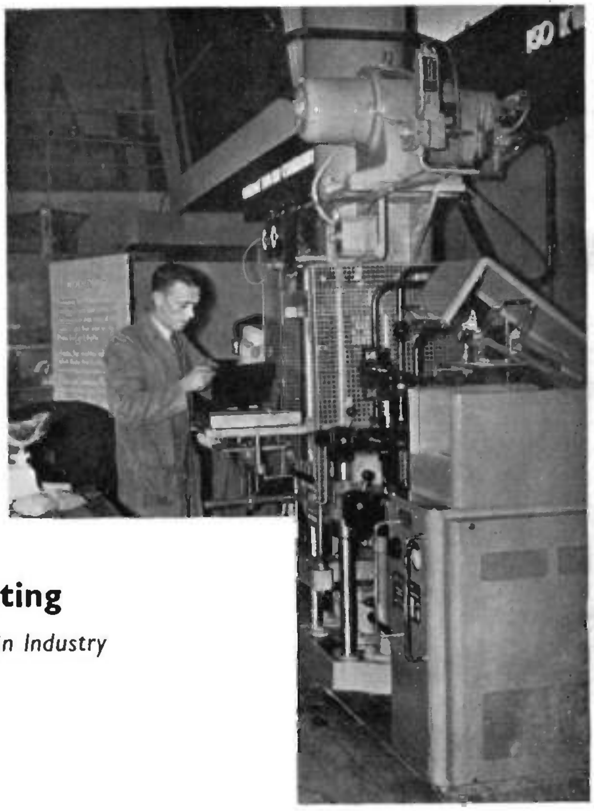
A New Glueing Process. W. Gallay and G. G. Graham. *British Plastics*, March, 1944, p. 103.

Heating Wood with R.F. Power. J. P. Taylor. *Trans. A.S.M.E.*, April, 1943, p. 201.

Table 1. Data on Typical British Equipment (Redifon)

Type No.	Output kW	Width	Depth	Height Closed	Height Open	Weight	Price
		in.	in.	in.	in.		£ s. d.
R.H. 21 ...	0.25	12	19	27½	37	130 lb.	115 10 0
R.H. 7 ...	2.5	20	30½	38½	38½	350 lb.	400 0 0
R.H. 31 ...	5.5	28	29½	60	60	14 cwt.	800 0 0
R.H. 4 oscillator	30	42	36	80	80	3 tons	2,050 0 0
R.H. 4 water unit	...	43	60	53	53		
R.H. 4 power unit	...	32	63	108	108		





More Applications of H.F. Heating

Photographs taken at the Exhibition of Radio Heating in Industry organised by Rediffusion, Ltd.

At the recent exhibition of H.F. heating at Dorland Hall, London, W.1, various examples were shown of the application of this new aid to industrial processing.

The model R.H. 7 generator shown on the left has an output of 2-2.5 kW at 16-18 Mc/s. and is suitable for a variety of purposes requiring medium power for drying or pre-heating. The photograph shows a cabinet fitted to the generator for rapidly drying plaster casts.

Above (left) is a good example of the speeding-up of one industrial process—the setting of sixteen glued joints simultaneously in a table or stool. The wood parts are held in place in a hydraulically operated jig which holds them firmly in place and applies the electrodes to the joints.

The photograph at the top (right) shows the same equipment adapted for preheating of moulding powder which is then treated in the press shown beyond the heater unit.

Details of the range of equipments shown are given in the table on the opposite page.

—Photographs by courtesy of Rediffusion, Ltd.

Detached Contact Circuit Drawings

By A. O. MILNE

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A RELAY, in essentials, is an electrically operated switch. It may be electro-magnetic or electro-thermal; the majority are magnetic.

Basically, a relay consists of a coil of wire wound on a soft iron core, so arranged that when a current passes through the coil, the core attracts an armature. This armature is constructed to effect the mechanical movement of one or more sets of spring-tensioned contacts, usually called " springs "; a number of contacts in one assembly being called a " spring-set." There are four types of contact combination for both relays and hand-operated switches:

Make; Break; Change-over; Make-Break, i.e., one contact makes on one circuit before breaking another.

The name of the contact, therefore, is a short way of indicating what it does when the armature moves. " Make " is short for " make contact when operated " and so on. A typical relay spring set-up is shown in Fig. 1.

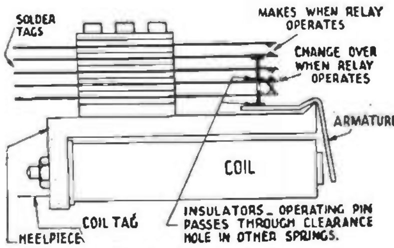

Fig. 1. Typical relay.

Relays and their associated contact springs are always shown on a diagram in their normal position, that is, with none of the relays energised. It is a simple matter, therefore, to follow the circuit operation in a logical manner when this fact is realised.

Detached Contact Diagrams

In the early days of telephone development, when the number of relays employed was very small, circuit diagrams usually depicted the relays and their associated contact springs in the manner of Fig. 2, but with the coming of automatic switching, with its complicated circuits and multitude of relays, some more simple method was essential if diagrams were not to be quite incomprehensible. Hence the " detached contact " system. In

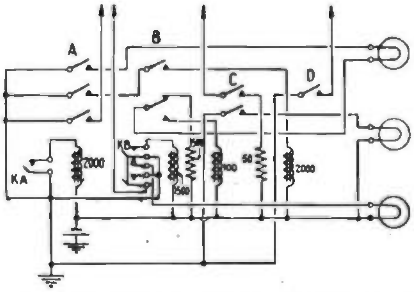

Fig. 2. "Attached" contact circuit diagram.

this type of drawing the relay contacts are disassociated from the parent relay and are shown in that part of the circuit which they serve, not necessarily near the relay coil itself. Fig. 3 shows the circuit of Fig. 2 drawn in the modern manner, the simplicity being self-evident. The convention of a cross within a circle indicates a lamp.

In telephone circuits, the exchange battery positive is earthed, the negative side is, therefore, referred to as " Battery," the positive as " Earth," the conventions being as shown in Fig. 3.

Each relay is identified by a letter, the number of associated spring sets being indicated as a fractional number. $\frac{A}{3}$ (*i.e.*, relay A) when energised will perform three separate switching operations. Reference to the relative circuit drawing will show where these occur and their function, make, break, etc. Each spring set is numbered, No. 1 being that nearest the frame of the relay.

The resistance of each coil of a

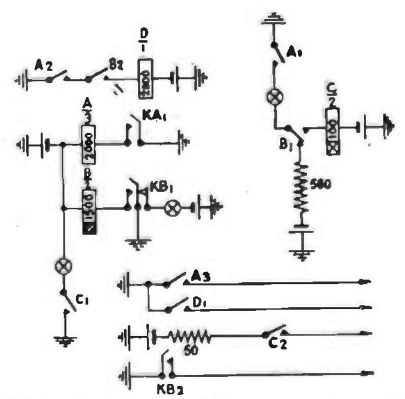

Fig. 3. Fig. 2 drawn with contacts " detached."

relay is indicated within the relay symbol; *see* Fig. 3. In the case of double coil relays the graphical symbol is divided and the resistance of each section shown separately.

Relays may be made " slow-to-operate " and " slow-to-release " by means of either a copper " slug " fitted to the coil or by the introduction of a short-circuited winding. " Slow-to-release " is attained by fitting the " slug " at the end of the coil remote from the armature. " Slow-to-operate *and release* " by fitting the " slug " at the armature end. The symbols for these two types are shown in Fig. 3. Relay B being slow to release and Relay C slow to operate.

