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Radiolympia 1949

COMMENT on events in the political world are not, as a rule, the subject of these editorial columns, but we cannot ignore the impression we have had lately that the last few weeks have not been happy ones for our governing politicians.

Apart from Sir Stafford's uneasy broadcast on devaluation, Mr. Strachey's visit to London Docks which coincided with a lightermen's strike, and the chaos produced at Liverpool Street on the occasion of Mr. Barnes' train driving efforts, our impression of this uneasiness was strengthened by Mr. Herbert Morrison at the opening of Radiolympia.

Most readers will already know that the opening was delayed by a strike among the Exhibition stand fitters, with the result that the Preview day was cancelled and the carefully prepared plans of the Radio Industry Council jeopardised.

As Exhibitors ourselves we are not likely to forget the harassing week prior to the opening or our disappointment at the uncompleted studios of the B.B.C. and the half finished stands—including our own—on the opening day itself.

This does not imply, of course, that the Exhibition was a failure. The total attendance was nearly 400,000 with a large number of overseas visitors, and according to the report just issued by the Radio Industry Council substantial orders were received in all sections of the Exhibition.

The result of the Exhibition may be judged by the statement made at the close of the Exhibition by Mr. F. W. Perks, the chairman of the organising committee, "Radiolympia has two aims—to stimulate public interest in the development of radio, television and electronics generally and to sell our products at home and abroad. Both aims have been achieved. Public eagerness to have television is proved, but it is no longer preventing the replacement of old radio receivers."

Realising the value of such a trade exhibition with the largest demonstration of television ever given in any part of the world, we are tempted to ask why Mr. Morrison omitted all reference to the strike in his opening speech.

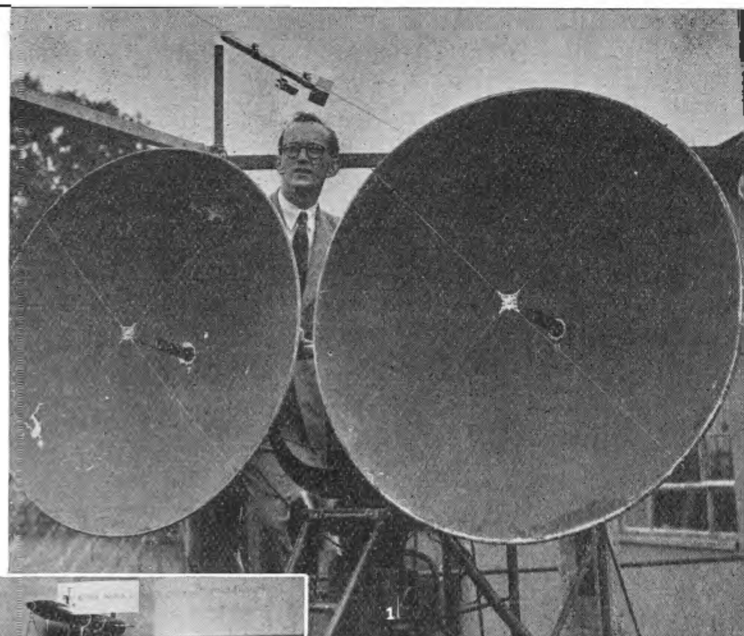
A few timely remarks on the enormous damage and loss of good will caused by such senseless strikes would not have been out of place in these present days of crisis when we are being urged to still greater efforts.

Indeed, as was so aptly stated by the *Spectator* "hearty exhortations to business men by Ministers with not a day's experience of business tend to be more irritating than effective, and they are in any case superfluous."

Photographs of selected exhibits at R.R.D.E., Malvern, are illustrated with brief technical descriptions :

1. Measurement of projectile velocity is demonstrated by a model rocket projectile travelling along a wire. The actual velocity of the projectile in this demonstration is read direct on a meter which is calibrated in miles per hour.
2. Demonstration model of an automatic following unit using a light beam.
3. A model projectile used to illustrate how radio signals and data are transmitted from it while in flight.
4. High-speed automatic plotter used in conjunction with Gun Laying Radar for location of enemy mortars.
5. A rear view of a wide angle scanner with a metallic lens.

(Photos 1, 3 and 5 by Fox Photos Ltd.)



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EXHIBITION AT R.R.D.E.

The Ministry of Supply's Radar Research and Development Establishment which is responsible for the research and development of army radar equipment held an exhibition on September 20-21 of this year. Over 100 exhibits were displayed to scientists and representatives of the various Services, Universities, Industry and Government Departments.

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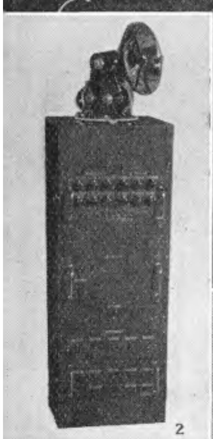

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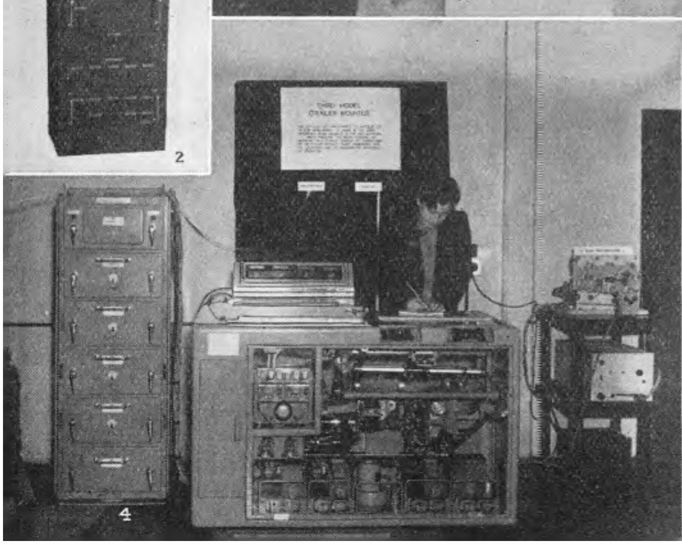

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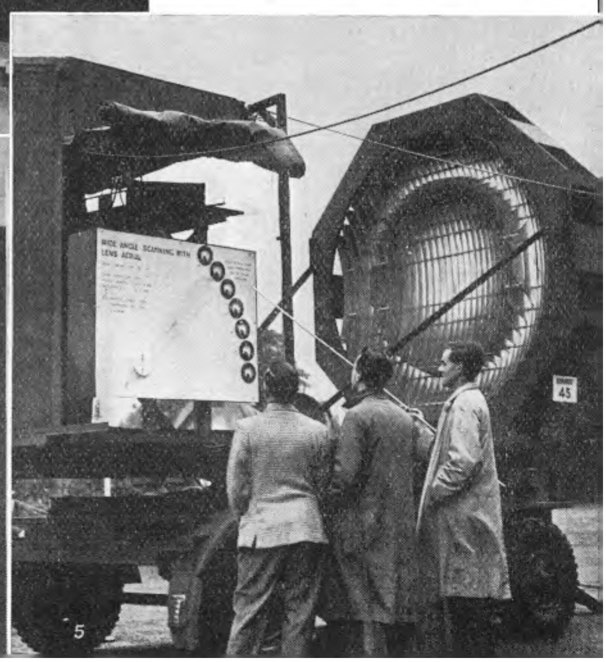

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Resistors for Deposited Circuit Techniques

By W. R. CONWAY, A.M.Brit.I.R.E., Assoc.I.E.E.*

IT was evident from the lively discussion which followed a recent informal lecture on Printed Circuits by J. E. Rhys-Jones and G. W. A. Dummer at the I.E.E. that electronic engineers are showing considerable interest in the development of deposited circuit techniques. It was also quite clear that the deposition of resistors was considered to be one of the major problems to be settled before the techniques could be economically employed. For some years deposited wiring techniques have been used or suggested for producing the wiring layout in a few manufacturing operations, and it is desirable that the components be incorporated as simply as the wiring, the use of the soldering iron being avoided if possible. The aim with fixed resistors is to connect them all simultaneously in their position in the layout in one or two automatic operations.

If the number of resistors in an equipment is small it may be advantageous to wire in standard components, provision would then be made in the wiring layout for them. By wiring in standard components the equipment designer can take advantage of the specialised knowledge and experience of the component manufacturers. The fixed resistor has been developed over a number of years so that a reasonably satisfactory component of known performance is available; resistors with comparable characteristics will be demanded for the new techniques. The development and technical characteristics of present commercial types of resistor has recently been admirably dealt with by P. R. Coursey in a paper presented to the I.E.E. For our purpose the commercial grade resistors can be separated into three classes, but all three have one feature in common, they are invariably cylindrical and this does not fit in with flat plate circuit constructions. The three categories are (a) the solid body or carbon film composition types generally known as the Grade 2 resistors, (b) the high stability or Grade 1 types in which either a hydro-carbon has been cracked on to a ceramic rod leaving a strongly adherent crystalline carbon film, or a metallic film has been deposited, and (c) the wirewound type which is of low resistance and high wattage. The resistance element is invariably a form of carbon or a metal or metallic alloy. Other materials such as metallic oxides and silicon carbide generally show undesirable non-ohmic characteristics or a high-temperature coefficient and erratic performance. In most electronic circuits, the Grade 2 carbon resistor is generally used, but for more critical applications the Grade 1 or high stability resistor must be specified. Based on many years of experience a range of sizes for different applications has been developed in each series. The nominal basis for these sizes is the wattage rating, and this in turn has been obtained from the temperature rise of the resistance element when in operation. The permissible temperature rise of a resistor is dependent on the thermal conductivity and capacitance of the materials used in its construction and the surface area available for cooling. In solid composition resistors the binding resin sets a limit to the operating temperature and thus to the wattage rating of the resistor; for the cracked carbon type, the limit is set by the protective lacquer. The low value wire wound resistors on ceramic or alumina rods with vitreous coating can be operated at considerably higher temperatures.

There is an obvious requirement for resistors of suitable dimensions to fit into the deposited circuit techniques, and experience on the present types of resistor is being used as far as possible in the development of the deposited resistors. Since the resistive element is required to be deposited on a flat surface and not on the normal cylindrical surface, many new problems are introduced. The ideal would be a two dimensional resistor area deposited directly on to the base material of the wiring layout. This base material must have a surface coating of high resistance or must be constructed of insulating material; both the bonded thermo setting plastic sheets and some ceramic materials are being used. There are a number of ways of planning the circuit using film type resistance, and it will be useful to survey some of these before discussing the resistive material.

Aspect Ratio

If the applied coating of film is of uniform thickness, structure and specific resistivity, then all the resistors for the circuit can be deposited on the wiring base at the same time. The resistance of a solid of uniform cross section is $R = pl/a$ where p is the resistance per unit cube, l is the length and a

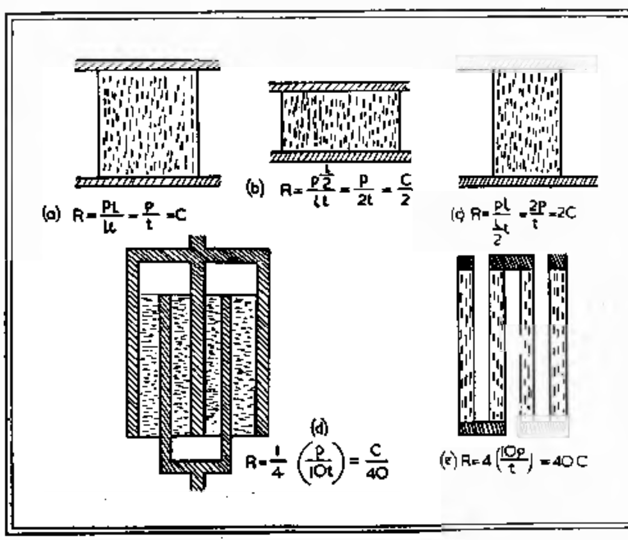


Fig. 1. Film resistors of constant thickness and resistivity

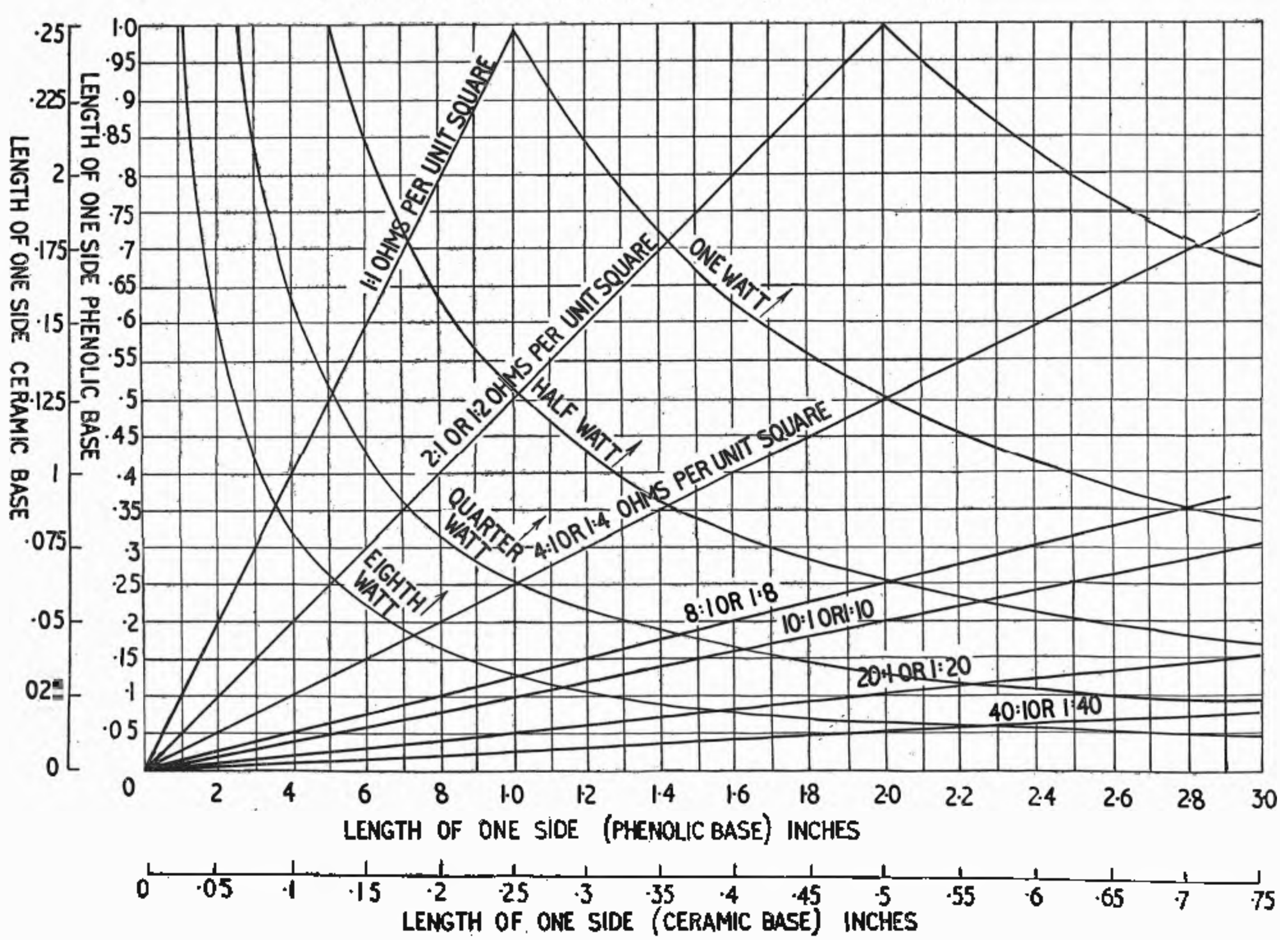
* Telecommunications Research Establishment, Malvern.

is the area of the ends. If the film is deposited in the form of a square then the resistance is $\frac{p \times l}{t \times l}$ where t is the thickness of the film. It will be seen that the resistance is now p/t, which is independent of the lengths of the sides. Thus these film resistors are usually compared in terms of their value in ohms per unit square. In existing cylindrical commercial resistances, the cracked carbon film type is made in values up to about 10,000 ohms per square. Certain proprietary stable film types are made in values of several megohms per square, while the sprayed carbon or graphite and resin volume control tracks are made in values up to about a megohm per unit square. This method of comparison is extremely useful and enables the size of a film resistance to be calculated. Substituting C for the constant p/t for a given material of uniform thickness the resistance of any rectangular area can be calculated from the ratio of the lengths of the adjacent sides; this has been termed the Aspect Ratio. Thus, if the length is twice the width, the resistance is $2l/l \times p/t = 2C$, i.e., twice the ohmic value of the square. Conversely if the width is twice the length, then $l/2l \times p/t = C/2$ or half the value of the ohms per square. Using a resistive material of uniform thickness and known resistivity, a wide range of values can be obtained on either side of the resistance per square by applying electrodes to the opposite sides of rectangles and with sides in predetermined ratios as shown in Fig. 1. When the ratio required causes the one side to be unmanageably long, the resistor can be compressed as shown in Fig. 1(d) and 1(e) by doubling back the area upon itself. Thus, using a film of 100,000 ohms per square, resistors of 2 megohms or 5,000 ohms can be obtained from an area with sides in the ratio of 20 to 1. The actual dimensions can be calculated if the required wattage dissipation and the allowable temperature rise of the base material is known.

It has been determined by experiment that a rating of 1 watt per square in. is a conservative one for synthetic resin paper bonded insulating boards. A rating of 4 watts per square in. is being considered for carbon films on ceramic sheets and about 8 watts for metallic films on ceramic plates. These ratings of 1, 4 and 8 watts correspond to 50° C., 100° C. and 200° C. rise respectively.