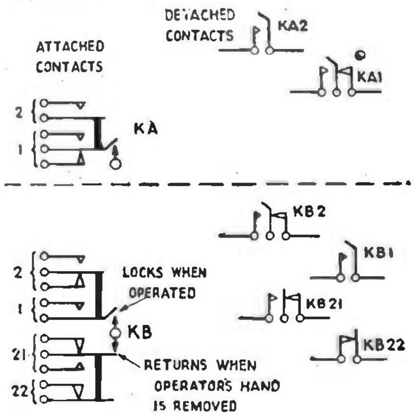

Fig. 4.

Hand-operated Switches

Many types of multi-contact hand-operated switches are now available, the most familiar being the Dewar-type switch known to telephone engineers as a " key," for reasons so ancient and obscure that they need not be pursued here.

These switches have many uses in the control of relays and other apparatus and are mentioned here because it is usual to show their contacts detached, just like relays. Fig. 4 shows some typical examples and also how they may appear on a detached contact diagram. The " keys " are designated KA, KB, KC, etc., and each spring set therein is separately numbered KA1, KA2, KB1, KB2, etc., just as in the case of relay springs. Where a " key " moves in two directions, the spring sets on one side are numbered 1-2-3, on the other 21-22-23, etc.

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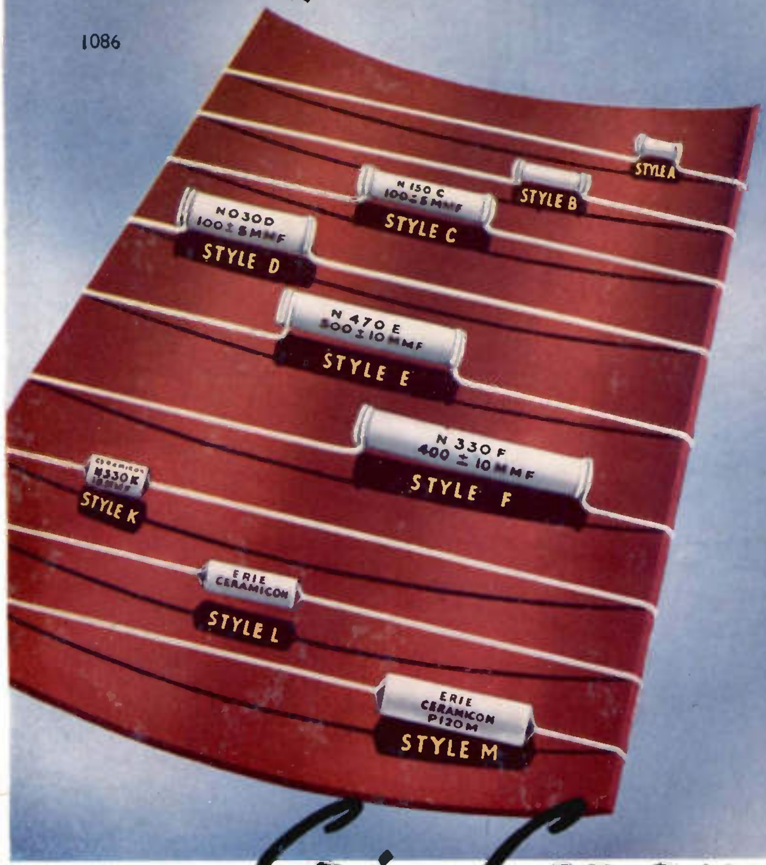

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When specifying Ceramicons for general purposes please state definitely that you can accept "any temperature coefficient between P100 and N750," when, in the majority of circumstances, we shall be able to deliver from stock because we shall then be able to supply any of the ten standard temperature coefficients listed below. The temperature coefficient of these Ceramicons will be between +160 and —870 parts/million/°C, as determined by measurement at 25°C and 85°C.

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STYLE or TYPE	P100	P030	NP0	N030	N080	N150	N220	N330	N470	N750	Maximum Overall Dimensions
K & A	Up to 9 MMF	Up to 10 MMF	Up to 18 MMF	Up to 18 MMF	Up to 20 MMF	Up to 24 MMF	Up to 27 MMF	Up to 30 MMF	Up to 36 MMF	Up to 51 MMF	K 5/8" × 1/4" dia. A 7/16" × 7/32" dia.
L & B	10 to 18 MMF	11 to 20 MMF	19 to 36 MMF	19 to 36 MMF	21 to 43 MMF	25 to 51 MMF	28 to 56 MMF	31 to 62 MMF	37 to 75 MMF	52 to 110 MMF	L 7/8" × 1/4" dia. B 11/16" × 15/64" dia.
M & C	19 to 63 MMF	21 to 68 MMF	37 to 120 MMF	37 to 125 MMF	44 to 140 MMF	52 to 160 MMF	57 to 180 MMF	63 to 200 MMF	76 to 240 MMF	111 to 360 MMF	M 1 1/4" × 11/32" dia. C 1 9/64" × 19/64" dia.
D	64 to 93 MMF	69 to 100 MMF	121 to 175 MMF	126 to 180 MMF	141 to 200 MMF	161 to 235 MMF	181 to 260 MMF	201 to 290 MMF	241 to 350 MMF	361 to 510 MMF	1 1/8" × 3/8" dia.
E	94 to 150 MMF	101 to 160 MMF	176 to 285 MMF	181 to 290 MMF	201 to 330 MMF	236 to 380 MMF	261 to 425 MMF	291 to 465 MMF	351 to 560 MMF	511 to 820 MMF	1 9/16" × 3/8" dia.
F	151 to 200 MMF	161 to 220 MMF	286 to 375 MMF	291 to 390 MMF	331 to 450 MMF	381 to 500 MMF	426 to 560 MMF	466 to 620 MMF	561 to 750 MMF	821 to 1100 MMF	1 15/16" × 3/8" dia.

Tolerance on Temperature Coefficient is ±60/parts/million/°C or ±15%, whichever is the greater.

Note : Styles A, B, C, D, E and F are non-insulated units. Styles K, L and M are insulated.

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Simplified Coil Testing

By G. T. CLACK

SOME of the production tests normally carried out on inductances do not require extreme accuracy and in most cases require only the employment of a production "standard" for comparison purposes. In such cases it is often possible to manufacture the necessary test gear from equipment already to hand, and with this in mind it is proposed to outline some of the simpler methods of production testing that can be carried out without resort to costly equipment.

Voltage Measurement

Before discussing coil tests, a preliminary note on voltage measurements is necessary. It is advisable to employ a valve-voltmeter for nearly every type of R.F. measurement, and the accuracy of any test will be dependent upon the stability and calibration of the valve-voltmeter. Alternatively, providing the stability is satisfactory, the need for an accurately calibrated meter is relatively unimportant, as in most cases the reading noted is used purely for comparison purposes and will affect the information given by a test only so far as absolute values are concerned. Sometimes more attention is given to the problem of input resistance of a valve-voltmeter than to the accuracy of its calibration, and rarely is even an expensive modern type of valve-voltmeter found to be better than ± 5 per cent. on the lower ranges owing to its short-term permanence of calibration.

For the usual broadcast and L.F. measurements undertaken in production, the operating range should extend up to 20 Mc/s. as this will then cover most of the measurements required of S.W. receiver circuits. Measurements at still higher frequencies may call for special components and naturally requires more consideration in design; once again the need for accuracy depends upon the type of measurement required as, where purely comparative figures are needed, most types of H.F. valve-voltmeter will provide sufficient information.

For general use such as pre-production tests, the valve-voltmeter should employ a probe connector, since by suitable design the input loading on the source, and frequency error, can be made small enough for satisfactory operation up to 50 Mc/s. A diode or reflex peak meter provides the most reliable means of measuring high radio frequencies, the input circuit being arranged so that the time constant is very large in comparison with the periodicity of the measured voltage, and if convenient can be followed by a D.C. amplifier with the usual "bucking" voltage adjustments (Figs. 1 and 2).*

For inputs above 0.1 volt the indication is proportional to the peak value of the measured voltage and may be calibrated to read RMS valves for sinusoidal voltages which corresponds to 0.707 of the peak value of a complex wave. Other types of peak voltmeters are the grid-leak and slide-back; the leaky grid is very useful owing to its higher sensitivity at inputs less than 1 volt, but the loading effect limits its application. The slide back meter is self-calibrating and has very satisfactory characteristics but uses two meters and requires a certain amount of manipulation of the controls before any reading can be obtained.

The anode-bend meter has similar characteristics to that of the slide-back and a simplified version of this is shown in Fig. 3.

The calibration of the leaky grid/anode-bend meters will exhibit square law characteristics over most of the range, whereas the diode peak type meter shows non-linearity due to curvature of valve characteristics only at inputs of less than 0.3 volt, becoming linear at inputs higher than this.

Measurement of Resistance

The first test operation made is one for continuity and measurement of coil resistance often below 1 ohm. Such tests are always made at low voltage in order to reveal high resistance joints, contacts, and open-circuited strands when litz wire windings are used.

The circuits shown in Figs. 4 and 5 are self-explanatory; in Fig. 4, the 5-ohm resistance is adjusted to produce full scale deflection on an

* Fig. 1. General Radio Co. Vacuum tube voltmeter, Type 726A.

Fig. 2. R.C.A. application note No. 47, May 20 1935.

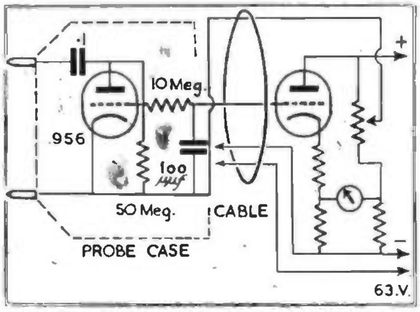


Fig. 1. Note—for 63 V. read 6.3 V.

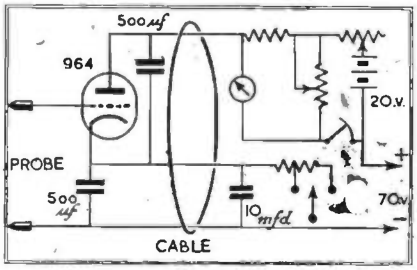


Fig. 2.

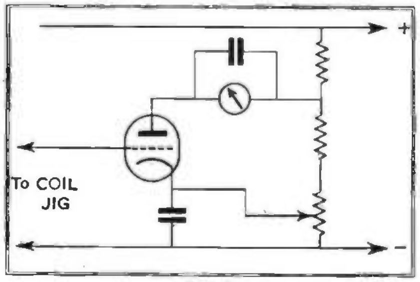


Fig. 3.

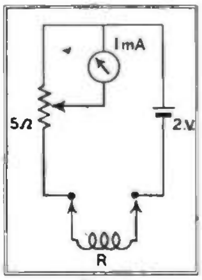


Fig. 4.

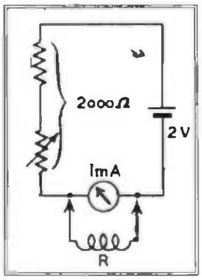


Fig. 5.

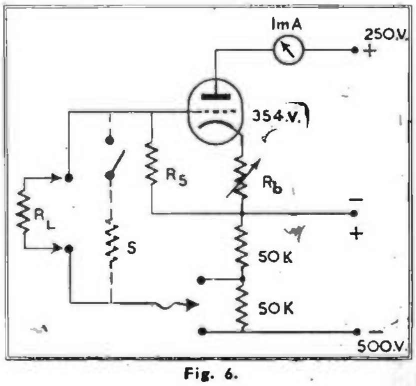


Fig. 6.

0-1 mA meter when the test terminals are short-circuited. The short-circuit is then removed and the meter calibrated in the normal manner by connecting a decade resistance across the terminals. Alternatively, a calibration curve is computed from the fact that as scale deflection is proportional to current, and this in turn proportional to $\frac{1}{R_x + 5}$, then resolving this in terms of scale deflection,

$$R_x = \frac{5}{I \text{ mA}} - 5$$

where I mA is the direct reading in milliamps (always less than 1.0) with R_x in circuit. The circuit given in Fig. 5 is less sensitive for low resistances using the same type of meter, and the calibration can be carried out as before or computed from

$$R_x = R_m\left(\frac{i_2}{I - i_2}\right)$$

where R_m is the internal resistance of the meter, and i_2 the reading in milliamps with R_x in circuit (i_2 is always less than 1.0 mA).

The calibration of this type of ohmmeter is independent of supply voltage as the meter is always set for full-scale deflection before taking measurements; the most useful sensitivity is between 0.1 to 10 ohms for Fig. 4, and 5 to 100 ohms for Fig. 5.

Insulation

There is rarely any need to test for leakage with normal production R.F. coils except in cases where overwound anode-coupler or regeneration-coupler windings are carrying D.C. It is then advisable to check the insulation in case the covering on the wire or the insulating spacer material has been damaged during the winding process. In most cases there will not be greater than 250 volts P.D. between such windings and an insulation test at 500 volts D.C. will prove satisfactory. The circuit in Fig. 6 is for insulation testing and can be made to measure up to several thousands of megohms.

The operation is that R_L and R_g form a simple potential divider determining the negative potential at the grid of the valve, thus controlling the anode current indicated by the meter. The bottom end of R_L is returned to the tapped bleeder resistance of 100,000 ohms across the negative supply and determines the test potential, 250 or 500 volts; another variation is the employment of an internal standard (S) of either 40 or 100 megohms, which is switched across the leakage terminals for calibration or comparison purposes.

In use, the anode current is adjusted by means of R_b to 1 mA (full-scale deflection on meter) with the leakage terminals open-circuited. Upon connecting a resistance to the leakage terminals the bias on the valve will change by an amount determined by the ratio of the leakage resistance to the grid leak R_g, which tends to drive the valve towards cut-off resulting in a decrease of anode current as observed on the meter. One big advantage is that the meter cannot be overloaded as would be possible with similar systems where the grid is driven positive. The calibration curve is similar to the usual E_g/I_p characteristics for the particular valve employed and tends to become very cramped at both ends; however, by altering the ratio between R_L and R_g the most linear portions of the characteristic can be employed for any particular range of resistances. Fig. 7 is for a typical calibration curve where the grid resistance has been arranged to bring 50 megohms at about mid-scale.

Inductance Measurements

There are two methods, one of which is a direct measurement of inductance and the other a resonance test. The former is often carried out on a low frequency bridge at about 1,000/2,000 c/s., and the latter at a frequency at which the coil is expected to function. The latter method is invariably adopted for production testing as it takes into account the self-capacity and other factors of the winding which produces an apparent increase in inductance. Variations in self-capacity and inductance experienced in production are due to a combination of (a) variation in wire-tension, (b) wire gauge, and (c) differences in thickness of insulation covering.

As the winding machine can be relied upon for ± 1 turn at the least, the normal production variations due to any one or all of the above (a, b, c) can be offset by spacing a few of the end turns, which can then be adjusted during the initial inductance test and again, if necessary, when the coil is included in the receiver and undergoing the alignment operation. Generally, no difficulty is experienced in keeping the tolerance better than ± 1 per cent. for normal broadcast coils.