Charts can be drawn up to enable the size and shape of a required resistor to be obtained assuming uniform thickness and structure, that is, a constant and known value of ohms per square. The charts shown in Fig. 2(a) and (b) have been drawn for carbon film resistors on phenolic bonded sheets allowing for a dissipa-

Fig. 2 (a). Chart for determining size of rectangular resistance elements



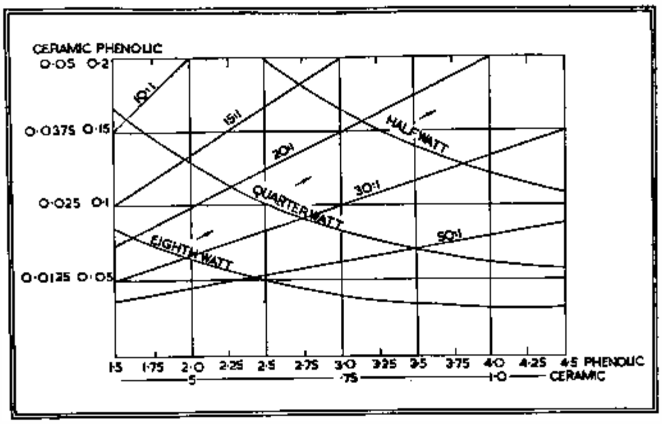


Fig. 2 (b). Chart for higher aspect ratios

tion of 1 watt per square in. The co-ordinates are the lengths of the sides in inches; the X axis gives the length of one side of a rectangular area, and the Y axis gives the length of the adjacent side to a different scale. Curves showing a constant product of x and y (where x and y are the length of the sides) are constructed for 0.125, 0.25, 0.5 and 1 square in; these correspond to $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ and 1 watt respectively. Each curve is a rectangular hyperbola, since the equation is $xy = C$, being the wattage rating. On the same chart lines of constant ratio of x and y are constructed. These correspond to a number of rectangles, the sides of which are in a given ratio. Having determined the value of the ohms per square of the deposit and the wattage rating, the dimensions of a required resistor can be read from the chart. The dimensions of a resistor to carry $\frac{1}{4}$ watt, would be found by selecting a convenient point on the straight line giving the required aspect ratio, which is just above the 0.25 product curve. Thus, a minimum size for each resistor is set by the product curve corresponding to its required power handling capacity. Fig. 2(b) is part of the same chart expanded in the Y direction and extended in the X direction. The second line of ordinates in each figure provide similar charts on a basis of 4 watts per square in. for ceramic bases. Fig. 3 shows how two values of unit square resistance can cover the resistance range of 100 ohms to 1 megohm with a maximum ratio of sides of 10 to 1. It is possible to design these resistors to have low self capacitance by making them long and thin with the electrodes far apart, but this requirement must be considered separately. One application of these aspect ratio resistors is to coat a sheet of insulating material by a capillary process, by spraying or by cataphoresis with a uniform resistance film of constant value of ohms per square, then to deposit the electrodes and inter-connecting conductors by sprayed metal or other suitable process, and finally to punch out the unwanted parts of the sheet.

Fractional Electrodes

It is, of course, important that the electrodes connect completely along the required opposite sides of the resistance area in film resistors. A change in value would result if they did not. The effect of shortened electrodes could, however, be used to a certain extent to adjust the value of resistors should they be too low. The actual calculation of the resistance when the electrodes are a fraction of the sides is a laborious process involving Conformal Representation. This method provides a means of representing any element of area in a plane by an equivalent area in a more convenient plane. Jeans in "Electricity and Magnetism" refers to some calculations carried out by H. F. Moulton in the Proceedings of the London Mathmetics Society to determine the resistance of a square sheet of uniform thickness with fractional electrodes. The solution of the two dimensional potential distribution equation

$$\frac{\delta^2 V}{\delta x^2} + \frac{\delta^2 V}{\delta y^2} = 0$$

by conjugate functions where x and y are the rectangular co-ordinates, provides an expression

$$U + jV = \phi(x + jy)$$

where U and V as constants represent the equipotentials

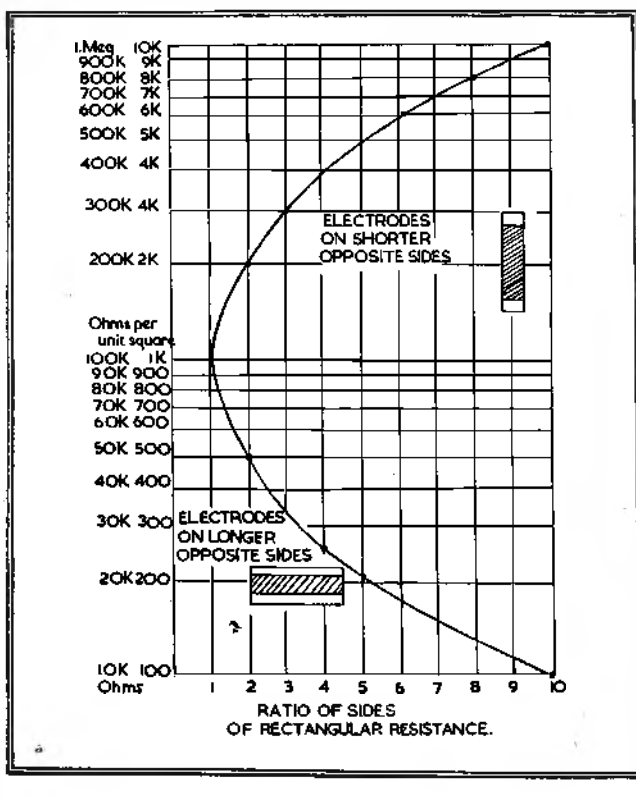


Fig. 3. Chart showing how resistance range of 100 ohms to 1 megohm can be covered with resistance areas of 1,000 and 100,000 ohms per square

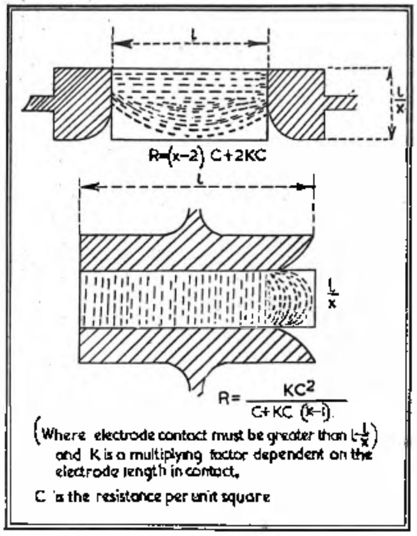


Fig. 4. Method of fractional electrodes in case of rectangular resistance areas

and the lines of force. Use is made of this expression when the electrodes are shorter than the sides. Writing $U + jV = W$ and $x + jy = \mathbf{Z}$ we can transform the field plot to an equivalent rectangle. Moulton has shown that the solution to this is $p/t \times L'/L$ where $L'/L =$

$$\frac{(sn^2mz_2 - sn^2mz_3)(sn^2mz_1 - sn^2mz_4)}{(sn^2mz_1 - sn^2mz_3)(sn^2mz_2 - sn^2mz_4)}$$

and z_1, z_2, z_3 and z_4 are the co-ordinates of the electrodes in the original $\mathbf{Z}$ phase and sn^2mz can be obtained from Legendre's Tables of Elliptic Functions. In this way Moulton calculated the area of a square sheet with electrodes equal to 1/5 of one side in the following cases:

(1) Electrodes at middle of opposite side $R_2 = 1.745\ R$.

(2) Electrodes at ends of opposite side $R_2 = 2.408\ R$.

(3) Electrodes at ends of opposite sides not facing each other $R_2 = 2.589\ R$.

where R represents the ohmic value of the square with electrodes along the length of opposite sides and R_2 represent the ohmic value with the fractional electrodes.

By dividing a rectangular area into uniform squares and applying electrodes in the same ratio as in the above examples an approximation of the final resistance can be obtained by assuming that the increase in resistance only occurs in the squares next to the electrodes. Thus an area with sides in the ratio of 4:1 with electrodes equal to 1/5 of the short side and connected to opposite corners of these sides will have a resistance of 7 C instead of 4 C. The value of a deposited film resistor can thus be adjusted by reducing the width of the electrodes as shown in Fig. 4. The value of K being obtained by calculation or experiment on a unit square. This method of Fractional Electrodes increases the current density in the neighbourhood of the terminals and in some constructions the weakness of the junction between the resistor and the conductor may cause failure at this point if the electrode is shortened too far. The wattage rating will be reduced to that equivalent to the area between the electrodes.

Instead of varying the length to width ratio and keeping the resistivity and thickness constant it is possible to keep a constant width and vary the distance between electrodes or to fix a constant ratio of sides and increase the area for different wattages. This means that either the specific resistance of the material or the thickness of the deposit will have to be varied to obtain the resistance range coverage. These methods have obvious advantages if the resistors are separately manufactured. The component manufacturer can supply resistance elements of uniform size regardless of the resistance and in this way advantage can be taken of the experience of the resistance specialist. Furthermore, the self-capacitance of the element can be made much the same regardless of the resistance value. In several methods proposed for forming suitable resistive films, it is suggested that large sheets of continuous tape be printed and these areas cut or stamped to form separate resistance elements. The separate units could be adjusted in value by either trimming the width or by using a method similar to the spiralling used on the familiar cylindrical carbon film resistors. One method is illustrated in Fig. 5, but it is obvious that this is not as neat a method as the spiralling technique. Parallel lines are engraved on the sheet at an inclined angle to the sides, alternate lines being taken to alternate sides, each line ending in the right-angled line in which the next line commences. One way in which the method could be carried out on cracked carbon sheets would be to have the sheet grooved before the hydrocarbon is cracked; using a fine grinding wheel, the sheet is pushed under the wheel, removing the tops of the grooves until the required resistance is obtained. Since the pitch of the cylindrical type of resistor is usually constant, a similar effect is obtained by pre-grooving. Machines for engraving lines in film resistors are being developed. The advantages of flat plate resistors as separate assembles compared with existing cylindrical types are not readily apparent, but flat resistors could be slipped into recesses in moulded deposited circuit panels without lowering the wattage rating by shielding a portion of the resistor surface, as would occur using a conventional cylindrical resistor. In order to make good electrical contact between the resistance element and the circuit panel it appears that soldering will be necessary. In recessed panel this could be accomplished by R.F. or infra-red heating which would enable all the resistance elements to be soldered in one operation. The ends of the resistance elements and the contact surface of the recess would be tinned or silvered and a small pellet of solder allowed to run between the contacting surfaces, a roller being used to press the element home. Such a method should be possible with ceramic plate resistors, but with synthetic resin board units it may be necessary to provide an eyelet in the silvered electrodes of the resistance element.

When resistance films are deposited directly on to the printed wiring layout by painting, spraying or printing processes it has been observed that any failures invariably commence at the terminals. This is due to the formation of a thinner resistance film at the junction resulting in an increased current density at this point in operation. This thinning of the resistance film is brought about by the finite step due to the thickness of the conductor forming the terminal. This weakness can be offset by paying special regard to the terminals, but it has been found that if the resistor can be deposited first and the electrodes deposited over the resistor ends, a more reliable termination is obtained.

Materials for Film Resistors

As in conventional resistor manufacture, two classes of materials have been used in film resistor layouts. These materials are, as previously stated, carbon and metals or metallic alloys. So far little success has been achieved with other materials because they have non-linear characteristics. As far as metals are concerned, the specific resistance of the mass metal is too low for the high values of resistance to be obtained in the small area available; but the thin metal films do appear attractive. It is known that when the thickness is decreased to the order of critical mean free path of the electron then the specific resistance increases considerably; an empirical equation suggested by Planck to account for this, was:

$$p = p_0 \left(1 + \frac{A}{D} \right)$$

where p is the resistivity of the mass metal, D is the thickness of the film, p_0 is the resistivity of the film and A is a constant dependent on the metal. It has recently been suggested that when the thickness of the film is a small multiple or sub-multiple of the length of the mean free path of the electrons, the number of electronic collisions will be increased and the classical expressions for resistivity and conductivity should be accordingly modified. The above expression now becomes

$$p = p_0 \left(1 + \frac{4l}{\pi D} \right)$$

where l is the length of the mean free path. This dimension is subject to considerable variation with small changes in temperature and the expression for the resistivity of the film must take this into account. There is evidence to support the view, however, that this change in specific resistance of these very thin films is due to imperfection in the film and that perfect films would most likely have the resistivity of the mass metal. The electrical properties of thin metal films have been investigated for many years, and although these atomic films can be produced by various methods, such as sputtering and evaporation, the resulting films are usually unstable. This is apparently due to the migration and aggregation of the atoms. There is a tendency for the films to become thick in some places at the expense of other parts of the film, as crystals form from an original amorphous state. Such thin films appear to have several changes of state after their deposition and these changes have been observed with

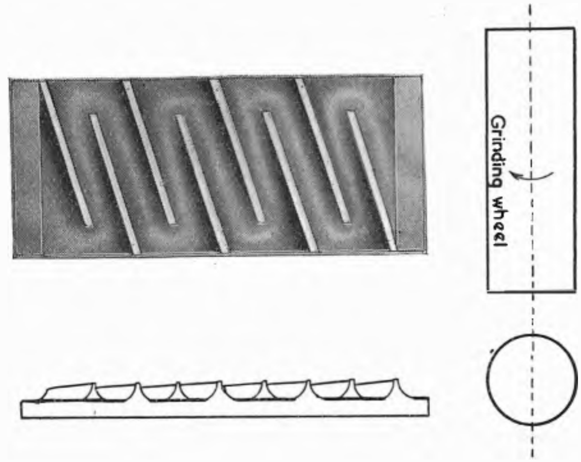


Fig. 5. Flat plate spiralling for cracked carbon resistors

the electron microscope. The rate at which the film passes through these transitional stages depends principally on the method of forming the initial film. By careful control of these stages, stable films have been prepared with high resistivities. Up to the present the only metallic film resistors in commercial production are of palladium, the thickness is considerably greater than the mean free path of the electron, so that the resistivity is that of the mass metal. Since this resistivity is 350 times less than that of carbon, it will be seen that a wide range of resistance is not possible without some method of introducing a gain factor similar to spiralling. Bismuth, which has a specific resistivity only 20 times less than that of carbon, appears promising, but the deposition of alloys would be even more advantageous. These thicker films should prove quite stable and if the production difficulties are overcome they should replace the wire wound type for deposited circuits. That is, they will be on ceramic or aluminal laminæ and be in the high wattage, low resistance class.

For the other resistor applications carbon, in one form or another, satisfies most of the requirements—annoyingly well, it has been said.

Among the amorphous forms of carbon, used for deposited circuits, are lamp black or acetylene black and gas carbon, with graphite and pyrolitic carbon as the crystalline forms. The most convenient form of carbon for printing is the colloidal graphite prepared by the Acheson process from sand and petroleum coke. The colloidal suspension is obtained by deflocculation in water containing tannin, hence the trade name of the product "dag" (deflocculated graphite). The suspension in water is known as Aqua dag; the colloidal graphite is obtainable as a dispersion in most solvents. Carbon black has been used as the principal element in the mixes for volume controls and variable film resistances and this has been mixed with other carbons, including graphite, to obtain the range of values required. The principal disadvantage of carbon black is its poor voltage and temperature coefficient and its noisy operation. These effects are due to the surface impurities—the gas absorbed on the surface expands with rise in temperature causing a poor temperature coefficient and breaks down under voltage stress, giving a poor voltage coefficient. The noisy operation is very likely caused by the poor molecular contact and consequent internal sparking. Since graphite is obtainable already dispersed in almost any solvent, it is relatively easy to combine the graphite with a resin appropriate to the solvent or to choose a synthetic resin with the required properties for use with the corresponding graphite loaded solvent. The graphite lattice consists of flat hexagonal rings of carbon atoms arranged in equidistant layers so that the atoms in alternate layers are in alternate positions in the hexagon. This causes a weakness in the structure since the fourth valency of each carbon atom is directed at an atom in the plane above or in the plane below at a greater distance than the three other atoms in the same plane.

Thus there is a ready cleavage of graphite in the direction of the plane of the hexagons. The colloidal nature of the graphite assists the flat particles or planes to lie like slates on the base to which they are applied. For both graphite and carbon black films considerable care is required in preparing the carbon and synthetic resin mixture to obtain reproducible results. The binding resin must be chosen so that the polymerisation temperature is not too high for the base material and yet the resin must set hard but be flexible. It must adhere well to the base material and have similar thermal characteristics to this base material The required value of ohms per square of the deposit is obtained by varying the ratio of the amount of synthetic resin to the amount of carbon material. The solvent is, of course, driven off by heat treatment, preferably by infra-red lamps which enable a sufficiently high temperature to be reached in the resin without overheating the base material. As the solvent leaves the binder, it will leave tiny capillaries in the mass, through which moisture can penetrate in due course with a disastrous effect on the value of the resistance. These capillaries can be reduced in number by coating the mixture, while still warm from polymerisation, with a coat of suitable varnish. Unfortunately this also changes the value of the resistance, but thereafter the resistance is usually stable at least over short periods under normal conditions. As in normal resistor production, it is essential that each sample is checked after deposition.

A little has already been said in this article about the use of the so-called pyrolitic films of carbon on ceramic bases. The technique has been adequately discussed elsewhere and the main requirement is for ceramic techniques to produce bases in suitable shapes. The cracking technique has been developed considerably more in Europe than in the U.S.A. and it is considered that this approach offers the best solution to the problem of resistors for deposited circuit techniques.

The properties of film resistors developed in the U.S.A. have been discussed at some length in recent National Bureau of Standards publications. Considerable statistical evidence is being obtained regarding the characteristics of similar resistors developed in this country and this will be published in due course.

The author wishes to thank the Chief Scientist, Ministry of Supply, for permission to publish this article.