The test equipment consists essentially of an oscillator and a valve voltmeter. One arrangement can be in the form of a comparator bridge where the test coil is directly balanced against an internal standard of similar characteristics at a frequency at which the coil would normally operate. The bridge would be excited from a local oscillator and any circuit strays balanced to zero by L and C compensating trimmers; great care would have to be taken with the screening and any potentiometers employed require to be non-inductively wound types. The accuracy expected is of the order of ± 0.05 per cent. and relatively independent of small changes in oscillator frequency.

A very much simpler method is shown in Fig. 8, which consists of a local oscillator and an anode bend detector across the grid of which is connected the test coil. It can produce reasonable results provided that the capacitance coupling the test coil to the oscillator is kept low in order to avoid frequency fluctuations due to the pulling of the oscillator frequency by the test coil.

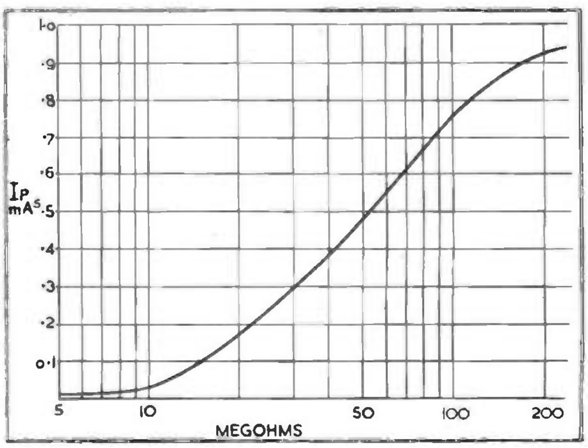


Fig. 7.

An improvement on this Fig. 9 is where advantage is taken of the improved stability obtained by using a cathode-coupled circuit and the decreased coupling between oscillator and test coil by using a pentode oscillator. The capacitance C is kept as low as possible consistent with satisfactory operation at the lowest test frequencies and will call for a compromise only when more than one oscillator range is employed. In operation, the preset cathode resistance RV_2 is adjusted to produce zero plate current (or nearly so) with the test terminals short-circuit. With a standard test coil connected, VR_1 is adjusted to produce a convenient reading on the meter M, once the test coil has been tuned to resonance by means of C_2. The grid circuit capacitance is then adjusted so that the trimmer or vernier, C_3, is at half-scale and then C_3 is calibrated. Experimental samples are then substituted for the standard and adjustments then made to the end turns to produce maximum reading at the same scale setting; alternatively, limits are imposed so that adjustments are only made on those samples which resonate outside the specified limits.

A third method of testing coils is that of utilising the dynatron circuit of Fig. 10. In this case the coil is made to oscillate by virtue of the negative resistance introduced by the valve-operating characteristics and which assists in maintaining oscillation in the coil without resort to feedback.

A coil undergoing test can be connected across a known capacitance and an indication of resonance given by a valve voltmeter. Once again a standard coil can be used to observe the initial conditions or a regenerative detector amplifier can be used to detect the frequency at which the coils must operate. This method of adjusting the coil to zero-beat can produce a high degree of accuracy as with careful adjustment it is possible to get within ± .01 per cent. of a required value.

Of the four methods mentioned, *i.e.*, (1) Direct inductance measurement at L.F., (2) Comparator bridge, (3) Oscillator and valve-voltmeter, and (4) Dynatron, (1) and (2) are very satisfactory but require a fair amount of time and care in design and manufacture, being less easy to reproduce in quantity than (3) or (4), as the production testing of many types of coils simultaneously at the rate of 16/18,000

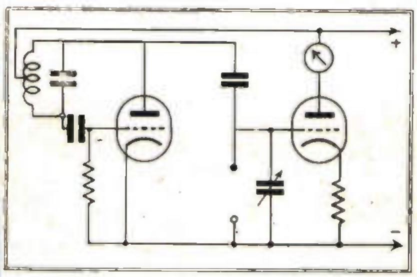


Fig. 8.

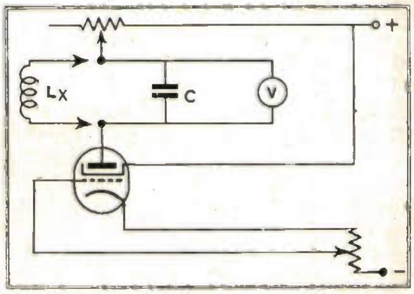


Fig. 10.

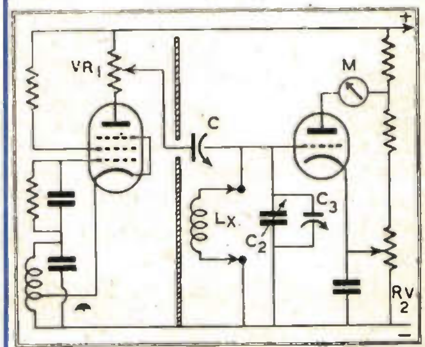


Fig. 9.

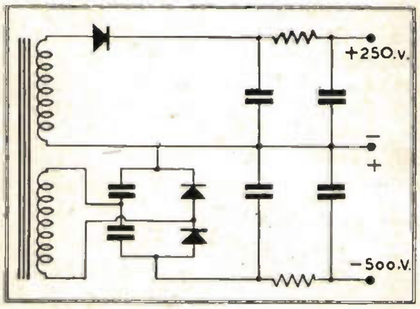


Fig. 11.

per week will require a considerable number of test gears.

The test gear should follow a basic design to simplify manufacture, the only differences being: (a) some will have a multi-range oscillator, (b) others will have one or two ranges for non-standard frequency range(s), and (c) others have internal or external plug-in type standards and perhaps a more sensitive detector voltmeter. For normal broadcast testing the gear (a) can be of the continuously variable type over several ranges or, simpler still, produce fixed frequencies consistent with the type of winding to be tested, *i.e.*, 200 kc/s., 465 kc/s., 1 Mc/s., 10 Mc/s., etc., for L.W., I.F., M.W., and S.W. coils respectively. The type (b) for use with H.F. chokes, whistle filters and high inductance windings up to 300 mH, etc. Type (c) for more accurate requirements and with flexibility of operation giving immediate access to the standard coils of a plug-in type and using, perhaps in the case of coils for television receivers, a more efficient type of valve-voltmeter similar to those described earlier in the article.

Direct measurement of inductance on an L.F. bridge need only be confined to a special test section associated with the coil-shop for the purpose of carrying out pre-production checking and the issue of sample coils as standards. This section would also carry out the periodic checking of test equipment, standards and selected production samples from subsequent batches.

The one advantage of using a standard exactly similar to that of the test coil is that temperature changes will be common to both.

Multiple windings, *i.e.*, I.F., combined M and L wave windings on same former, must have all floating windings short-circuited during the tests unless the test gear has been designed to simulate working conditions. The test gear should be arranged to select the appropriate winding and to bring in the correct standard winding at the same time; the others automatically becoming short-circuited during this operation. A point worth mentioning is the manner in which the coil is connected to the test gear. If leads must be used, they should be kept as short as possible consistent with ease of manipulation. But the best system is always some form of jig into which the coil is plugged. Contact resistance must be kept consistently low and, furthermore, the metal parts of the jig should be kept to a minimum or so placed where they cannot influence the test inductance. This, incidentally, also applies to the placing of tags on the coil former, especially where all dimensions have been kept down to a minimum in an effort to produce the smallest possible coil dimensions.

Variable dust-core types are adjusted exactly to resonance by means of the core which is then waxed into position unless a further adjustment will be required during the alignment operation. If this is so, a small amount of fixative is used so as not to impede the core movement at a later date, after which complete fixing is made as before.

Where it is desired to adjust a coupling winding in relation to another winding it can be done by arranging for feedback to occur between the two windings with the aid of a valve and noting the amount of grid current produced. The position of the coupler should be adjusted to produce the same as that produced by the standard, and then sealed carefully into position with a high grade lacquer varnish.

Power Supplies

The test equipment described requires some form of stabilised H.T. supply and the use of stabilising neons such as two Cossor S130's in series across a 250-volt 60-mA D.C. supply will result in a regulation characteristic of <-2 per cent. for 0 to 60 mA load. Also mains supply variations of ± 5 per cent. are reduced in effect by 10 times, *i.e.*, showing a change of less than ± 0.5 per cent. across the D.C. output.

The power supply for the leakage test, Fig. 6, can follow that given in Fig. 11. The transformer can be of the usual broadcast receiver type with the H.T. winding separated at the centre tap to enable each half to be used independently. A half-wave rectifier on one side is employed to produce 250 volts D.C. for the valve circuit and a voltage doubler on the other half to produce -500 V for the leakage potential.

Finishing Varnish

After the initial test for inductance the coil is subject to proofing against humidity and temperature. This process is simply the waxing or varnishing of the winding and whichever is used depends upon the ultimate use to which the coil is placed. Modern agents are fairly reliable, and introduce, in some cases, very little change in characteristics after the coil has been treated, and only in special cases, *e.g.*, precise values, need the coils be rechecked.

If wax is used it should be of a pure neutral mineral wax, free of chemicals, *i.e.*, chlorine and sulphate, and synthetics to avoid electrolytic action. It should also have an operating range of about 70° to -30° C. if tropical and extreme temperature requirements are to be satisfied.

The results obtained with modern lacquer varnishes show much the same results as waxes, and it can be made a practice to lacquer varnish all LW, MW, SW, oscillator and signal circuit coils and to wax dip or impregnate I.F., filter, and other high inductance windings. The use of varnish for all work simplifies the operation, as with wax a dipping bath must be kept at a temperature of about 100-130° C.

Q Tests

In all cases a direct index to the magnification of a coil is given by the voltage measurement taken on the test gear at resonance. Variations with coils can be observed during tests and in any case poor connexions, open circuited (Litz) strands, shorting or partial short-circuiting turns show up readily as much reduced readings on the valve-voltmeter. The jig into which the coil is connected can be a source of trouble due to poor contact resistance. The obvious cure for this is a well-designed contact system capable of withstanding continuous use without introducing resistance.

DECEMBER MEETINGS

*NOTE.—In general, visitors are admitted to the meetings of scientific bodies on the invitation of a member, or on application in writing to the Organising Secretary at the address given. In certain cases (marked *) tickets may also be obtained on application to the Editorial offices of this Journal.*

Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Ordinary Meeting

Date: December 6. Time: 5.30 p.m.
Lecture:
" The Electrical Engineering Industry in After-War Economy."
By:
G. L. E. Metz.

Measurements Section

Date: December 14. Time: 5.30 p.m.
Lecture:
" A Precision A.C./D.C. Comparator for Power and Voltage Measurement."
By:
G. F. Shotter and H. D. Hawkes.

Radio Section

Date: December 5. Time: 5.30 p.m.
Lecture:
" The Design and Use of Radio-Frequency Open-Wire Transmission Lines and Switchgear for Broadcasting Systems."
By:
F. C. McLean, B.Sc., and F. D. Bolt, B.Sc.

Date: December 11. Time: 5.30 p.m.
Discussion on:
" The Servicing of Radio and Television Receivers."
Opened by:
R. C. G. Williams, Ph.D., B.Sc. (Eng.).
The Secretary:
The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

London Students' Section

Date: December 18. Time: 7 p.m.
Lecture:
" Atmospherics and Their Location."
By:
C. Clarke.
Hon. Secretary:
R. V. Darton, 27 Church Rise, Forest Hill, London, S.E.23.

Cambridge Radio Group

All meetings of the Cambridge Radio Group will be held in the Cambridgeshire Technical College.

Date: December 10. Time: 6 p.m.
Inaugural Address as Chairman of the Radio Section (London).
By:
A. H. Mumford, B.Sc.(Eng.).
Group Secretary:
D. H. Hughes, c/o Pye Ltd., Radio Works, Cambridge.

Institute of Physics

Date: December 13. Time: 6.30 p.m.
Held at:
The Reid Knox Hall, 32 Welbeck Street, London, W.1.
Lecture:
" The Production and Applications of Supersonics."
By:
E. G. Richardson, B.A., Ph.D., D.Sc.
Hon. Secretary:
H. Lowery, South-West Essex Technical College, Forest Road, London, E.17.

Radio Society of Great Britain

All meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Date: December 29. Time: 2.30 p.m.
Lecture:
" Radiolocation."
By:
R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E., D.I.C., A.R.C.S.
The General Secretary, R.S.G.B., New Ruskin House, Little Russell Street, London, W.C.1.

Bradford Electronics Society

Date: December 12. Time: 7 p.m.
Held at:
The Technical College, Bradford.
Lecture:
" Metrosil."
By:
W. Needham.
Hon. Secretary:
G. N. Patchett, The Technical College, Bradford.

Institution of Electronics

Date: December 6. Time: 6.30 p.m.
Held at:
The Great Hall, Manchester College of Technology.
Lecture:
" Bright Light Sources—Part 2—Electric Discharge Lamps."
By:
J. N. Aldington, B.Sc., F.Inst.P.
Hon. Secretary:
L. F. Berry, 105 Birch Avenue, Chadderton, Lancs.

Brit.I.R.E.

North-Eastern Section

Date: December 12. Time: 6 p.m.
Held at:
The Mining Institute, Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture:
" Review of Industrial Electronics."
By:
J. Hare and J. C. Finlay.
Section Secretary:
H. Armstrong, 69 Osborne Road, Jesmond, Newcastle-on-Tyne.

Kingston-upon-Hull Electronic Engineering Society

Date: December 11. Time: 7.30 p.m.
Held at:
The Electricity Departments Showrooms.
Lecture:
" Modern Electric Discharge Lamps."
By:
— Bowtell.
The Secretary:
C. W. Wyan, 2 Lockton Grove, Hull.

Correction

In the article " Cathode-Ray Tube Traces—Part 3," by Dr. H. Moss, which appeared in the October issue of this Journal the following corrections apply:

p. 723. Equation 41. $\cos^2\theta$ and $\sin^2\theta$ should be interchanged.

p. 729. Line above Equation No. 44 reads—while the steady-stage voltage . . . should read—while the steady-state voltage . . .

BOOK REVIEWS

The Electrolytic Capacitor

A. M. Georgiev. (Murray Hill Books, Inc., New York, 1945, $3.00; English price, 18s approx.) 181 + xii pp., 72 figs.

It was about 1930 that electrolytic condensers began to come into common use in radio and allied equipment, although the principles of their operation had been familiar for many years, but it was not until 1939 that Coursey published his book "Electrolytic Condensers." Another six years elapsed; now comes this very welcome major addition to the somewhat scanty literature on the subject. The author is associated with the Delco Products Division of General Motors Corporation and it is thus to be expected that the majority of the condensers considered in his book are those associated with electrical practice—power factor correction, capacitor-motors, etc.—rather than types used in radio equipment, although these are covered to some extent and, of course, the technique is precisely similar.

From the point of view of the users of condensers (the main bulk of readers presumably) a good portion of the book is of academic interest only. Pages 20-103 deal very thoroughly with the theory, construction and manufacture of electrolytic condensers and are most useful to the inquirer wishing to study the inner secrets. The physico-chemical aspects of electrolytic condensers are well covered and references to actual plant for manufacturing condensers are numerous.