Thermistor Continuous Temperature Control for Biological Research

By C. J. DICKINSON, B.A., B.Sc.*

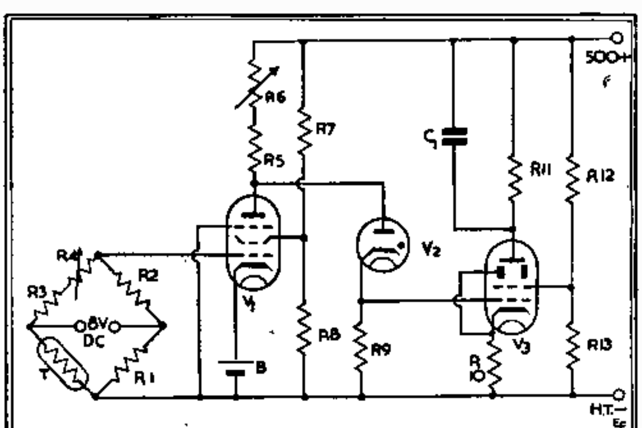


Fig. 1. Schematic of the thermistor temperature control system. The basic similarity to the circuit described by Andrew in *Electronic Engineering*, September 1947, will be observed

R_1	4.7K	R_8	4.7K	V_1	EF50 (Mullard)
R_2	4.7K	R_9	500K	V_2	VS110, S130 (Cossor)
R_3	820	R_{10}	300	V_3	807
R_4	1000 Variable	R_{11}	1500 Heater		
R_5	680K	R_{12}	50K	T=Type F Thermistor, 1200 Ω at 38° C.	
R_6	250K Variable	R_{13}	20 K		
R_7	47K	C_1	8μF 500V. Wkg.	B=2V accumulator.	

A USEFUL application of the thermistor[1] in biological research was described recently,[2] which inspired a further elaboration of this method for a specific purpose. This was to maintain at 38° C. ± 0.1° C. a metal chamber measuring internally 8 in. by 8 in. by 4 in., while the conduction rate of a small mammalian nerve was being measured. Not only was fairly accurate temperature control necessary, because of the high temperature coefficient of conduction rate, but it was also desirable that the apparatus should not interfere with the high gain amplifier used for displaying a compound action potential, with a maximum voltage swing of only 50 microvolts. An alternative would have been to switch off the whole heating system while taking photographic records, but this would have been troublesome, since many readings had to be taken; and it was found that a very simple circuit fulfilled both requirements. Fig. 1 shows the essential circuit details.

The initial bridge stage, incorporating a Type F thermistor (Standard Telephones & Cables, Ltd.) and the D.C. amplifier stage are exactly the same as those in Reference 2, except that the valve is battery biased (by a 2 volt accumulator) in the cathode circuit, to achieve maximum theoretical gain. To avoid the danger of pick-up from sparking relay

* Laboratory of Physiology, Oxford University.

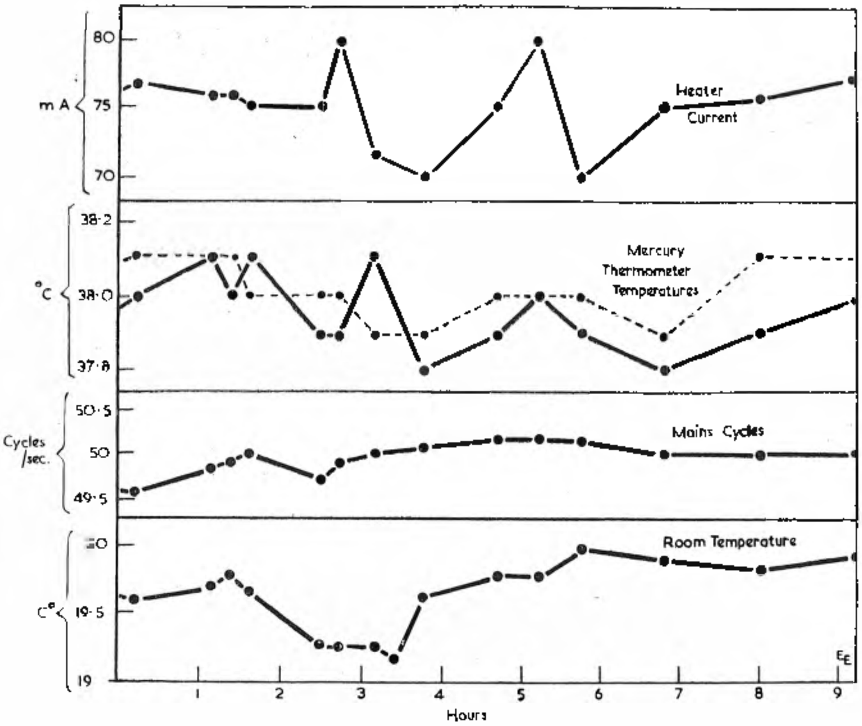


Fig. 2. Curves showing the amount of temperature control achieved

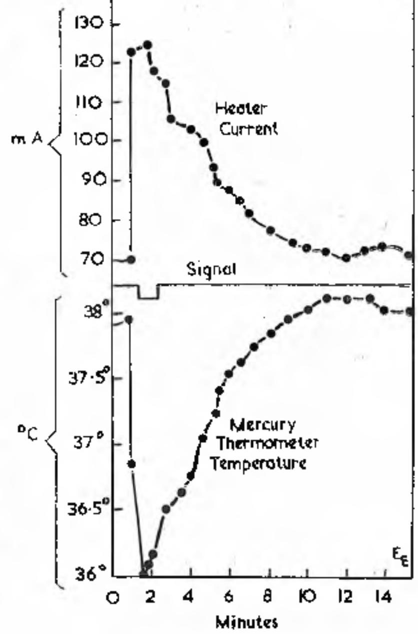


Fig. 3. Effect of raising the lid of the temperature controlled chamber for thirty seconds

contacts, and from sudden current surges, the auxiliary heater, supplying 7-20 watts, was placed in the anode circuit of a power valve, D.C. coupled by a constant voltage drop neon to the previous amplifier stage. The power valve also functioned as an amplifier, so that the gain of the whole assembly was high. The use of an A.C. bridge and amplifier, though simpler still, would have introduced too much interference; and instead, a smoothed D.C. supply of 500 volts was used for the whole apparatus.

The D.C. supply for the bridge was taken from the rectified and smoothed heater supply, which compensated slightly for mains voltage fluctuations. These fluctuations were also minimised by feeding the supply transformer from a constant voltage transformer. In fact, probably an input voltage stabilised power supply would be desirable for greater accuracy. The operating temperature was set by means of *R*4, and the variable anode load of *V*1 was adjusted so that the neon remained "struck" throughout the operating range. A milliammeter in the anode circuit of *V*1 registered temperature directly, but it had to be empirically calibrated for any particular setting of *R*4. Since the input and output leads were for convenience in one screened cable, there was positive feedback, and the system sometimes oscillated. This tendency was prevented by inserting a capacitor across the heater.

The chamber itself was heated from below by the method already described, and also by a main heater which supplied 30 watts continuously. The gas in the box was stirred by the passage of a fairly rapid stream of the necessary composition (95 per cent oxygen and 5 per cent carbon dioxide) from a cylinder. A layer of water over the whole floor of the chamber ensured saturation of the gas with water vapour.

Not unnaturally, control is better at the centre of the chamber. The continuous line indicating temperature close to the incoming gas (Fig. 2) was subject to slightly greater fluctuations, and was, for the most part, below that elsewhere in the chamber. Fine degrees of control are not indicated in this prolonged test run, in which corresponding slow fluctuations of heater current and chamber temperature are roughly in the same phase. They are probably due to the inherent limitation of accuracy of a circuit depending on a constant voltage drop neon, and on a steady mains supply. Fig. 3 shows the effect, on a 2 minute time scale, of raising the glass lid of the chamber for 30 seconds. Recovery is remarkably efficient, and is complete within ten minutes, or less. In practice, necessary adjustments can be made by raising the lid for only a few seconds. The thermal inertia of the control system is far smaller than that of the mercury thermometer, and five seconds after raising the lid, the power valve is taking maximum current. The continuous control, instead of the "*on-off*" type minimises "hunting," which might otherwise be troublesome in a heater system which is necessarily rather slow in transmitting its fluctuations to the gaseous medium inside the chamber. The heater must be below the floor, and it must exert its effect through a thin layer of water. In practice, there is small degree of 'hunting," or overswing, which can be seen in Fig. 3, but it is within the permissible temperature range.

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Salvaging Electrically Twinned Quartz

By J. L. RYCROFT, B.Sc.* and L. A. THOMAS, B.Sc.*

QUARTZ, the beautifully clear rock crystal, fashionable for jewellery and ornaments in the Victorian era, has during the present century found an application of the greatest strategic and commercial importance. In all branches of telecommunications, the need for highly accurate frequency control has only been met satisfactorily by the use of piezoelectric oscillator plates.

The quartz vibrator, first put to practical use during the First World War, became a vital component during the Second World War, and a quartz crystal industry grew up, producing in Great Britain alone over a million crystals a year by 1945. The problems created by this expansion were two-fold. On the technological side a full description has been published[1] of how the industry developed with an ever-increasing efficiency of fabrication of the quartz plates, off-set against continually growing stringency in final stability requirements. The other aspect, and a critical one, was the raw material supply.

Natural quartz crystals of the size and freedom from imperfection essential for piezoelectric use are obtained almost entirely from Brazil. This restriction of source presented a grave problem during the war because of shipping difficulties, and the problem has been carried over into peace-time because of the need to conserve hard currency. Moreover, high grade quartz is an expensive commodity costing approximately £15 a kilo, and only about 10 per cent of the raw material appears in the final plate. It will be apparent that any means of economising in consumption of raw material is of the highest importance.

Stimulated by these factors, two parallel programmes of research were started late in 1942. One of them was the preparation of synthetic quartz as an alternative to the natural mineral, and the other was the search for an "untwinning" process to enable the considerable proportion of Brazilian quartz which is rejected on account of electrical twinning to be salvaged. Only the untwinning work[2] is to be described here, but first it is necessary to outline the various faults which commonly occur in natural quartz and to give sufficient details of quartz technology so that the significance of the results obtained can be appreciated.

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Imperfection and Twinning in Quartz

Visual Imperfections.

The single crystals or stones of quartz received from Brazil vary in size from one or two hundred grams to several kilograms. A typical crystal might be some 10 cm. long by 6 cm. thick and weighing about 750 gm. It would usually be colourless and clear and either have well developed faces or, more commonly nowadays, a fractured or water-worn unfaceted exterior. Possible visible faults are inclusions, veiling, ghost crystals, cracking and discoloration. While the latter fault is by itself unimportant, the other faults mentioned are associated with impurities or mechanical weaknesses which must be avoided in cutting up the quartz stone. Among the more subtle effects, which are not usually shown up by simple visual inspection, twinning is the most important.

Twinning.

Idealised drawings of normal single-crystalline quartz and the two common types of twinning are shown in Figure 1.

The normal stone is a hexagonal prism with pyramidal terminations. The prism faces are labelled *m* faces and the pyramidal faces alternately *R* and *r*. Crystallographically and piezoelectrically, the properties of the *R* and *r* faces are markedly different so that the vertical optic or Z-axis of the crystal is a trigonal and not a hexagonal axis. Perpendicular to the Z-axis are three diad X-axes inclined at 120° to each other (only one of these axes is shown). For convenience, a third non-crystallographic axis, the *Y* or mechanical axis, is chosen to complete a set of orthogonal axes with the Z-axis and one of the X-axes. Quartz is optically active and thus there are two mirror-image forms of quartz depending on the direction in which plane polarised light is rotated when it passes through the crystal parallel to the optic axis. In the rare examples of natural quartz showing the minor *x* faces, this face *x* occurs at the bottom left or the bottom right corner of an *R* face according to whether the quartz is left- or right-handed. Thus the example shown is a left-handed crystal.

The electrically twinned stone shows the superposition of *r* faces

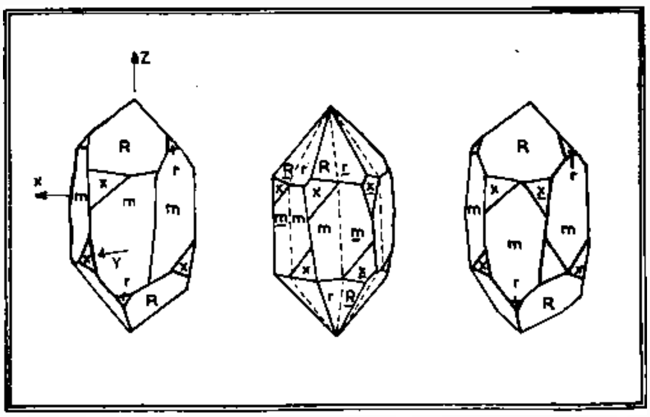


Fig. 1. Idealised drawings of normal single-crystalline quartz (*left*) and the two common types of twinning. *Centre:* Dauphine twin (electrical). *Right:* Brazilian twin (optical)

on R faces (faces underlined in the diagrams are derived from the twin orientation) and corresponds to a 180° rotation of the quartz structure in the twinned region with respect to the normal stone orientation. Because the electric axes in the twinned and normal regions are in opposition, plates cut from such a stone would have their piezoelectric effect reduced to greater or less extent depending on the relative proportions of the two polarities. Also, electrically twinned plates are in general elastically inhomogeneous with the accompaniment of spurious frequency responses and severe damping of the resonant vibrations. In practice, therefore, electrically twinned quartz is reject material.

The opposed electrical polarities are also a feature of the optically twinned stone illustrated. Here left- and right-handed quartz co-exist, giving the mixed polarity, but the R and r faces are distinct. Thus optically twinned material is elastically homogeneous but it is still rejected on the score of piezoelectric inefficiency.

Natural stones are, however, hardly ever sufficiently well faceted for twinning to show up visually. The highly idealised diagrams of Fig. 1 also correspond in practice to closely interpenetrant twinning with irregular boundaries, such as are shown in the later figures. Optical twinning can be revealed by optical examination in plane polarised light which can readily be carried out in the original stone by total immersion in a liquid of matching refractive index. On the other hand, inspection for electrical twinning is most conveniently carried out by etching slices or plates cut from the stone in a hydrofluoric acid solution of 20-25 per cent strength. The resulting etch patterns show up clearly any electrical twin boundaries; optical twinning is also shown, but this is readily distinguishable by experienced quartz technicians.

Practical Cuts in Quartz

The plates for oscillator use are cut from the quartz stone in definite directions and, with few exceptions, they can be divided into two groups, the rotated Y-cut group and the rotated X-cut group. The former group comprises the Y-cut itself, now obsolete, and cuts designated by the accepted lettering AT, BT, CT etc., which are derived from the Y-cut by rotation of the plate about

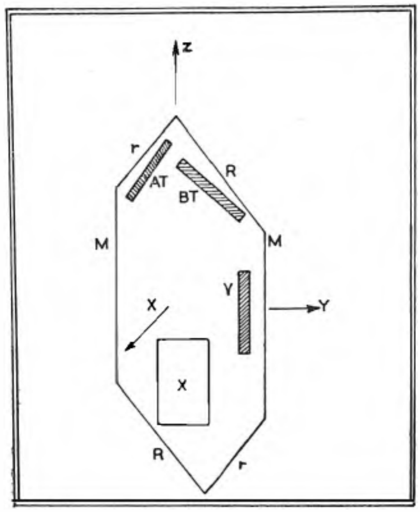


Fig. 2. Various quartz crystal cuts used for oscillator plates

the X-axis. Similarly the X-cut is the parent member of the second group, although in this instance the family of cuts is obtained by rotation of the X-cut plate in its own plane. In particular the BT and AT cuts are used for the majority of high frequency oscillator plates, and plates from the X-cut family are largely used for crystal filters. Examples of the various cuts are shown in Fig. 2 in relation to a vertical cross-section taken through the crystal. It should be noted that the AT and BT cuts tend very roughly to parallelism with the r and R crystal faces respectively.

Using diamond saws, the stone is cut into quartz slices having the required crystallographic orientation, as checked by X-ray diffraction methods. These slices are subsequently cut into plates or bars and taken down to the required surface finish and dimensions by a carefully graduated lapping procedure. A final adjustment is made by using direct frequency measurement. Any process of untwinning is most usefully applied at the slice stage, because inspection at this stage is readily carried out and also the slices are less susceptible to thermal shock than are the original stones.

The Possibility of Untwinning Quartz

When quartz is heated to above 573° C. it changes from low temperature α-quartz to high temperature β-quartz. With simple precautions, this transformation can be carried out on a plate or bar of quartz without fracture or loss of shape. Because β-quartz possesses hexagonal symmetry, the X-axes cease to be polar axes and consequently quartz which is electrically twinned below the α-β transformation temperature becomes single crystalline above this temperature. The original approach to the problem of removing electrical twinning was to influence the quartz plate during cooling from a temperature above 573° C. so that it remained single-crystalline instead of reverting to a twinned state. Possible methods of achieving the necessary preference for the single-crystalline form included the use of an external electric field and mechanically or thermally applied stresses.

The atoms of quartz are held together in such a way that the changeover from one polarity of quartz to the other polarity, still having the same optical sense, can take place without the necessity of breaking any strong interatomic bonds. Thus there was no fundamental objection from the structural aspect to the removal of electrical twinning, provided a workable method could be found. In contrast, with optically twinned material the change from the left- to right-handed forms involves a complete re-arrangement of the atom groupings, and the sense of optical activity is unaltered by the α-β transformation. For these reasons it is almost certain that the removal of optical twinning is impossible. Consequently all the efforts of the research programme were concentrated on the salvaging of electrically twinned material. This alone would be worth while, especially if a grave shortage of quartz developed.

Early Experiments

The movement of electrical twin boundaries during thermal or mechanical treatment being comparatively well-known, the object of the early experiments was to find means of controlling this movement so that usable material resulted. Complete removal of twinning, that is, the production of a single crystal, was the ideal; but twins having a regular form could also be used, either by cutting the specimen into single-crystalline individuals or for certain special vibrator plates where an essential feature was the opposed polarities. This property would normally be obtained by special electrode arrangements on a single crystal. Broadly speaking, the early experiments tended to produce twin distributions which in certain instances were highly regular and reproducible, but they were unsuccessful in removing twinning altogether.

The experimental procedure was much the same whatever method was used. Quite small plates or bars (say, 50 × 10 × 5 mm.) were cut in definite crystallographic directions from electrically twinned quartz. These bars were etched in hydrofluoric acid and the resultant twin patterns photographed. They were then subjected to the thermal process, with the applied stress appropriate to the experiment, running up slowly to a temperature well in excess of 573° C., followed by slow cooling to room temperature. After removing the original twin patterns by lapping with fine abrasive, the bars were then re-etched and the final twin patterns recorded photographically.