These chapters are preceded by three of general condenser and electrolytic condenser information, while the remainder cover measurements and tests, troubles and repairs, design and uses, etc. A short glossary explains the more unfamiliar terms used in the text and a bibliography, lists of patents and a surprisingly comprehensive index complete the work. A fascinating little section covers emergency repairs, giving information on repairing condenser units when it is impossible to secure replacements. The list of patents is a valuable feature although some indication of their subject matter might obviate much unnecessary searching in the files. It is surprising, too, to note the enormous numbers of American patents in comparison with the dozen or so British ones.

It is clear that the author is very familiar with his subject and his statements may be accepted with the assurance that they represent good modern practice. The publishers' description on the dust jacket gives a good indication of the many and varied classes of electrical engineers using electrolytic condensers and it may be confidently stated that all will find the book of use.

E. D. HART.

Fields and Waves in Modern Radio

Simon Ramo and John R. Whinnery. (John Wiley & Sons, 30s. net.) 502 pp., many figs.

This volume is one of the series of textbooks written for the advanced training of graduate engineers employed by the American General Electric Co., by members of the research staff of that organisation. It is the first one to be specifically concerned with radio communications.

The purpose of the work is to serve as a connecting link between the techniques used in medium and shortwave radio and those used in microwave work. This same ground has been covered by several recent books such as Slater's "Microwave Transmission" and Schelkunoff's "Electromagnetic Waves," but the present work will prove much more acceptable to engineers than anything so far published. It has the two great virtues of being up to date and of presenting a clear physical picture of the phenomena described. Furthermore, the authors have not bilked at including the necessary mathematics so that the book can actually be used in the laboratory for design purposes.

The book starts with a general chapter on lumped constant circuits and the engineering treatment of uniform transmission lines. The next two chapters, which are very well done, are on electro- and magneto-statics leading up to Chapter 4 on Maxwell's Equations. In these chapters all the necessary concepts of vector analysis are developed along with the physics which they describe Chapters on circuit concepts at high frequencies and on skin effect follow. The next three chapters, of some 130 pages, are on electro-magnetic waves and wave guides. In this work Schelkunoff's impedance concept is freely used and a good deal of the equivalent circuit analysis developed by the authors in the *Proc. I.R.E.* is included. This will be a great relief to all, since although equivalent circuit methods have been used for years no description has been printed until the present.

The book concludes with a chapter on cavity resonators and one on radiation. Both these chapters show that the authors have understood what is needed by and is useful to engineers and physicists working in these fields, very completely. The section on cavities could have been improved by the addition of material on the various approximation techniques which have been used for resonance calculations. These include the perturbation theory of quantum mechanics and Southwell's relaxation method. The basic material is, however, included.

The book creates a very favourable impression by a workmanlike quality which is often absent in such works. The authors have very considerable empirical knowledge of their subject and have also taught it to rather critical students. This has allowed them to write a book which will be useful for many years and is neither too advanced for good students nor too elementary for research workers in the field. It can be confidently recommended as a work to buy and not to borrow.

A. H. BECK.

Demonstrating the Properties of Aerials—(*continued*)

tained with a simple parasitic aerial located a quarter wavelength behind the main radiator. The radiator is normally set up in the centre of the vertical arc of pick-ups, and the receiving aerials show equal signal strengths. (Fig. 12.) When the parasitic aerial is placed in position and made longer than the fed dipole by extension of the telescopic arms the parasitic is a reflector (Fig. 13). The aerials are all at a height of $\lambda/2$ to keep radiation at a low angle.

Another simple sky-wave aerial of practical significance is the so-called three-quarter wave end-fed. Actually somewhat shorter than the quoted length so as to be capacitative this aerial has a low terminal impedance and is fed by a coaxial. The practical layout gives much the same result as the more conventional dipole for short distance working, producing a result similar to that of Fig. 9. By erecting aerials having various slopes, the effect of such a slope in deciding the proportions of "ground" and "sky-wave" radiated can be shown, using both sets of pick-ups in the vertical arc.

Miniature Aerials

By far the easiest section to construct and to make function is the miniature aerials section. Correspondingly its instructional value is slight, but it is recommended as the first stage in the assembly of an aerials demonstration.

The aerials are constructed to scale and have wired in series with them at 2-in. centres the same types of lamp previously mentioned. These lamps produce inductive loading of the wire and the length of the aerial must be selected by experiment.

T-top Aerial

A wire-made T aerial is included (Fig. 14) to show that a substantially uniform current distribution is obtainable in the vertical ground-wave radiator, while the top current is not sufficient to light the series-wired lamps. The top does not then radiate sufficient "sky-wave" to produce fading.

Short Distance "Sky-Wave" Radiators

Fig. 15 illustrates the end-fed three-quarter wave aerial and shows a current minimum about the fourth lamp from the right. The "roof" thus includes one half-wave plus the extra length to the right of the minimum; the behaviour is practically that of the dipole for short sky-wave ranges.

The formation of the minimum indicates that the lamps do not produce sufficient attenuation to make reflexion insignificant; the method may thus be used even for quite long aerials without obtaining apparently incorrect results.

The dipole (Fig. 16) gives the customary half-wave distribution of current; it is fed by a piece of twisted feeder taken from a Service set.

Both these aerials are erected within $\lambda/4$ of the ground.

Low-Angle Dipole

A dipole about $\lambda/2$ above ground is fed in this case by an open-wire line via any one of a number of matching sections.

A resonant stub match is shown in operation (Fig. 17). Three lamps are point-soldered on to the feeder with small tin capacity-plates soldered to their second leads; the lamps are separated by $\lambda/8$ and indicate line voltage. Their relative brightness indicates the effectiveness of the matching section; alteration of the top of the matching section causes decrease in the aerial current and indication of standing-waves on the feeders by the three lamps.

Fig. 18 shows the same aerial modified for delta-feed.

Conclusion

The description given has been necessarily limited to essentials, but an indication of the possibilities of the method is obtainable. Equally so, the limitations of the method have been underlined, but these limitations will be overcome by two developments in hand.

To avoid the objectionable coupling due to the pick-ups being well within the radiator induction field, the frequency, for the radiation section only, is to be raised to 600 Mc/s., increasing the working radius in terms of wavelength. Secondly, in order to accommodate long-wire arrays such as rhombics, an additional section is being added working at 10 cms. (3,000 Mc/s.); it is then possible, as an experimental model has shown, to obtain the normal vertical and horizontal polar diagrams. The complete demonstration will then cover as much of aerial theory as it is practicable to deal with within the confines of a building.

ABSTRACTS OF ELECTRONIC LITERATURE

ELECTRON OPTICS

The Resolving Power of the Magnetic Electron Microscope

(V. E. Cosslett)

The chief factors limiting the performance of electron microscopes are discussed: spherical and chromatic aberration, diffraction, imperfections in lens construction. Methods of approach to the correction of aberrations are reviewed. It appears preferable to proceed from a consideration not of the final aberration equations, but from the fundamental equations of electron motion, with the use of relaxation methods. It is shown that, even if the mechanical difficulties in lens construction are overcome, a very great reduction in spherical aberration is required to improve the resolution to below 10 A. Further reduction in chromatic aberration is unnecessary in present circumstances.

—*Jour. Sci. Inst.*, Sept., 1945, p. 170.

Stationary Electron Swarms in Electromagnetic Fields

(D. Gabor)

Electron clouds rotating in axially symmetric magnetic fields have been known for a long time, but the agreement between theory and experiment is still very unsatisfactory. The discrepancy appears to be due to the interaction of electrons. Before approaching this difficult problem it is desirable to possess a more complete theory of stationary swarms without interaction. In the present paper the distribution density is calculated on the basis of classical statistical mechanics. It is shown that electrons injected at any point with very small initial velocities will distribute themselves with a density inversely proportional to the distance from the axis, in a certain annular space. Only the limits of this space, not the distribution inside it, will be dependent on the electric or magnetic fields. The uniform or nearly uniform distributions calculated by previous authors are singular solutions, inconsistent with any degree of statistical disorder. Other laws of density distribution can be realised by simultaneous injection of electrons at several points. These offer a possibility to realise dispersing electron lenses and corrected electron optical systems. It is shown that the ring current produced by the rotating electron cloud can reduce the magnetic field at the axis very considerably in devices of practicable dimensions. It appears also possible to produce clouds of free electrons with densities sufficient for observable optical effects.