The various methods tried included the use of externally applied compressional stress, thermal stress resulting from a temperature gradient and bending by 3- and 4-edge presses. Very little work was carried out using external electrical fields because of practical difficulties and the more hopeful results obtained by simpler means. It should, however, be remembered that mechanical stresses are accompanied by electrical fields as a result of the piezoelectric behaviour of quartz. This early work will not be described in detail, but the temperature gradient method will be given as an example.

An apparatus was constructed for holding a bar-shaped specimen in the muffle furnace so that, by the use of an auxiliary heater, a temperature gradient of a few degrees was maintained down the length of the bar. Under these conditions the result of the thermal cycle was to change the random twinning of the untreated bar into a reproducible twin pattern characteristic of the crystallographic orientation of the bar. The practical example sketched in Fig. 3 is typical of Z-X bars, that is, bars cut normal to the Z-axis with their length parallel to the X-axis. Idealised diagrams of the pattern for this orientation and for Z-Y bars are shown in Figs. 4(a) and (b) respectively. The shaded areas indicating the reversed polarity of the twinned portions. Fig. 4(c) shows how an X-cut plate, cut from the cross section of a regular twin of the Z-X type, can be used to produce a face flexural vibration with a normal electrode arrangement, whereas with a single-crystalline X-cut plate, divided electrodes would be necessary. Regular twins have been used successfully in this way as low frequency oscillator plates.

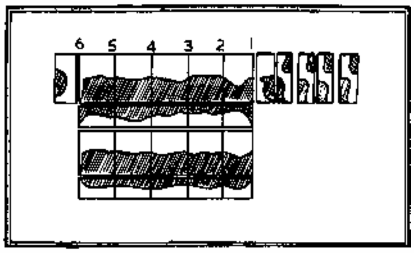


Fig. 3. Twin pattern resulting from temperature gradient along Z-X bar

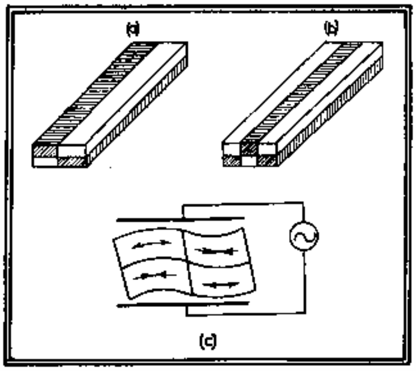


Fig. 4. Regular twins formed by temperature gradient

The Torque Method

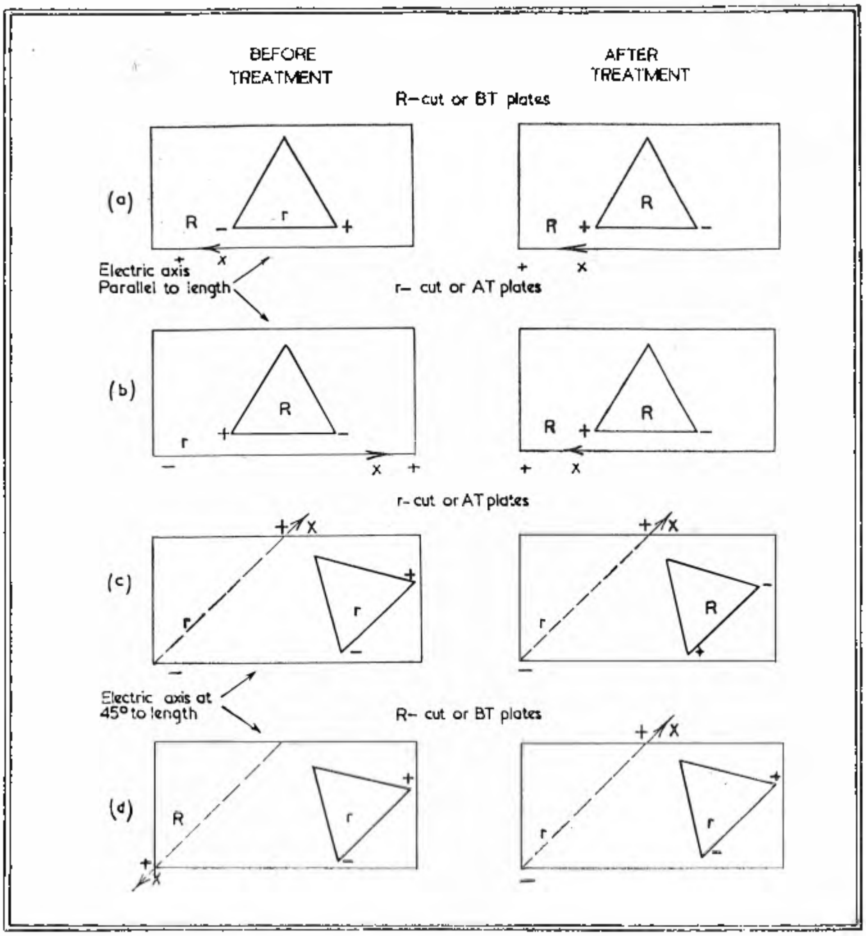
The turning point in the early work was the discovery of the torque method. Largely as a result of piezoelectric considerations, the application of an external torsional stress to a twinned R-cut plate was tried. The plate was mounted in a simple jig holding one end of the plate in a fixed clamp. The other end was held in a pivoted clamp loaded by a lever arm so that the plate was twisted about its length. The lever arm, being gravity operated, was unaffected by temperature and the torsional stress could easily be adjusted by the use of a movable weight on the lever. After the usual thermal cycle the *R*-cut plate was rendered, for all practical purposes, single-crystalline.

From this early experiment has developed the process for salvaging electrically twinned quartz now preferred. It has been found unnecessary to take the thermal cycle above the nominal transformation point at 573° C. and a maximum temperature of about 400° C. is equally effective. Apart from details of technique and results which are described below, the torque method is similar to the others in that it is dependent on the orientation of the plate. In general the method can be applied successfully to all plates of the rotated Y-cut class excepting the Y-cut itself and the Z-cut, (within a few degrees of these two excepted cuts there is a substantial decrease in effectiveness). Unfortunately the method is not applicable to X-cut plates and there has been little experience of its application to other cuts of the rotated X-cut family although successful results have been obtained in a few isolated instances. Briefly, therefore, oscillator plates such as AT, BT, CT are readily treated but the process has not yet found practical application to X-cut filter plates.

In an electrically twinned plate of the rotated Y-cut class there are two crystallographic orientations present which make equal angles on opposite sides of the Z-axis. That is, one orientation is on the *R*-cut side of the Z-axis and the other is on the *r*-cut side of this axis. If we term these orientations the normal and the supplementary cuts we can state two working rules.

1. Plates having their lengths parallel to the X-axis untwin so that the final orientation lies on the *R*-cut side. Thus a twinned BT plate after treatment becomes a single-crystalline BT-cut, while treatment of an AT plate yields the supplementary AT-cut.

2. Plates having their lengths inclined at 45° to the X-axis (that is



since the untwinning process takes care of this point.

Technique of Untwinning by the Torque Method

Fig. 6 shows the equipment designed for treating quartz plates in pairs. The plates normally used have the dimensions 60 × 30 × 4 mm. but the apparatus is adjustable to cover variations in length from 30 to 75 mm. and widths from 10 to 30 mm. Two of the grooved holders, arranged to support the quartz plates, are fixed while the others are mounted on the ends of short rods of nickel chrome steel which are free to rotate in cast iron bearings. Weighted arms attached to these rods apply steady torques about axes through the centres of the two plates parallel to their lengths. When the plates are mounted in the apparatus, thin mica strips are used as packing between the sides of the grooved holders and the faces of the quartz. These strips do not appear to be essential for the success of the process but they help to distribute the mechanical load over the surface of the plates.

The whole equipment, loaded with quartz plates, is placed in a furnace which is then heated to a temperature of 400° C. in about 2 hours and subsequently cooled until the plates

by a rotation of the normal cut in its own plane) untwin so that the final orientation lies on the *r*-cut side. In this instance a twinned AT-45° X plate becomes a single-crystalline AT-45° X plate after treatment.

These two rules are illustrated in Fig. 5. From a practical standpoint it is the normal cut that is described. Hence to produce twin free BT plates the starting material may be either BT or (BT) (the parentheses indicate a supplementary cut), the length being parallel to the X-axis. On the other hand, to produce AT plates the starting material must be AT-45° X or (AT)-45° X. Note the further advantage that in the original cutting of the plates from the quartz stone there is no need to distinguish between the normal and supplementary cuts

Fig. 5 (*above*). **The torque method applied to the rotated Y-cut family**

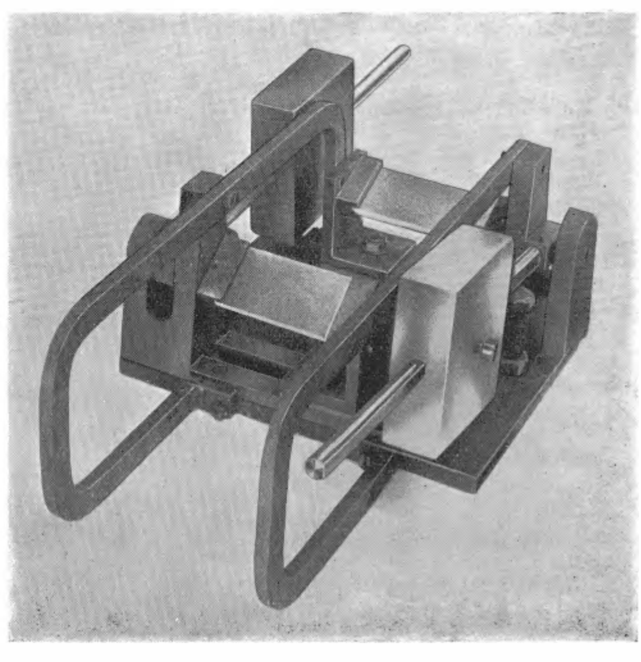


Fig. 6 (*right*). **Torsion apparatus suitable for the heat treatment of quartz plates on a small production scale**

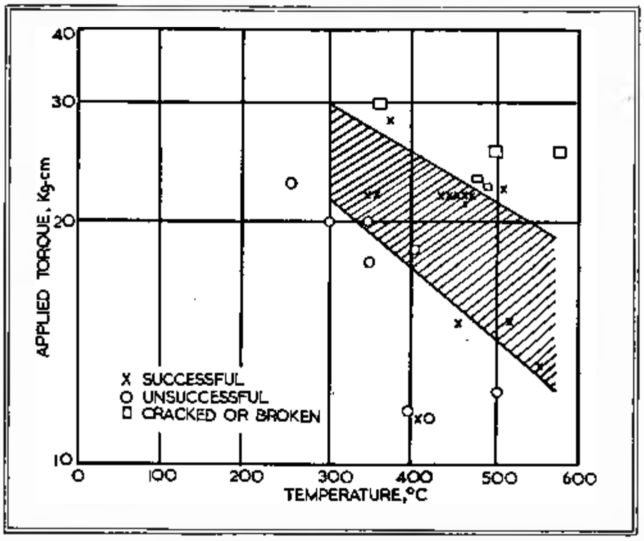


Fig. 7. Conditions for the untwinning of BT-cut quartz plates 60 by 30 by 4 mm. by heat treatment under torsional stress

can be conveniently handled. It has been found important to maintain the temperature in the region of the quartz plates uniform within 5° C. Excessive temperature gradients appear to reduce the effectiveness of the untwinning process while the incidence of breakage is also increased when precautions to reduce temperature differences in the furnace are not taken. For practical purposes the furnaces should be constructed with lightweight heat insulation and arranged with programme thermal controls to give the required rates of heating and cooling automatically.

Results of the Treatment of Quartz Plates

Experiments have been made to determine the conditions of temperature and torque required for the substantial removal of electrical twinning from BT-X cut plates. Fig. 7 shows the preferred conditions for untwinning 60 × 30 × 4 mm. plates, in graphical form as a shaded zone bounded by straight lines drawn through experimental points with temperature measured in degrees centigrade as abscissae and applied torque in kilogram-centimetres as ordinates. Under conditions of temperature and torque represented by points in the area below the lower boundary of the shaded zone, the effect of untwinning is appreciably reduced and the result of a single heat treatment would not normally produce sufficient movement of the twin boundaries to untwin the plate. For conditions above the upper limit of the shaded zone, a plate heated to a particular temperature under the torsional stress indicated would be expected to crack or break during the process. The conditions for untwinning quartz plates cut with orientations such as AT-45°X, BT-45°X and AT-X have not been found to differ significantly from those for BT-X cut plates.

In the case of BT-X cut plates, 30 mm. wide and 4 mm. thick, it was found that for a given temperature the torque necessary for the removal of the twin boundaries was independent of the length of the plate, within the limits of length 30-75 mm. covered by the experiments. Fig. 8 shows a photograph of a BT-X cut quartz plate 45 mm. in length before and after single heat treatment to a temperature of about 400° C. with an applied torque of 22 Kg./cm.

For plates 60 mm. long and 4 mm. thick the torsional stress required to clear the plate was found to be directly proportional to the width of the plate for variation in this dimension from 10 to 30 mm.

The dependence of the torque required for untwinning at a given temperature on plate dimensions may therefore be summarised as follows:—

(i) the torque is independent of the length of the plate

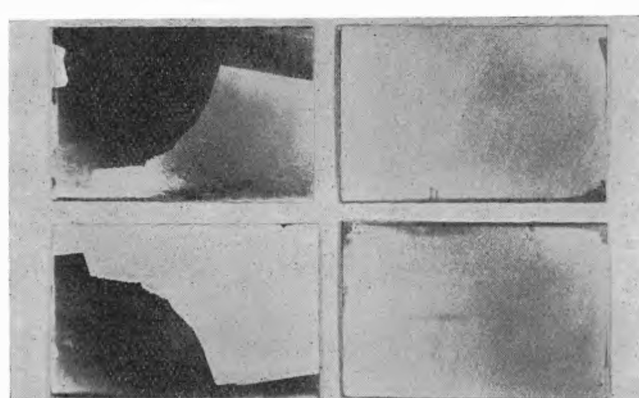


Fig. 8. Examples showing the effect of single heat treatments on BT-X cut quartz plates at a temperature of 400° C. and an applied torque of 22 Kg-cm.
(a) 75 × 3 × 4. *(Top Left)*
(b) 60 × 30 × 4 mm. *(Top Right)*
(c) 45 × 30 × 4 mm. *(Bottom Left)*
(d) 30 × 30 × 4 mm. *(Bottom Right)*

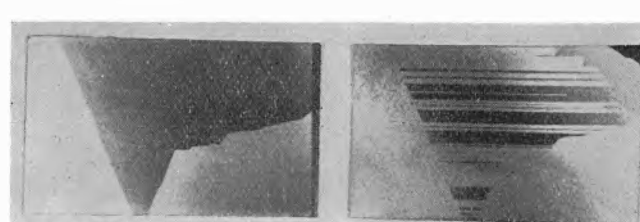


Fig. 10. Photographs showing initial twin patterns and developed comb structure on BT-X cut plate

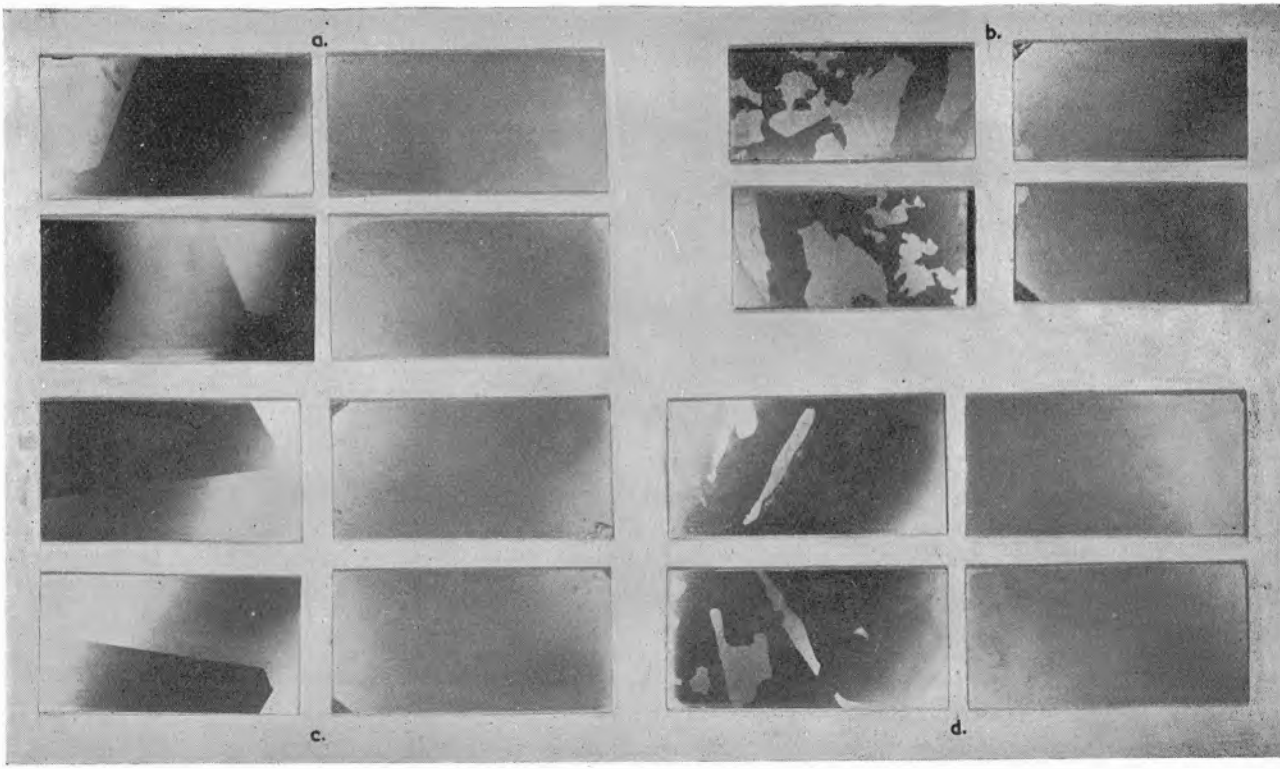


Fig. 9. Illustrating the application of the untwinning process to quartz plates of various orientations

(a) 60 × 30 × 4 mm. (430° C., 22Kg-cm.) twinned BT-X cleared to BT-X
(b) 50 × 30 × 4 mm. (410° C., 18.3 Kg-cm.) twinned AT-45° X cleared to AT-45° X
(c) 60 × 30 × 4 mm. (410° C., 22 Kg-cm.) twinned BT-45° X cleared to (BT)-45° X
(d) 60 × 30 × 4 mm. (500° C., 22 Kg-cm.) twinned AT-X cleared to (AT)-X

(ii) the torque is proportional to the breadth of the plate

(iii) the dependence of torque on thickness has not yet been established over sufficient range to give more than a working rule that the untwinning torque is proportional to the thickness raised to the power 3/2.