—*Proc. Roy. Soc. A.*, June, 1945, p. 436.

New Developments of Electron Microscopy

(R. G. Picard)

The author discusses the advantages of the electron microscope over the optical type and gives a diagram showing the analogy between the two. The principles of the electron microscope are described with reference to the universal electron microscope and the console type, manufactured in America, and new developments in instrumentation are mentioned. Problems involved in the preparation of specimens are discussed and a new "cyclone knife" microtome is described which uses a cutting edge travelling at several thousand feet per minute. Methods of measuring depth in specimens by stereoscopy are also discussed.

—*Jour. Frank. Inst.*, June, 1945, p. 421.*

INDUSTRY

Silicones

(S. L. Bass and T. A. Kauppi)

New dielectrics obtained from silica and by modification with organic groups are described. They include liquid dielectrics, electrical sealing compounds, insulating varnishes and other forms in which organic dielectrics have been used. Physical and electrical properties of these materials, produced by the Dow Corning Corporation of America, are given in tabular form. The uses of silicone greases, high-temperature-silicone insulation and thermo-setting silicone resins are discussed and the waterproofing of ceramic insulator surfaces is mentioned.

—*Proc. I.R.E.*, July, 1945, p. 441.*

* Abstracts supplied by the courtesy of Metropolitan Vickers Electrical Co. Ltd., Trafford Park, Manchester

Electronic Mechanism for Measurement and Control in Plant and Industry

(T. A. Cohen)

An electronic instrument relay is described in which a light aluminium disk attached to the pointer of a sensitive measuring instrument moves between two inductances which form part of the grid circuit of an oscillating thermionic valve. The large changes in plate current due to small departures from resonance are used to operate an electromagnetic relay in the anode circuit. The author gives an analysis of the inductance change in the valve grid circuit due to movement of the disk and also considers the repulsion effect due to currents induced in the disk.

—*Instruments*, April, 1945, p. 228.*

Brazing with Electric Induction Heat

(A. M. Setapen)

This article describes three general methods of producing high frequency electric energy suitable for silver alloy induction brazing, namely, the rotating electric generator, the resonant spark gap and the vacuum tube oscillator. After discussing their relative merits the author goes on to describe the principal types of joint used in silver brazing. The design of a conductor arrangement which will give the proper heat producing magnetic field confined to the joint area is considered with reference to various forms of coil, both single and multiturn. In reviewing the advantages of induction heating for this type of work the author points out the simplicity of operation and low cost and the high speed at which brazing can be carried out.

—*Steel*, 2/7/1945, p. 92.*

Dielectric Heating

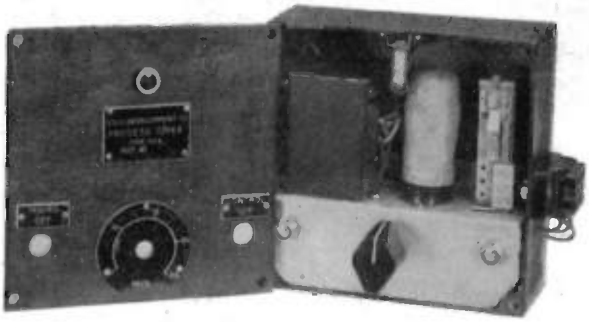
(J. C. Quayle)

The necessity for an efficient machine to repair p.v.c. cables arises from the fact that during extrusion the p.v.c. will sometimes suffer local damage. This paper describes a high frequency heater suitable for this purpose, but which may also be used for repairing v.i.r. cables. The time required for a repair ranges from 5 to 15 seconds. A high frequency plastic seam welder is also described. P.v.c. in strips of thickness up to 0.025 in. and up to 6 in. wide can be accommodated on this equipment and a good weld made in 1 to 5 seconds according to the type of job.

—*El. Rev.*, 14/9/1945, p. 363.*

The G.G.C. Electronic Process Timer

(Type PT 101A)



The electronic timer, manufactured by the G.G.C. Development Co., is a small self-contained timing device or the control of processes and machine tools.

The attachment is extremely robust and is assembled in an ironclad case to withstand rough handling.

Only one valve is used and the controlling circuit can handle up to 5 amps. A.C. for one kW at 230 V, but larger contactors can be fitted to order.

The control is effected by setting the dial to the required time and switching on the control circuit. By a special arrangement of relay contacts, the circuit can be made to function either as a time delay or a process timer.

Typical examples of the two applications are:

(a) To provide a time delay between the application of two processes.

(b) To apply a process or function for a predetermined length of time.

Since the control is continuously adjustable over its range, it can be used for such applications as the timing of photographic exposures and similar devices needing any variable time control.

Specification.

Mains input ...... 200-250 V 50 c/s.
Standard timing range ... 0-25 sec.
Accuracy .... within 5 per cent.
Weight .... 10 lb.
Size of case ... 6 in. × 6 in. × 3 in.

Full details can be obtained from the G.G.C. Development Co., Ltd., 109 Belgrave Road, S.W.1.

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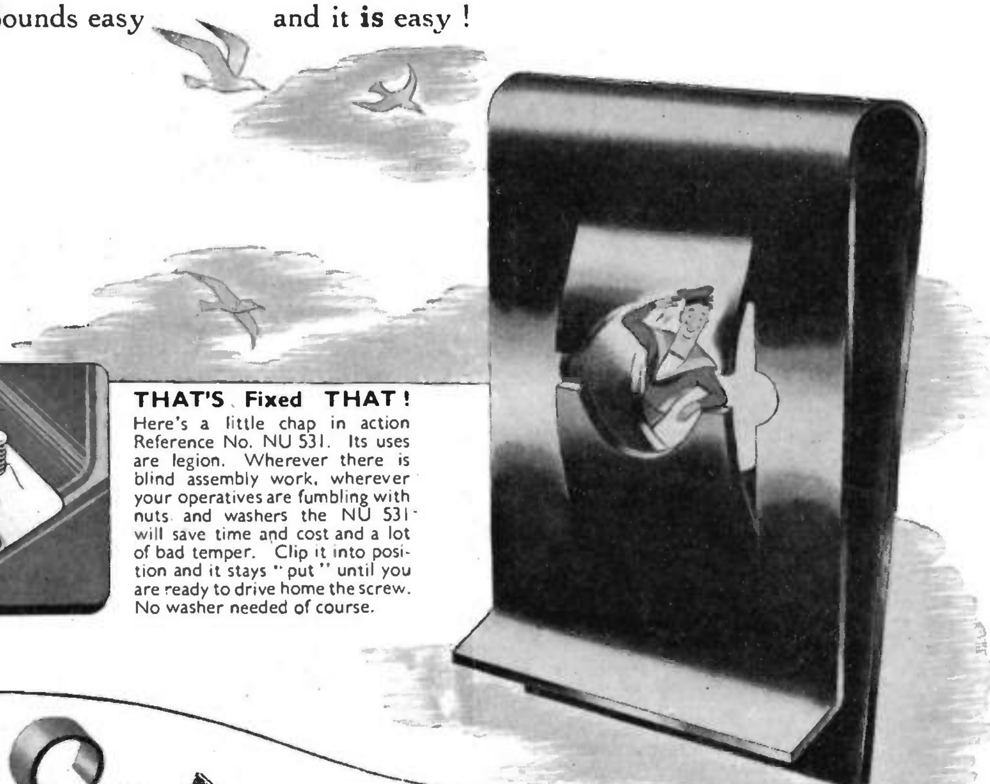

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Vacancies advertised in these columns do not relate to men between the ages of 18 and 50 inclusive, or women between the ages of 18 and 40 inclusive, unless they are exempted from the provisions of the Control of Engagements Order, 1945, or the vacancies are for employment excepted from the provisions of that Order.

IN STOCK. Rectifiers, Accumulator Chargers, Rotary Converters, P.A. Amplifiers, Mikes, Mains Transformers, Speakers of most types, Test Meters, etc., Special Transformers quoted for.—University Radio, Ltd., 22, Lisle Street, London, W.C.2. GER. 4447.

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WE HAVE A LIMITED number of Avo meters, test oscillators, valve testers, bridges, etc. Send stamp for details of these and other equipment, including components, amplifiers, multi-meter kits, pick-ups, etc., to Electrocraft, BCM/Electrocraft, London, W.C.1

TELE-RADIO (1943), LTD.—distributors for Great Britain of Denco Maxi-Q Coils—wound on miniature polystyrene formers, iron-cored, permeability tuned, 175 kc. to 32 Mcs. in five bands with .0003 tuning condenser. Octal plug-in or chassis mounting types available for T.R.F. or communication receivers. Denco permeability tuned 465 kc., I.F. transformers.

SPECIALISTS in high grade precision components, communication receivers and test equipment. Everything for the Amateur and Professional Constructor. All components brand new and first class quality. Price List "E" available. Please send S.A.E. (We are open Saturday afternoons. Early closing Thursday). Tele-Radio (1943), Ltd., 177, Edgware Road, London, W.2. Phone: PAD. 6116.

Classified Announcements (Continued).

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Metal Rectifiers, large size, output 50 volts 1 amp., 35/-.

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Large Paxolin Panel, size 14 in. by 7 in. by ½ in., fitted massive switch arm, 12 large studs and contact blade, very smooth action, price 7/6 each.

Block Condensers, 2 MF, 1,500 v. D.C., working, 7/6 each.

X-Ray Transformers in oil, input 200 v., output 80,000 volts, rating 5 K.V.A., with Coolidge winding, £50; ditto, 2½ K.V.A. at 90,000 volts, £45; ditto, dental type, 45,000 volts, £30.

Fluorescent Screens, selt, 15 by 12, with lead glass, £5.

Large Fan Motors, all direct current, approx. ¼ h.p., 110 v. series wound, in first class condition, 20/- each; ditto, complete with stand, starter, cage, and fan, 30/-.

D.C. Motors, as above, only for 220 volts, in perfect order, 25/-; ditto, complete with stand, starter, cage and fan, 35/-.

Rotary Converter, input 230 v. D.C., output 230 v. A.C., 50 cycle, single phase, 1½ kW., constant rating, a high-grade job of very solid construction, £35.

Transformer Core to suit 2½ kW. transformer, complete with clamps and bolts, 25/-.

Large Outdoor Bells, 110 v. D.C. working, 6 in. gong, 17/6.

D.C. Motor, totally enclosed, shunt wound, 220 v. D.C. 1/10 b.h.p., large size, high-grade, 45/-.

Auto Transformers, tapped 0-110-200-220-240 step up or down, 500 watts, £3 10s. 0d.; 2,000 watts, £9.

Moving Coil Meter, reading 0-100 milliamps, 2½ in. dia., flush mounting, F.S.D., 5 M/A, 30/-.

Metal Rectifiers, output 12 volts, 2 amps., large size, 32/6.

Prepayment Meter for 230 v. A.C., 50 cycle, single phase, as new, 1/- slot, sixpence per unit, 5 amp. load, £3.

Block Condensers, large size, in metal cases, 20 MF, 300 v. A.C. working, 15/-.

Rotary Converter, input 220 v. D.C., at 9 amps., output 68-125 volts, 500 cycles, single phase, 1½ kW., massive construction, price £12.

Block Condenser, large size, 4 MF, 3,000 volts working, 20/-.

Fixed Resistances on fireproof mounts, size 12 in. by 1 in., 2 ohms, to carry 10 amps., 2/6.

Closed half-day Thursday. Open all day Saturday.

Galpins Electrical Stores, 408, High Street, Lewisham, London, S.E.13. Phone: LEE Green 0309. Terms: Cash with order. No. C.O.D.

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A.M.I.E.E., City and Guilds, etc., on "NO PASS—NO FEE" terms. Over 95 per cent. Successes. For full details of modern courses in all branches of Electrical Technology send for our 112-page handbook —FREE and post free. B.I.E.T. (Dept. 337B), 17, Stratford Place, London, W.1.

HEAD FOREMAN for coil-winding department required by company engaged in large-scale manufacture of light to medium electrical products, West Country area. Applicants must have extensive experience similar capacity with firms of repute. Write full details of qualifications, past experience, etc., to Box 772, "Elec. Engg."

DEPARTMENTAL MANAGER required by company, West Country area, to take charge of large-scale loudspeaker production. Applicants must have extensive experience in similar capacity. Write details of qualifications, past experience, etc., to Box 773, "Elec. Engg."

RADIO.—Repairers and testers urgently required. Sound knowledge of modern radio receivers. Write stating wages and experience. Box 780, "Elec. Engg."

Classified Announcements (Continued).

BERRY'S (SHORT WAVE), LTD., have immediate vacancies for Counter staff. Applicants must reside in or near London, have good technical knowledge of Communication and V.H.F. equipment. Please state (in writing only) age, experience, pre-war occupation, salary required and when free, to 25, High Holborn, London, W.C.1.

REQUIRED, Technical Assistant for commercial technical department of well known radio valve manufacturers. Write in first case giving details of qualifications, experience, age, salary required, etc., to Box 783, "Elec. Engg."

DESIGNER DRAUGHTSMAN required, experienced in design and development of light electro-mechanical apparatus; experience of communications laboratory gear preferred; knowledge of workshop practice and production problems essential; must be capable of working on own initiative. Apply stating age, qualifications, salary, etc., Box 777, "Elec. Engg."

TELEVISION RESEARCH Engineer Required. Must have had previous experience. B.Sc. preferred. Box 786, "Elec. Engg."

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LAMPS, RADIO VALVES, Vacuum Devices. Graduate, 16 years executive and technical experience in above fields, available 1946 for initiation of new projects. Box 781, "Elec. Engg."

RADIO ELECTRICAL. Buyer, sound organiser and thoroughly experienced all departments seeks post in factory. Box 779, "Elec. Engg."

WIRELESS MECHANIC. R.A.F. Corporal, demob. January, requires post in telephone, broadcast or electronic firm in London. Wide maintenance and construction experience. Box 784, "Elec. Engg."

PHYSICIST with Research and Development experience of navigational, scientific, supersonic, electronic and communicational instruments, and accustomed to conferring with Government Departments, desires senior position, preferably in or near London. At present head of section in Industrial Research Laboratory. Box 785, "Elec. Engg."

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TWO YOUNG ELECTRONIC ENGINEERS, wide experience of design development and research, desire to enter small manufacturing firm with production facilities, as equal partners. Both have good business contacts. In the first place reply in confidence to Box 782, "Elec. Engg."

CONTRACTORS recently engaged on manufacture of M.A.P. and M.O.S. equipment now have capacity available for light bench assembly work. Box 761, "Elec. Engg."

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Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors and Publishers, Hulton Press, Ltd., 43-44, Shoe Lane, London, E.C.4. Sole Agents for Australia and New Zealand : Gordon and Gotch (Asia), Ltd. South Africa : Central News Agency, Ltd. Registered for Transmission by Canadian Magazine Post.