Fig. 9 illustrates the applications of the untwinning process to twinned quartz plates with orientations BT-X, AT-X, BT-45°X and AT-45°X, the conditions of temperature and torque being stated. Experience with other cuts of the rotated Y-cut class is comparatively small but experiments have shown that CT, DT, ET, FT, and GT cuts can be treated successfully using the technique described.

The experimental work on untwinning by the torque method has been followed by production trials, mainly on BT and AT plates. The majority of the plates were successfully untwinned, as shown by the etch patterns observed before and after treatment. A representative sample of untwinned material has also been fabricated into oscillator plates which gave a performance in no way inferior to control plates cut from natural single crystalline quartz.

A number of plates however showed anomalous behaviour, and although the percentage of these in the trials was not excessive, the proportion which fail to respond to untwinning treatment, when large consignments of raw material are handled, may be as high as 10-20 per cent. Evidence was also obtained which showed that quartz plates cut from one parent crystal, or at least from the same part of the crystal are similar in their response to the untwinning treatment. Plates which show residual areas of twinning after treatment, may often be traced to a particular parent crystal and alternatively if a plate is successfully untwinned after a single treatment, others cut from the same crystal will also respond to the untwinning process.

It was also observed that quartz plates which do not readily untwin by heat treatment under torsional stress frequently show residual areas of twinning having a characteristic ' comb ' structure, a typical example of which is shown in Fig. 10.

X-ray techniques have been applied to the examination of some of the quartz plates which have developed these ' comb ' structures. The observations made indicate that the untwinning process is affected by the presence of impurities or anomalies in the structure of the quartz which are closely related to the growth history of the natural crystal.

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Capacitance Measurement with an A.C. Voltmeter

By IVAN SOUDEK*

IN ELECTRONIC ENGINEERING for November 1946 an article was published entitled "Capacity Nomogram for use with Avometer Type D." It describes the measurement of capacitance by means of an A.C. voltmeter connected in series with a capacitor Cx under test, across the A.C. mains supply. A nomogram was given for one range of the meter named, but the method is generally applicable and the present article shows how the nomogram for any voltmeter may be scaled from a graphical construction when the experimental method is precluded by absence of suitable standard capacitors.

The object is to correlate a chosen set of capacitance values with the appropriate points on the voltmeter scale. Let C be one such chosen value, expressed in Farads for which the voltmeter reading $E2$ has to be found. $E1$ is the corresponding voltage across the capacitor. The angle AFB (in Fig. 1) will be almost 90° since a good voltmeter will have a low proportion of inductance and the capacitor should not involve power loss.

Vectorially $E1 + E2 = E$, the mains voltage,

$$\text{Now } E1 = I/2\pi fC \quad \ldots\ldots\ldots\ldots\ldots (1)$$
$$\text{and } E2 = IR \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where I is the current through the meter and capacitor, f is the mains frequency and R is the resistance of the voltmeter for the range used. From the diagram

$$\tan \alpha = E2/E1 = 2\pi fCR \quad \ldots\ldots (3)$$
$$\text{and } BG = E \tan \alpha = 2\pi fCRE \quad \ldots (4)$$

A scale diagram can now be produced by drawing a semi-circle with the mains voltage as diameter BA, to which BG and AD are perpendicular, G from Equation (4) being associated with capacitor C. By joining GA the length BF will represent the voltmeter reading to the same scale as AB.

Thus the axis BG may be subdivided in proportion for smaller capacitors chosen and extended in like manner for larger capacitors. For large capacitors it is more convenient to determine the point F by finding where the line BF, produced, meets the other perpendicular to the diameter.

$$AD = E \tan \phi = \frac{E}{\tan \alpha} = \frac{E}{2\pi fCR} \quad (5)$$

Thus D is also associated with the same capacitor C, but for a capacitor of twice the value, the G will move to twice the original distance from B while the D will move down to half its original distance from A.

The accuracy of this method of measuring capacitance depends on

(1) The calibration of the meter and the accuracy of reading.

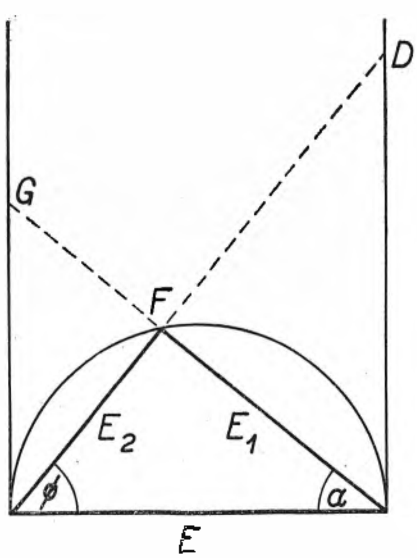
(2) Constancy of mains voltage and frequency.

(3) The vectors for $E1$ and $E2$ being in quadrature.

(4) The absence of harmonics from the wave-form of the supply.

In the British Standard Specification for instruments the meter error below half-scale deflexion is given as a percentage of the full scale reading. Thus the relative error increases as the readings decrease. The capacitance scale is non-linear; its upper end being very compressed. The result of both these influences is that in an area around the middle of the scale the relative errors caused by meter inaccuracy are constant, but the accuracy deteriorates towards both ends of the scale—particularly the upper end.

For large capacitors the point F may be kept away from A by providing a resistance in parallel with the voltmeter so as to by-pass a known proportion of the current. If such a "shunt" is used the symbol R above must be interpreted as the resultant resistance in series with the capacitor under test. This modification avoids the error consequent upon the use of the upper end of the scale.



Mains frequency can be accepted as constant enough and the wave form of the supply voltage will generally suffice for purpose of the test.

The relative error in $E2$ caused by variations of supply voltage will be proportional to these variations and the correction is readily found by checking the mains voltage before making the measurement.

The quadrature of $E1$ and $E2$ can be affected in two ways; The meter is not purely resistive, but the inductance of a good A.C. voltmeter reading up to 230 V is small enough to permit the assumption of pure resistance. The capacitor has been taken as loss free—an assumption justifiable from the fact that if losses were present, that would be sufficient reason for rejecting the component by insulation test.

It can be shown that the absolute value of the error $\Delta E2$ in the value of $E2$ for the loss free capacitor is given by

$$\left|\frac{\Delta E2}{E2}\right| = \frac{\tan \delta}{\sqrt{4\pi^2 f^2 C^2 R^2 + 1}}$$

where $\tan \delta$ is the dielectric dissipation factor, which is less than 0.02 for paper dielectrics and less than 0.002 for mica and ceramic dielectrics. Thus the error can never exceed the value of $\tan \delta$.

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WINDING CAPACITANCE

By N. H. CROWHURST

THIS data sheet assists in computing the various winding capacitances of multilayer windings used in the construction of audio-frequency transformers, chokes and other equipment. They apply to windings in which turns are wound on layer by layer, either interleaved or random wound, so that the P.D. between adjacent turns belonging to consecutive layers will be much greater than that between adjacent turns in the same layer. The capacitance effect between adjacent turns in the same layer is neglected, only that between layers being considered. Capacitance between winding and core, and electrostatic screens, if used, must also receive attention.

Fig. 1 illustrates a cross section of a piece of winding in which layer interleaving is used. It is seen that the dielectric between adjacent conductors in consecutive layers is complex both in shape and material. The turns on the top layer shown fall so that each turn drops in the space between two turns on the second layer, corrugating the interleaving material with a slight resulting increase in capacitance compared with that between the middle and bottom layers shown. Due to the spiral form of each layer, the position of turns in consecutive layers to one another will change at different points round the direction of windng, thus the capacitance between any pair of layers will automatically take up the average value. The composite dielectric is made up of conductor insulation, most commonly enamel, interleaving material and the triangular shaped spaces left between adjacent turns and the interleaving material. These spaces will be filled with dry air if the windings are dried out and hermetically sealed, or with impregnating compound if the windings are vacuum impregnated. The latter procedure will give rise to a somewhat higher capacitance.

In practice the major controlling factor determining the total capacitance between two adjacent layers of winding is the thickness of the interleaving material, thus distributed capacitance may conveniently be estimated in terms of the thickness of interleaving material, giving this material a value of dielectric constant empirically obtained, allowing for the average effect of the other dielectrics in the composite arrangement.

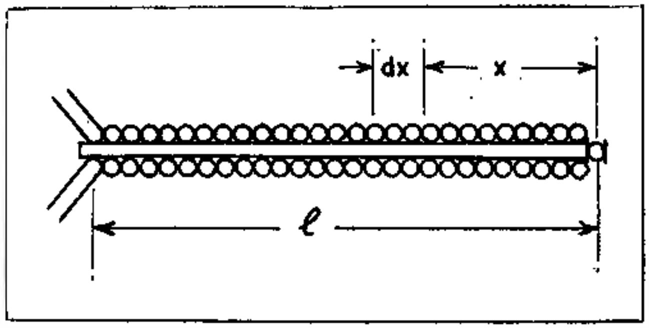


Fig. 2. Effective capacitance of a pair of layers

Effective Layer to Layer Capacitance

Take a winding having only two adjacent layers, its turns distributed uniformly throughout the two layers as shown in section at Fig. 2. Consider an element dx at a distance x from the end of the winding where the conductor steps up from one layer to the other. In the complete winding the elemental capacitance due to the section dx will be transformed so that it can be represented as an equivalent value across the whole winding. If the length of the whole layer is l and the capacitance per unit layer length C, then the effective capacitance of the element referred to the whole winding will be $(x/l)^2C.dx$ The capacitance due to the whole winding will be

$$\int_0^l (x/l)^2 C.dx = \frac{1}{3} l.C$$

Thus the effective capacitance of such a two-layer winding is one-third of the capacitance between two layers measured when their far end is unconnected.

Take now a winding consisting of n whole layers: there will be $(n-1)$ adjacent pairs of layers throughout the winding and the effective capacitance of each pair of layers, referred to the whole winding will be a capacitance of $(2/n)^2$ times their capacitance referred to the high potential and considered as a pair. Thus the capacitance of n whole layers referred to the whole winding becomes

$$\frac{4}{3} \cdot \frac{(n-1)}{n^2} .Cl$$

For large values of n the capacitance becomes inversely proportional to the number of layers. Fig. 7 illustrates a typical winding shape together with the dimensions as used in the data sheets. The capacitance per layer, given in the foregoing formula as Cl, is proportional to the product of the length per mean turn L_{MT}, and the length of layer L_W.

Vertical Sectionalising

It is sometimes of advantage to sectionalise the winding as shown at Fig. 3, each vertical space being filled completely before proceeding to fill the next one. Although physically the winding will have the same overall cross-sectional dimen-

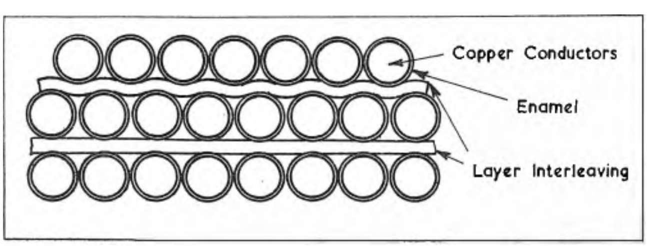


Fig. 1. Section through layer interleaved winding

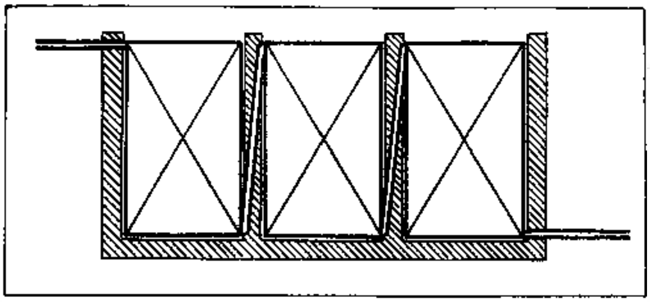


Fig. 3. Sectionalising to reduce capacitance

sions its self-capacitance will be equivalent to that of a winding having $1/N \times$ layer length and $N \times n$ layers, where N is the number of vertical sections. The distributed capacitance of the winding due to such sectionalising thus is reduced by the factor $1/N^2$. Note that this rule applies only to referred interlayer capacitance and does not apply to capacitance between the top and bottom of the winding and adjacent windings or screens. The various reduction factors for vertical sectionalising are given in Table 1.

Effect of Mixing Windings

In the design of a transformer it is often necessary to mix the primary and secondary windings in order to reduce leakage inductance. This arrangement will generally be a disadvantage as regards minimising winding capacitance, since it exposes greater surface area of winding in proximity to either the other winding or an earthed screen. If the ratio of the transformer is fairly high, then from the high impedance winding the whole of the low impedance winding appears at common audio potential, usually earthy. But if the ratio of the transformer is not very high, capacitance between points at differing audio potentials in the two windings may have serious effects, and it is generally best to arrange the windings so as to avoid such capacitance.

Fig. 5 shows a cross-section suitable for an inter-valve transformer designed to operate two valves in push-pull from a single valve on the primary side. The H.T. end of the primary is earthy and is therefore diagrammatically earthed. The high potential end of the primary is adjacent to the earthy end of one of the half secondaries so that the capacitance between windings at this point is effectively from anode to earth. The two high potential ends of the secondary are remote from the primary and so minimise the possibility of unbalanced capacitance transfer from primary to one half secondary.

Another problem which often arises is in the design of push-pull output transformers, particularly for Class AB or Class B circuits, where it is essential that each half of the primary be well coupled to the whole secondary. From the viewpoint of leakage inductance and winding resistance, it is unimportant whether the secondary sections are connected in series or parallel. Fig. 6 illustrates three arrangements for a transformer of this type, each of which may be best suited under different circumstances. At (a) is an arrangement which gives minimum primary capacitance, but suffers from the defect that leakage inductance and winding resistance are unequal for the two primary halves. For Class A operation using valves requiring an optimum load of high impedance this arrangement is sometimes the best. At (b) is an arrangement intended to equalise winding resistance and leakage inductance from each half-primary to the whole secondary as well as primary self-capacitance. This arrangement is particularly suited to circuits employing low loading Class AB or Class B operation. The alternative arrangement shown at (c) results in a slightly lower referred capacitance across one half only of the primary. In general this unbalance is not desirable, but if leakage inductance is adequately low, the coupling between all the windings may be so good that the reduction in capacitance may be apparent across the whole primary.

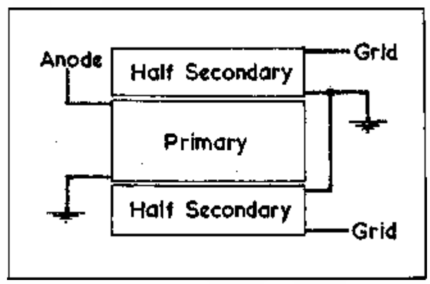


Fig. 5. Push-pull secondary intervalve transformer secondary arrangement

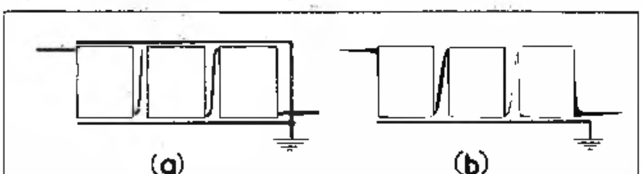


Fig. 4. Arrangements using vertical sectionalising. See Table 1 (below)

Number of Vertical Sections	Distributed Capacitance Component	Winding to Screen Capacitance Arrangement as Figure 4		
		(a) One side earthy	(a) Centre point earthy	(b) One side earthy
1	1	1	0.5	0
2	0.25	0.75	0.25	0.125
3	0.111	0.704	0.185	0.185
4	0.0625	0.6875	0.1875	0.219
5	0.04	0.68	0.160	0.24
6	0.0278	0.676	0.176	0.255
∞	0*	0.667	0.167	0.333

* The method of winding is here changed so that for the purposes of this column, the dimensions Lw and Tw will change places.

Table 2 gives a pictorial representation of various ways in which high impedance windings may be arranged in relation to earthy points shown as screens. The table is equally applicable if these points are earthy low impedance windings. The capacitance factors for alternative connexions of the winding, with either one side or the centre point at earth potential, are given relative to the average capacitance between one end layer of the winding and one screen. The two arrangements marked with an asterisk indicate that it is necessary to reverse the direction of winding in order to achieve the capacitance factor shown.

Random Winding

In what is known as random winding, no interleaving material is

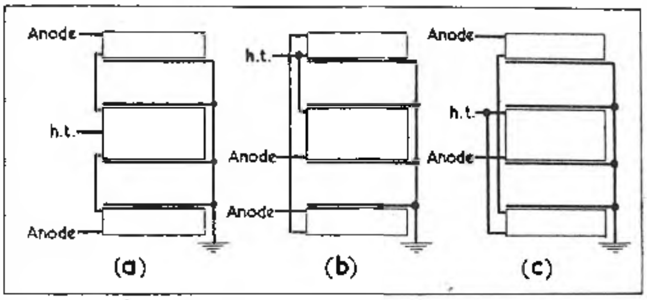


Fig. 6. Arrangements for push-pull output transformer

used. For ideal random winding the layers should be built up so that at all times during winding the top surface is level. Failure to do this will not greatly affect the self-capacitance, but will result in increased danger of breakdown due to electrical or mechanical stresses. As the number of layers is always large, it is convenient to reduce the calculation to simple terms of the winding dimensions.

The essential variables are: length of winding L_W, length of mean turn L_{MT}, winding thickness T_W (see Fig. 7), and number of turns, T. Considering variation of each of these quantities in turn, the others being taken as constant: variation of L_W will vary the referred capacitance per layer as before, and additionally the effective number of layers will vary inversely as $L_W^{\frac{1}{2}}$; variation of L_{MT} simply varies the layer size, as before; variation of both T_W and T varies the number of layers in direct proportion to $T_W^{\frac{1}{2}}$ or $T^{\frac{1}{2}}$. Thus the whole expression for variation of capacitance can be written,

$$C_P \propto \frac{L_{MT} L_W^{3/2}}{T_W^{\frac{1}{2}} T^{\frac{1}{2}}}$$

The lower half of the data sheet is based on this relation and empirical values obtained from average results with random windings.

Example 1

A push-pull output transformer is arranged as at Fig. 5: primary winding has a total of 12 layers, $T_D = 3$, $k = 2$; insulation between primary and screen, $T_D = 15$, $k = 5$; main dimensions, $L_W = 2''$, $L_{MT} = 8''$.

Distributed capacitance, using upper data sheet, $L_W = 2''$, $L_{MT} = 8''$, $T_D = 3$, $k = 2$ and $n = 12$, is $C_P = 240$ pF.

Capacitance from each primary to screen, substitution $T_D = 15$, $k = 5$, is C_P = 1200 pF. The capacitance factors for the arrangement of Fig. 5 are: (a) 0.25; (b) 0.5; (c) 0.375. Thus the total capacitance referred to the whole primary for each method of connexion is,

(a) 300 pF + 240 pF = 540 pF.
(b) 600 pF + 240 pF = 840 pF.
(c) 450 pF + 240 pF = 690 pF.

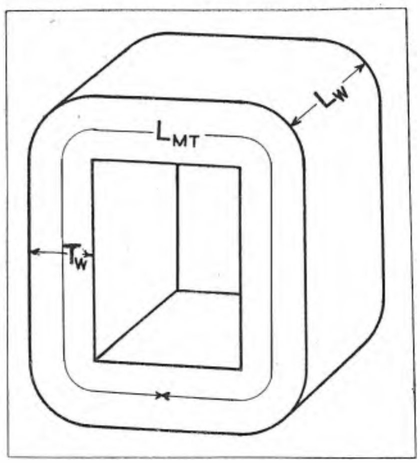


Fig. 7. Dimensions used on data sheets

Example 2

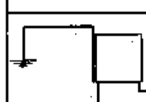
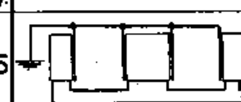
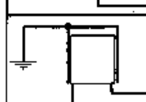
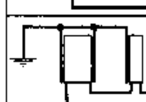
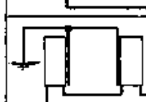
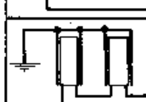
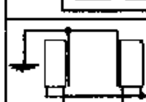
An intervalve transformer, to operate from push-pull to push-pull, uses a simple arrangement having both windings all in one section: $L_W = 0.6''$, $L_{MT} = 2.5''$, T_W (each winding = $0.1''$; insulation between windings, T_D, $k = 3$; Turns, 4,000 c.t./12,000 c.t.

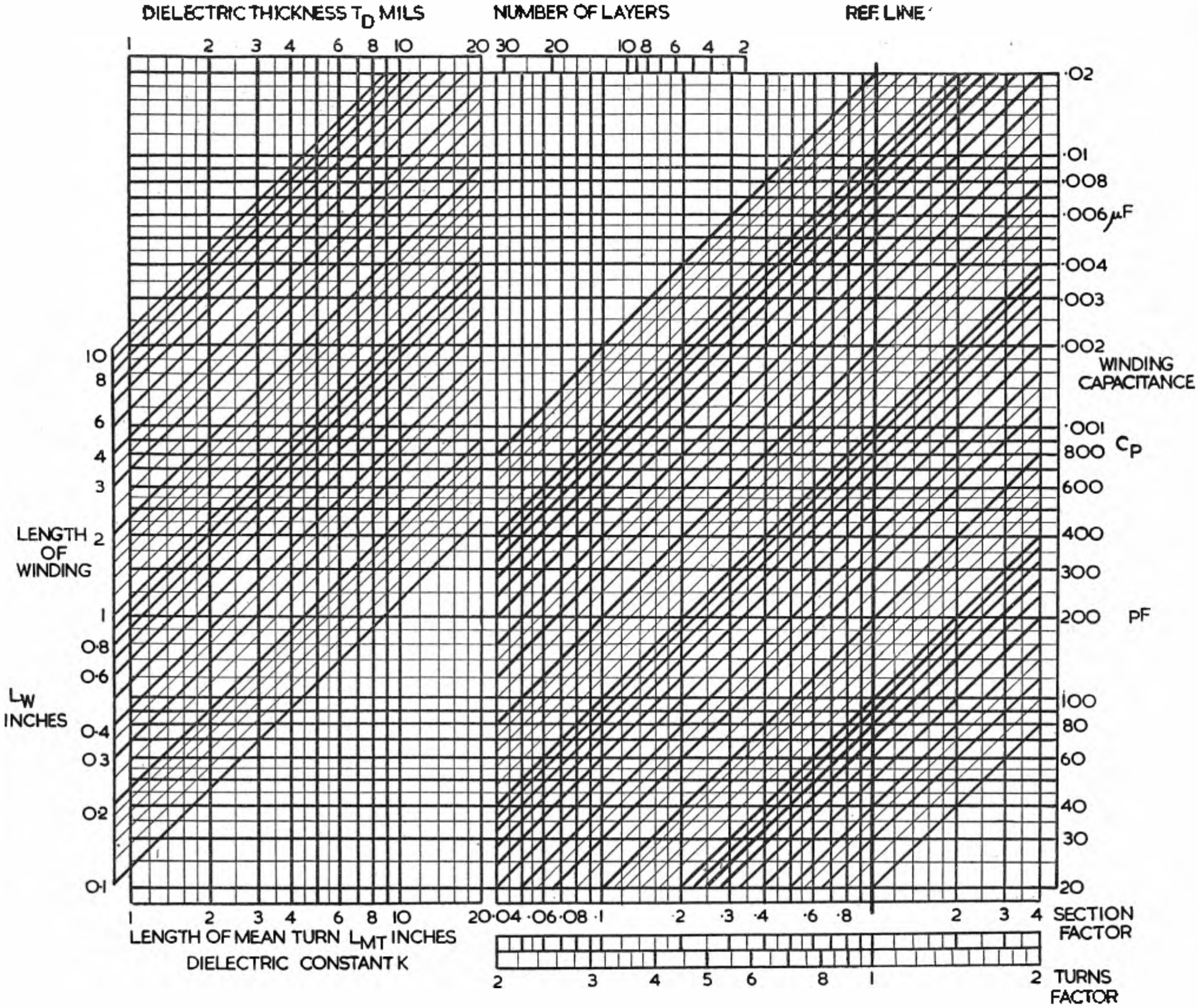
Distributed capacitance, using lower data sheet, $L_W = 0.6''$, $L_{MT} = 2.5''$, $T_W = 0.1''$, T (primary) = 4,000, is Cp = 58 pF. For secondary, T = 12,000, Cp = 34 pF.

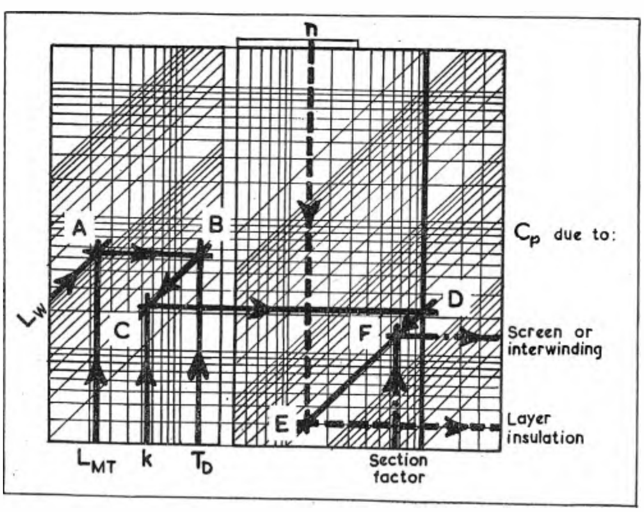
Capacitance coupling between one-half primary and one-half secondary, using upper data sheet, actual capacitance, $L_W = 0.6''$, $L_{MT} = 2.5''$, $T_D = 10$, $k = 3$, is C_P = 100 pF. Both windings wound in same direction, turns factor across this capacitance referred to whole primary is $\frac{1}{2} + 1\frac{1}{2} = 2$, so referred capacitance is 400 pF. Windings wound opposite directions, turns factor referred to primary is $1\frac{1}{2} - \frac{1}{2} = 1$, so referred capacitance is reduced to 100 pF.

(Continued on page 431. Data sheets overleaf)

Table 2. Effect on referred winding-to-screen capacitance of various arrangements

WINDING & SCREEN ARRANGEMENT & CONNEXION	CAPACITANCE FACTOR One side earthy.	CAPACITANCE FACTOR Centre point earthy.	WINDING & SCREEN ARRANGEMENT & CONNEXION	CAPACITANCE FACTOR One side earthy.	CAPACITANCE FACTOR Centre point earthy.
	—	·25		1·25	·25
	1	·5		1·11	·11
	·22	·055		2·11	·611
	·5	—		1 *	1
	1·5	·5		3	1·5
	— *	·5		1·94	·44
	2	1		1·75	·25



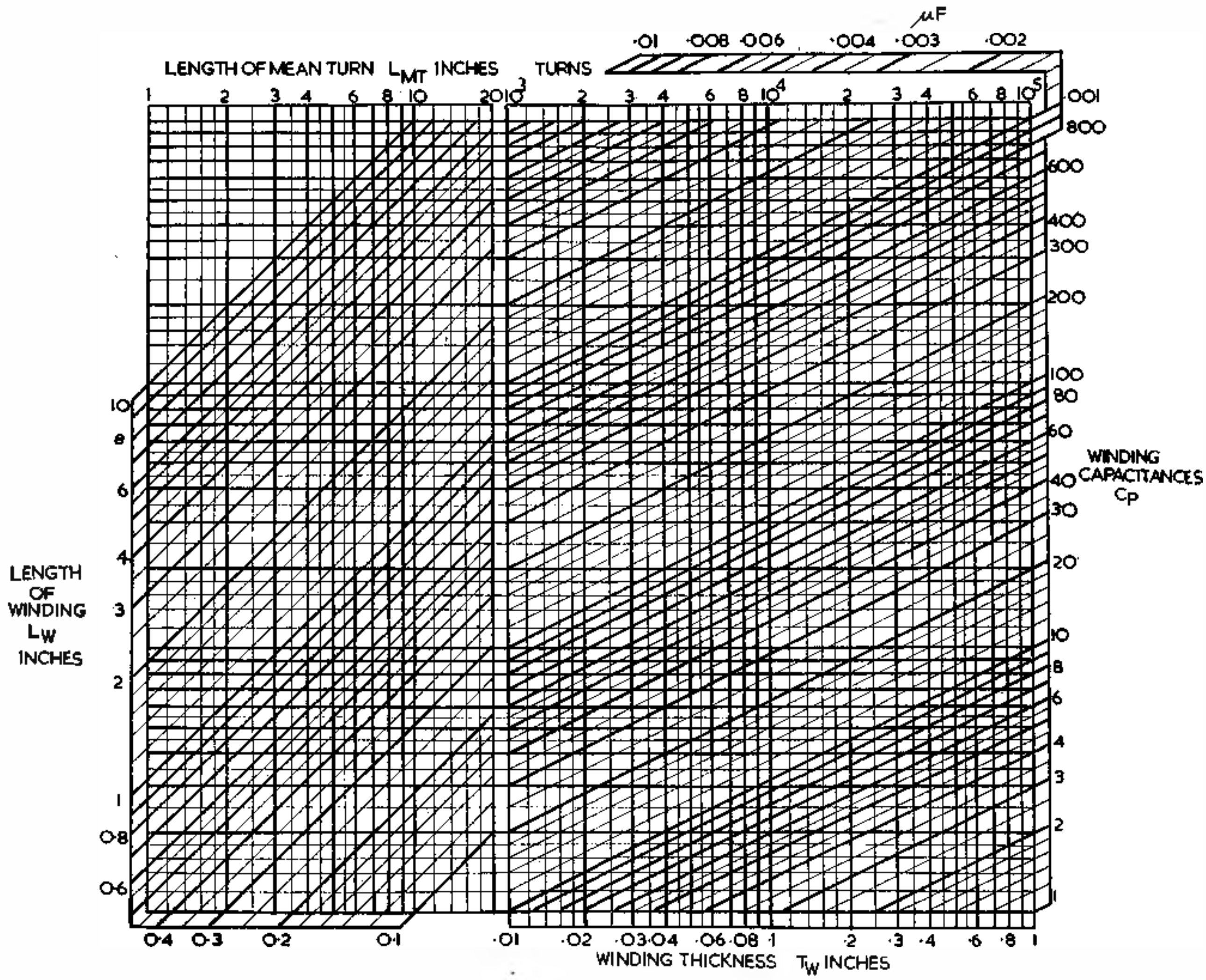


For Distributed Capacitance due to Layer Winding:

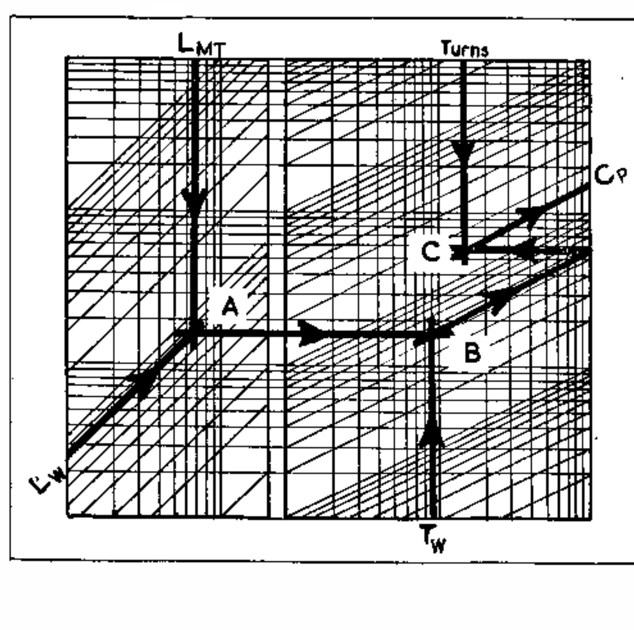
Refer length of winding L_W, and length of mean turn L_{MT}, on their respective scales, to intercept at A (figure 8 left), then along the horizontal reference lines to intercept with the thickness of dielectric material T_D, at B. From this point refer along the slanting reference lines to intercept with the empirically determined value of dielectric constant k, at C, then along the horizontal reference lines to the unity reference vertical at D. From this point refer down the slanting reference lines to intercept with the number of layers n, at E, whence the referred capacitance is read off on the scale at the right.

For Interwinding, or Winding to Screen Capacitance:

As above, for the winding dimensions and dielectric thickness to a point corresponding to D, whence, for winding to screen capacitance, or interwinding capacitance when the other winding is all at low potential, refer down the slanting reference lines to intercept with the section capacitance factor obtained from Table No. I. For interwinding capacitance where there is appreciable potential in the adjacent portions or both windings, individual attention will be necessary for each interwinding space, and the turns factor scale will assist here.



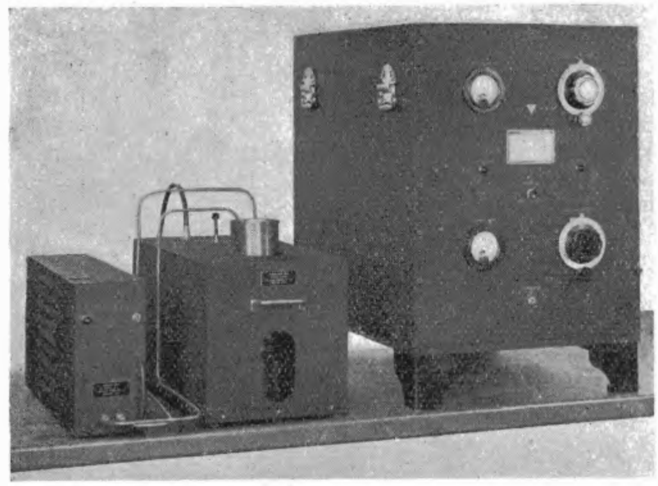
For Distributed Capacitance due to Random Winding: Refer length of winding L_W, and length of mean turn L_{MT}, on their respective scales, to intercept at A (figure 9 right), then along the horizontal reference lines to intercept with the vertical line for thickness of winding T_W, at B. From here refer up the slanting reference lines to the right-hand edge of the data sheet, and then back along the horizontal lines to intercept with the vertical line for the number of turns at C, from which referred capacitance is read off along the slanting lines at C_P.



ULTRASONICS : *A Brief Survey*

By JOHN H. JUPE, A.M.I.E.E.

IN the study of acoustics the term "ultrasonics" is usually taken to mean those frequencies that are above the normal upper limit of human audibility, about 18,000 c/s. The word is considered preferable to "supersonics" which now has a particular significance in aeronautical engineering.



Model U.300 Ultrason, maximum output 250 acoustic watts

History

The study of these frequencies began about a hundred years ago, in 1845, when Despretz claimed that certain musicians had heard high octaves up to 30,000 c/s. However, in 1874 Koenig condemned these early results owing to the lack of accurate measuring equipment at the time they were obtained. We now know that Despretz' claims may have been fairly correct since a few individuals *are* able to detect sounds of about 25,000 c/s.

In 1883, Francis Galton invented his ultrasonic whistle, capable of generating frequencies up to 25,000 c/s. Tuning forks only a few millimetres long were perfected in 1899 by Koenig. These forks, tested by Kundt's "dust figure" method, vibrated at frequencies as high as 90,000 c/s. The next year Edelmann improved the Galton whistle and enabled it to generate up to 110,000 c/s.

In 1907, Altberg recorded a frequency of 332,400 c/s. but with the exception of improvements made by Schultze and Lebedev, few discoveries were made until 1917, when Langevin produced a submarine detector which used the Poulsen arc as a supersonic generator.

During the next few years scientists in several countries made ultrasonic investigations. Giebe and Scheibe of the German Reichsanstadt explored the field of quartz plate vibration; Hartmann perfected his air-jet generator and Cady made advances in connexion with crystal vibrators that led eventually to the Pierce oscillator.

In 1925 a new type of sound-wave generator was created. This generator used a magneto-striction arrangement whereby a rod of ferrous material was brought into an oscillating magnetic field and a stretching effect was produced. It suffered from the disadvantage that high frequencies could not be stably maintained because of temperature variations and as a consequence attention was turned to the generation of ultrasonic frequencies with thermionic valve/quartz crystal combinations.

From then onwards investigations were made of many aspects of high frequency sound, including such things as emulsification, coagulation, cavitation, and many commercial and scientific possibilities emerged.

Model U.500 Ultrason, capable of giving a maximum of 6 watts output power

Generators

The first commercial ultrasonic generators were produced in Germany in the early 1930's but they were expensive, complicated and difficult to operate, and except for widely scattered investigations these troubles caused the new science to fall into the doldrums. The second World War however, caused the subject to be reopened, and several quite simple and reliable commercial ultrasonic equipments are now available.

One of these is the Ultrason, a generator designed without any special application in view by the Televiso Products Company of America. The Model U.500 Ultrason with its associated crystal holder is intended as a research instrument for the observance of ultrasonic effects with the microscope. It develops a maximum of 6 watts of power at the crystal.

The Model U.300 Ultrason can be used either for research where high power is required or for specific industrial applications It produces a maximum of 250 acoustic watts in an oil bath and has a crystal holder that can be used to treat granular materials or adapted to continuous flows of liquids or gases. Both models operate at a frequency of 450,000 c/s. This value has been chosen as a result of theoretical and practical investigations and nearly all results at other frequencies can be repeated at 450,000 c/s. The larger model can be varied between the limits of 420,000 and 500,000 c/s., while for the measurement of sound velocity in liquids and gases, the smaller model can create frequencies as high as 14 Mc/s., though for normal working an upper limit of 7.5 Mc/s. is recommended.

Applications of Ultrasonics

In all probability the widest use of ultrasonics will be in the field of industrial chemistry, since many interesting effects have already been noted in the chemical sphere. The non-destructive testing of various materials is also likely to lead to many uses.

The following is a summary of some of the interesting phenomena that have been noted.

Normally immiscible liquids such as oil and water or oil and mercury can be converted into stable emulsions. Very fine dispersions of metals in water can be obtained. This result is achieved by subjecting a cathode to ultrasonic waves during electrolysis, when the metal is flung out into the liquid at high speed; so finely divided that it remains in suspension. By varying the frequency etc., any metal that can be electrolysed can be dispersed. The degree of dispersion depends on power, electrode material and the cathode surface.

In the paint world, manufacturers are investigating the possibilities of ultrasonic suspension of refractory pigments in a nitrocellulose vehicle and plastic companies are seeking to use the waves to prepare colloidal dispersions of resins and plasticisers in water and organic media.

In dairy products, preliminary work has been done on the emulsification of cream cheese mixtures and on the pasteurisation of milk at low temperatures. The homogenising of milk is already a production process.

The effects of ultrasonic waves on gels are of marked value. Pulp and paper industries are working on modifying gel structures to improve coatings for art papers.

A few of the metallurgical uses are the crystallisation of low melting-point materials, nitrogen hardening of steel and the elimination of hydrogen after plating. Metals such as tin and aluminium solidify more rapidly when subjected to high frequency sound waves and the structure has a finer grain. There are also many applications in connexion with the preparation of alloys.

Liquids and melted substances can be de-gassed by ultrasonic waves because a negative pressure is brought about through the expansion of the fluids being processed. This negative pressure allows the dissolved gas to emerge. An obvious application of the process is to obtain gas-free materials for electronic tubes.

Non-Destructive Testing

A use of ultrasonics that is already well into the commercial stage is the non-destructive testing of materials for hardness, cracks, pits, non-homogenity, etc. Most of the present applications are connected with metals, but the procedure is entirely applicable to other substances, particularly to rubber. One of the largest tyre companies in the U.S.A. tests its entire output by this method.

Although ultrasonic waves have a strong dispersive action they can also have a coagulating effect, particularly on aerosols; and dusts, smokes and mists can quickly be agglomerated and precipitated. Work has already been carried out on the retention of soot within factory chimneys and the removal of fog from aerodromes.

There are also a number of biological effects which may be useful. Diathermy and radiotherapy are easier this way since the feelings of physical heat is absent and no high voltage electrodes need be brought near the patient. The sterilisation of foods and liquids is possible, also the killing of insects in wheat and other food products.

As an aid to those who may wish to start investigations in the field of ultrasonics a bibliography of the more important sources in literature up to the present time is appended.

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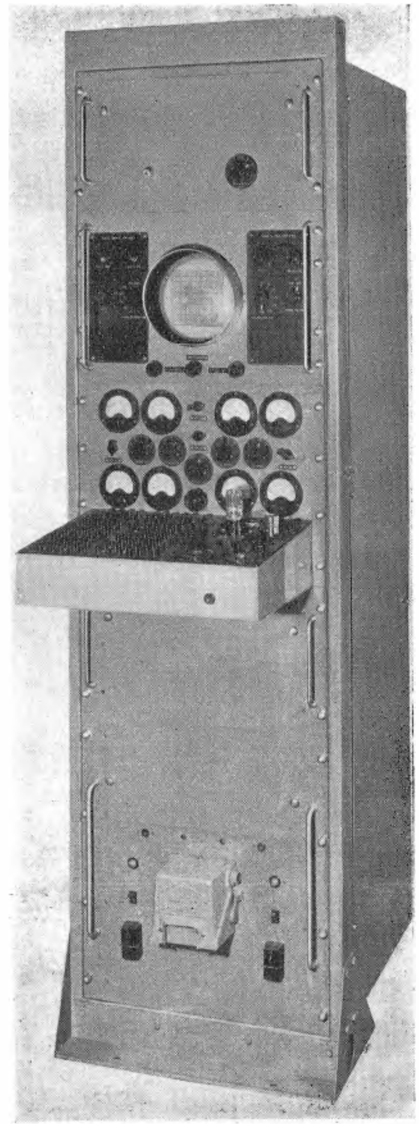
A UNIVERSAL VISUAL VALVE TESTER

By

F. L. HILL, B.Sc., and C. W. BROWN*



A VALVE tester which will display a family of valve characteristics has many obvious advantages over the more usual static testers. It is possible to see at a glance whether a valve conforms to the maker's specifications, and one can very rapidly investigate the effect of variation of any parameter by adjustment of the controls, so that the optimum operating conditions to suit any application are very readily determined. The time taken to plot a family of, say, ten curves is about half a day, whereas with a visual device of the type described below the time taken is 1/50 second, and to obtain a second set of curves at a different screen voltage, or with bias on the suppressor grid, the time is only that required to adjust the appropriate control.

Several visual testers have been described in the past. One such system, limited to output valves and employing mechanical switching was described in 1940,[1] and an electronic device in 1947.[2] That described below, of which a photograph is shown on this page, is believed to be unique in several features, and to be the first commercially available visual valve tester. A model has been in daily use for some eight months and has proved its usefulness and stability. The sample curves shown were taken with an ordinary camera, but it would not be difficult to provide a permanent camera, an auxiliary light source being used to illuminate the graticule.

Basically the tester consists of means of displaying on a cathode-ray tube a complete family of anode volts/anode current curves for ten different grid voltages. Sockets are provided to accommodate all modern types of valve, and a universal connexion board enables any electrode to be connected to any supply. This is achieved by means of a series of push-button switches arranged in ten rows with ten buttons in each row. Each horizontal row corresponds to one valve pin, e.g., the first row is connected to pin No. 1 in all the valve sockets, the pins being numbered according to the B.V.A. standard notation. The vertical rows correspond to the various supplies appropriate for anode, screen, heater, etc. By depressing the button in the horizontal row 1 and column "*Anode*", pin No. 1 is connected to the anode supply, so that by pressing up to ten buttons suitable connexions for any valve can be made. The push buttons are interlocked horizontally so that two supplies cannot be connected to the same electrode, but there is no vertical interlock so that any number of electrodes may be connected to one supply. For example, a pentode may be connected as a tetrode, triode or diode as well as the normal connexions, and the connexions may be changed from one to the other instantaneously.

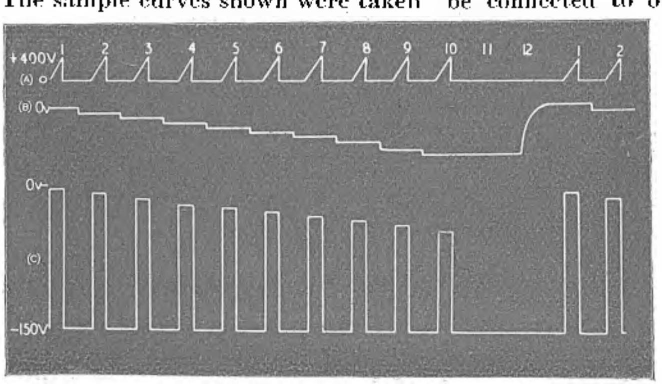


Fig. 1. Fundamental wave-forms

Principle of Operation

The voltage applied to the anode of the valve on test is of the form shown in Fig. 1(a). This voltage is also applied through a D.C. amplifier to the "X" deflecting plates of the cathode-ray tube, so that horizontal deflexion is proportional to anode volts. The anode current of the valve is passed through a resistance selected according to the

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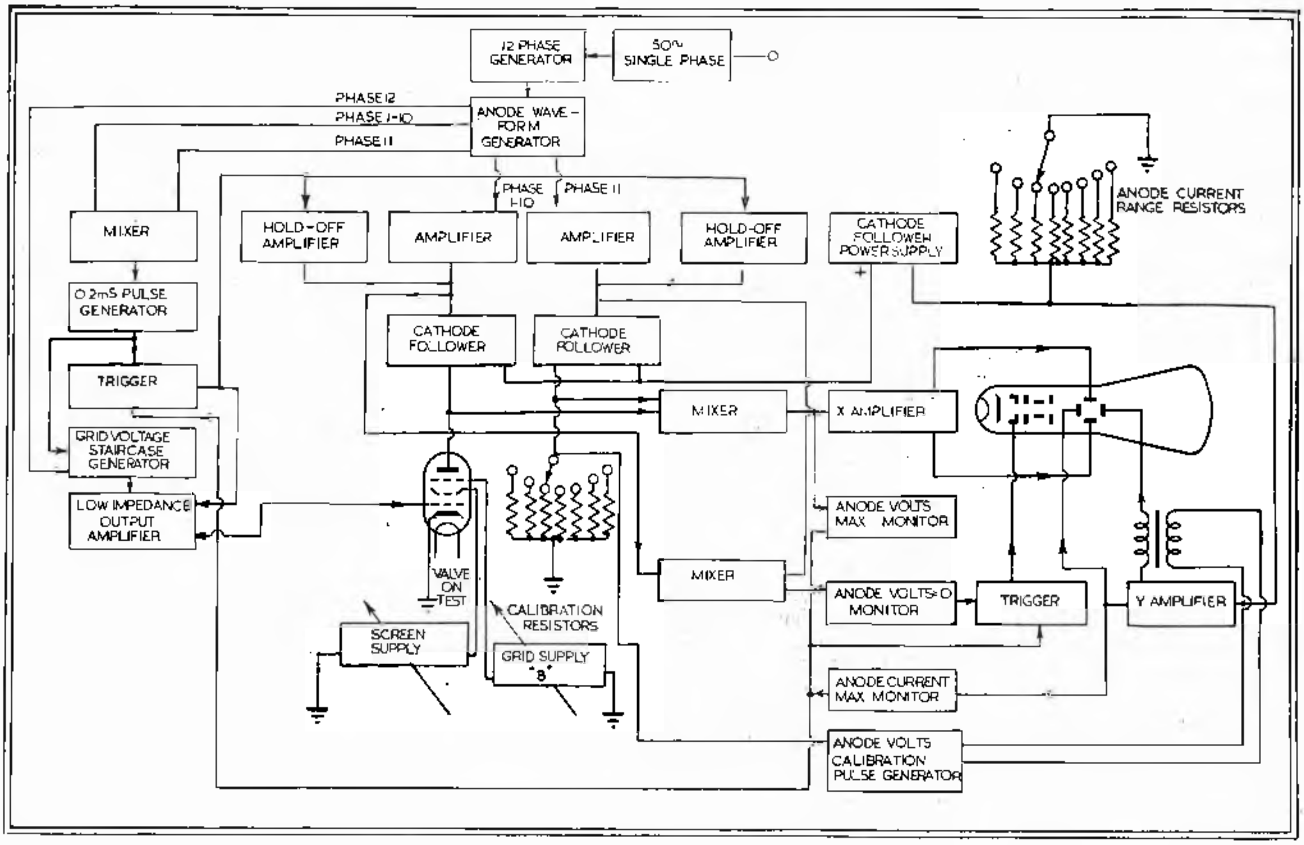


Fig. 2. Block schematic of visual valve tester

range of anode current required, and the resulting voltage is applied, through another D.C. amplifier, to the "Y" plates, so that vertical deflexion is proportional to anode current. The anode voltage waveform is derived from a twelve-phase supply, the first ten phases giving rise to the sweeps of anode voltage at the ten different grid voltages; phase eleven inserts a calibration signal and phase twelve restores the grid potential to zero in preparation for the repetition of the family of curves. Between sweeps of anode voltage is a resting period during which the grid voltage is changed by a controlled step, the magnitude of which is selected by the "grid voltage step" switch. This resting period also serves to reduce the ratio of mean to peak dissipation in the valve, enabling valves to be tested at higher peak dissipations than would otherwise be possible. There are eight ranges of anode current, from 5 mA full scale to 1 amp., giving a possible peak dissipation of 400 watts.

The grid voltage waveform which immediately presents itself as suitable is that shown in **Fig. 1(b)**, where the grid voltage is initially zero and increases in a negative direction in equal steps each time the anode voltage returns to zero. This is quite satisfactory for triodes, but reference to Fig. 1 will show that the anode voltage is zero for a large part of a cycle, and when testing pentodes or tetrodes the screen will take the whole cathode current during this time, resulting in excessive screen dissipation. To overcome this difficulty the grid waveform actually used is that shown in Fig. 1(c), where the grid is held well beyond cut-off except during the time when the anode voltage is applied. Steps of grid voltage of 0.5 V, 1 V, 2.5 V, 5 V and 10 V are available, and are selected by the grid voltage step switch.

The screen supply is a low impedance D.C. voltage source, variable from zero to 400 volts, and capable of delivering 100 mA anywhere in this range, and a negative supply up to 150 volts in four ranges is available for application to suppressor grids of pentodes or the oscillator grid in mixers.

Static Tests

Provision is made for making static tests by means of a switch which cuts out the cathode-ray tube, and connects a set of meters in circuit. Meters are provided for measurement of anode voltage and current, screen voltage and current, heater voltage and current, and two independent grid voltages. For static tests the anode voltage may be varied from zero to 400 volts and 300 mA may be drawn at any voltage in this range. This involves a special type of voltage regulator, as if the conventional type of series control regulator is used, it will be seen that for an output of 400 volts, an input to the regulator of about 600 volts will be required, and if the output is turned to a low value, almost the whole of this 600 volts will be dropped across the series valve. If the maximum current is now drawn, the dissipation in the series valve will be 180 watts, and a very large valve or combination

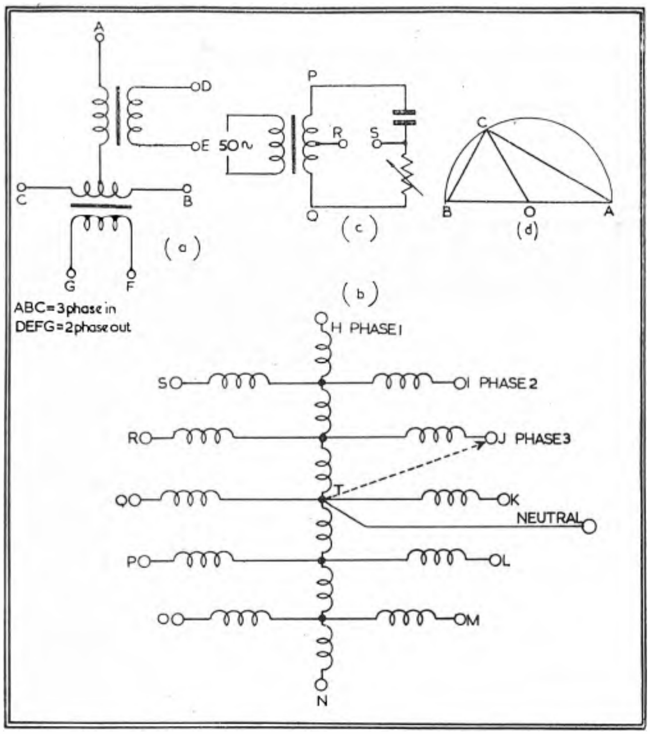


Fig. 3. Derivation of twelve phase circuits from either three or single-phase supply

of valves will be required. In this power supply a pair of grid controlled rectifiers is used, the bias for the rectifiers being obtained from the voltage drop across the series regulator valve, so that as the output is turned down the input is automatically reduced, resulting in almost constant voltage across the series valve. The screen supply and the two grid supplies are all independently regulated so that there is no inter-action between them. Jacks are provided for measurement of grid current in the two grid circuits when making static tests. Heater voltage is adustable from 1 volt to 300 volts, the maximum power available being 100 watts, except on the lower ranges, where the current is limited to 10 amps. Ranges of 1-3 volts, 3-10 volts, 10-30 volts, 30-100 volts and 100-300 volts are covered by a "Variac" adjustable transformer.

Visual Tests

Returning now to visual tests, the cathode-ray tube is provided with an engraved graticule which is moulded to fit the face of the tube, and is calibrated with 100 vertical and horizontal divisions corresponding to anode current and voltage. The sensitivity of the **X** and **Y** amplifiers and corresponding shift controls may be adjusted with the help of the calibration signals to be described below, to line up with the engraved marks.

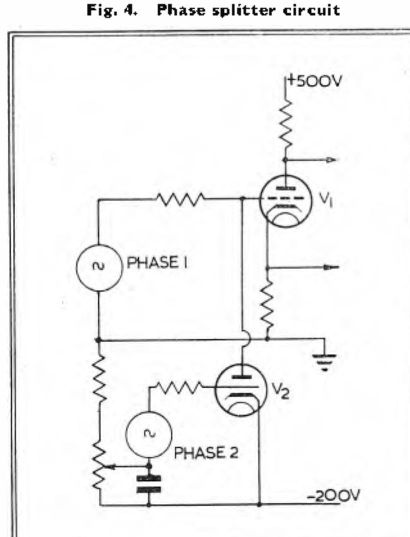
A block schematic diagram of the whole equipment is shown in Fig. 2. A twelve-phase supply at 50 c/s. provides the main timing signals, being converted to the wave-form of Fig. 1(a) by the anode voltage generator. Only the first ten phases appear in the anode waveform, phase eleven being used for the calibration signals and phase twelve generating a pulse which triggers the grid voltage generator back to zero at the end of a complete cycle. Phase eleven is of the same wave shape as phases one to ten; it is applied not to the valve on test, but to one of a set of resistors of known value, selected by a switch according to the range of anode current. The voltage across this resistor is monitored by a set of voltage markers, which inject small pips into the "**Y**" deflexion amplifier at 100, 200, 300 and 400 volts, so that the voltage calibration is readily checked, and since the values of the resistors are known, the current calibration may also be checked. A mixing circuit employing two cathode followers enables the voltages on the anode of the valve on test (phases 1-10) and on the calibration resistor (phase 11) both to be applied to the input of the "**X**" amplifier, so that the calibration pattern appears superimposed on the valve curves. By turning the switch to the position "O" the calibration line is made to coincide with the "**X**" axis.

An automatic limiter is provided, which returns the anode voltage to zero, ready for the next stroke as soon as the spot on the cathode-ray tube reaches the edge of the graticule in either direction, so that once the maximum values of anode voltage and current have been set up on the range switches, these values cannot be exceeded, even instantaneously. As an extreme example, if the anode supply is short circuited a vertical straight line is drawn up the left hand edge of the screen stopping at the edge of the graticule. This feature protects both the valve and the equipment, and also gives a neatly trimmed edge to the set of curves.

Anode Wave-Form Generator

The first requirement is to produce a 12-phase supply. This may be done in several ways. One of which has been used successfully starts with a 3-phase supply, from which a two-phase supply is obtained by means of a Scott-connected pair of transformers, as shown in Fig. 3(a). In Fig. 3(b), winding **HTN** is the winding **DE** in Fig. 3(a) and the windings **SI**, **RJ**, **QK**, **PL**, **OM** are separate windings corresponding to **GF** in Fig. 3(a), each being centre tapped and having its centre point connected to a tap on **HN**. The voltage between **T** and the points **H-S** consist of the sum of two

Fig. 4. Phase splitter circuit



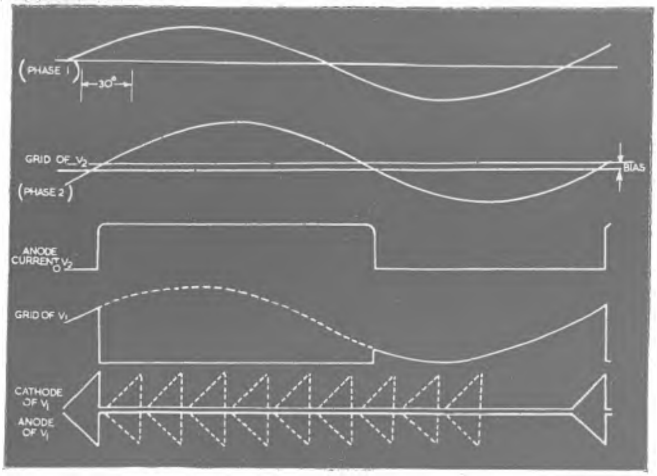


Fig. 5. Wave-forms in anode supply generator

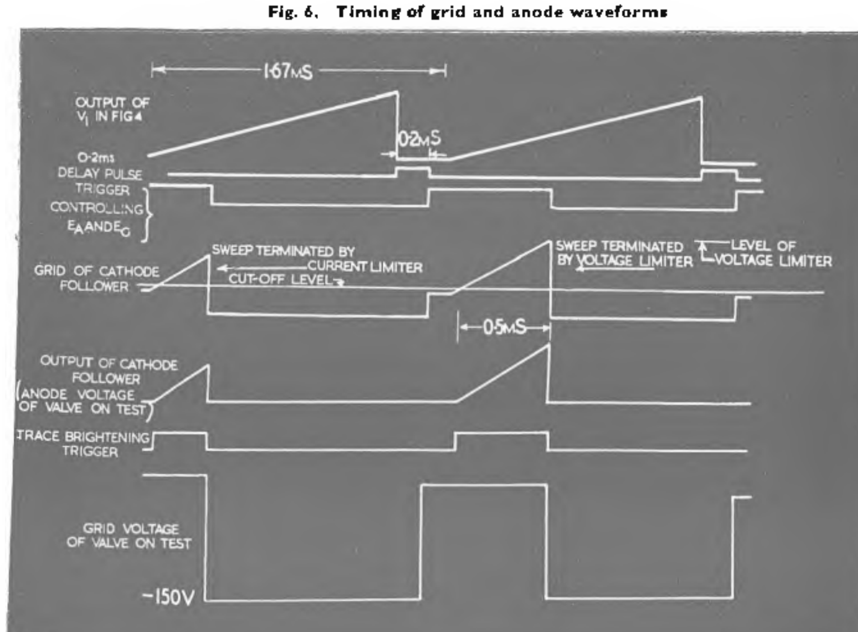
voltages in quadrature and by proper choice of turns ratio the voltages on points H-S may be made to be equally spaced around a circle whose centre is T, so that the voltages from these points to T are equal in amplitude and spaced 30° apart in phase.

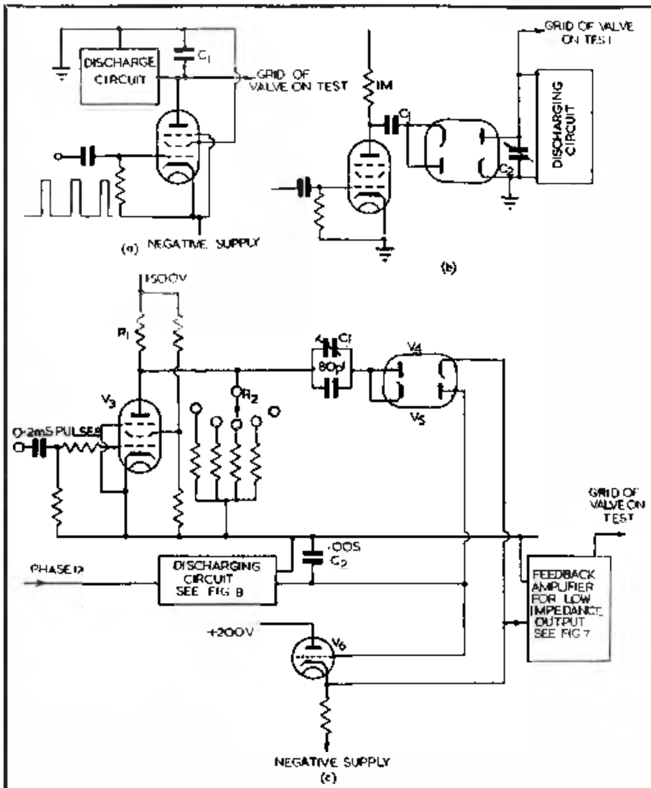
Where 3-phase mains are not available the circuit of Fig. 3(c) is more suitable. This is the well-known phase shifting circuit. In the vector diagram Fig. 3(d) OA represents the voltage across the winding RP in Fig. 3(c), OB the voltage in RQ. The vector sum of the voltage across the capacitor, CA, and that across the resistor, BC, is equal to AB, and since these voltages are in quadrature the point C lies on a semicircle and the voltage OC, i.e., the voltage between R and S in Fig. 3(c) is constant in amplitude and varies in phase from zero to 180° with respect to OA as the resistance varies from infinity to zero. By employing a number of pairs of resistors and capacitors connected in series across PQ any number of phases between 0 and 180° may be obtained, and by interchanging the capacitor and resistor a further set between 180° and 360° will complete the circle. The only limitations are the excessive power consumption if the resistances are made too low, and the disturbing effect of the load across R-S if the impedances are made too high, but it is possible to arrive at a satisfactory compromise.

The first ten phases of the 12-phase supply (sine-wave) are applied to the grids of a set of triode valves, one of which is shown as $V1$ in Fig. 4. This valve is connected as a phase splitter with equal loads in anode and cathode, and a second triode valve $V2$ is connected from the grid of $V1$ to a negative supply. A sinusoidal voltage in phase with phase 2 (lagging 30° behind phase 1) is applied to the grid of $V2$, in series with a source of positive bias and a resistor to limit grid current. The resulting wave forms are shown in Fig. 5. In the diagram showing anode and cathode wave forms of $V1$, the full line curves show the voltages due to phase 1 on the grid of $V1$ and the dotted curves show the voltage variations due to successive phases on the grids of similar valves, whose anodes and cathodes are connected in parallel with those of $V1$. Owing to the positive bias, $V2$ commences to conduct less than 30° later than $V1$, and so the output voltage wave form consists of saw teeth with a short resting period between peaks.

The voltage on the anode of $V1$ is applied to the grid of a phase reversing amplifier which drives a high power cathode follower, consisting of two **D.A.30** valves in parallel supplying up to one ampere of anode current at 0-400 volts to the anode of the valve on test. Also connected to the grid of the cathode follower is the anode of a valve, whose cathode is connected to a negative supply, and whose function is to hold the grid of the cathode follower beyond cut-off between sweeps of anode voltage. It is controlled by a trigger circuit, and is switched to the "off" position (grid of cathode follower cut-off) by the output of the monitors of the anode current and anode voltage wave forms, thereby returning the anode voltage to zero, when the edge of the graticule is reached as described above. It is switched on again by the trailing edge of a pulse lasting for about 0.2 mS. which is initiated by the return of the voltage wave on the anode of $V1$ (see Fig. 6), i.e., immediately before the commencement of the next anode voltage sweep. This trigger circuit also holds the grid of the valve on test beyond cut-off except when the anode voltage is applied, as described below under "grid voltage generator." The

Fig. 6. Timing of grid and anode waveforms





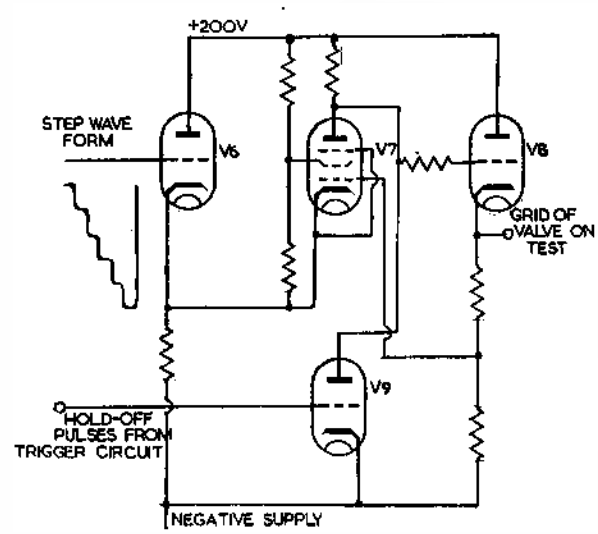


Fig. 7 (*left*). **Step waveform generators**

Fig. 8 (*above*). **Grid circuit low impedance output stage**

0.2 mS. delay is necessary to ensure that the anode voltage on *V*1 has fallen to a low value before the trigger is restored, otherwise oscillations are liable to occur.

A second trigger circuit is used to brighten the trace of the cathode-ray tube during each sweep of anode voltage. It is switched on by the grid voltage of the cathode followers approaching the potential at which current commences to flow and is switched off by the pulses which return the anode voltage to zero. This arrangement removes the bright spot at the origin due to the spot being stationary while the anode voltage is at zero.

The power supply to the cathode follower has its negative pole connected to earth via the anode current measuring resistor, the voltage across which is connected to the input of the " Y " amplifier, so that special precautions have to be taken to prevent unwanted signals such as hum and signals due to capacitance currents from flowing through this resistor. These precautions include the use of a power transformer with double screening, and a circuit for balancing out current flowing to earth from the cathode circuit of the cathode followers through the circuit wiring capacitances.

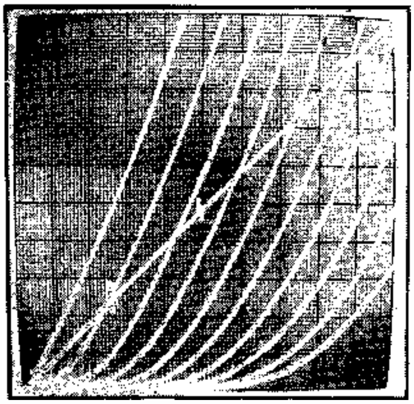
A separate amplifier and cathode follower are used to apply a voltage sweep to the calibration resistor during the operative portion of phase 11, and suitable mixing circuits, mainly consisting of pairs of cathode followers with common loads are used for mixing the signals at appropriate points, so that the protective and tube brightening circuits operate for phase 11 as well as phases 1-10.

Grid Voltage Generator

Various methods have been described for generating the waveform of Fig. 1(b), and some of them are shown in Fig. 7. " a " represents a pentode valve which has pulses applied to its grid, so that for each pulse a charge is transferred to the capacitor. For equal steps it is necessary that these charges should be equal. The amount of the charge is controlled by the current and the time, and so the amplitude and duration of the pulses must be accurately controlled.

The circuit 2 of Fig. 7(b) gives steps independent of pulse duration, and if the pentode valve is allowed to bottom during positive pulses the steps will also be independent of pulse amplitude. When the grid is negative the anode voltage approaches that of the positive supply line, and the capacitor *C*1 is charged to line volts through the lower section of the double diode. When the grid is driven positive, this diode ceases to conduct, the upper diode conducts and the anode potential falls to a low value, and the charge on *C*1 is shared between *C*1 and *C*2. Since *C*2 is much larger than *C*1 the change in potential in *C*2 is small compared with that in *C*1, and for small steps the voltage change per pulse will be uniform, but for larger changes the voltage will tend to rise exponentially. Change of voltage per step is varied by switching *C*2.

The circuit used in the Universal Valve Tester is shown in Fig. 7(c). Pulses applied to the grid of the pentode charge *C*1 and discharge it into *C*2, as in Fig. 7(b). Here, however, the voltage to which the capacitor *C*1 is charged is controlled by the combination of *R*1 and *R*2, the latter being switched to give the different ranges of grid steps, using a fixed value of capacitor for *C*2. This gives constant discharge time



Anode characteristics of a triode

and renders exact adjustment of of steps easier. Another refinement is the use of the cathode follower $V6$ to supply the cathode potential of the diode $V4$, which ensures that each step is the same, and not falling exponentially.

Let E_A be change in anode potential of $V3$

Let E_C be the voltage across $C2$ before the pulse

Let E be the voltage across $C2$ after the pulse

Total charge before pulse = $(E_A + E_C)\,C1 + E_C C2$ =

Total charge after pulse = $E_G\,(C1 + C2)$ where

$$E_G = \frac{E_A C1 + E_C C1 + E_C C2}{C1 + C2}$$

$$E_C + \frac{E_A C1}{C1 + C2}$$

Hence change in volts = $\dfrac{E_A C1}{C1 + C2}$

which is independent of E_C

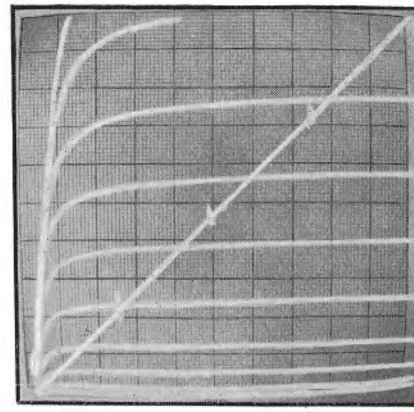
For Fig. 7(b), proceeding in a similar manner

$$E_G = \frac{E_A C1 + E_C C2}{C1 + C2}$$

so that each step is less than the preceding one because E_C is increasing.

The output from the cathode of $V6$ is fed into an amplifier whose output impedance is rendered very low by negative feedback so that any grid current which may be flowing in the valve on test will not affect the accuracy of the grid voltage steps.[3] The circuit is shown in Fig. 8 where $V7$ and $V8$ operate in a similar manner to the well-known voltage stabiliser circuit, the reference voltage being the cathode voltage of $V6$. Hence the output voltage will be accurately proportional to $V6$ cathode protential which carries the required staircase wave form of Fig. 1(b). $V9$ converts this wave form to that of Fig. 1(c) by holding the grid of $V8$ negative except during the time the trigger circuit is operated, i.e., except when the anode voltage is applied to the valve on test. When the trigger is operated $V9$ is biased to cut-off and so does not effect the operation of the circuit. When $V9$ conducts the grid and hence the cathode of $V8$ go negative, carrying the grid of $V7$ beyond cut-off and breaking the feedback chain.

The discharge of the capacitor $C2$ in Fig. 7(c) is controlled by phase 12 in the 12-phase supply, so that the grid potential during the phase 1 sweep will be zero. In Fig. 9 $C2$ is the same as in Fig. 7(c), and is shunted by the triode $V10$ which



Anode characteristics of a pentode

is normally biased beyond cut-off. Pulses controlled by phase 12 are applied to the grid of $V10$ and also the anode of a diode $V11$ so that the maximum positive excursion of the grid of $V10$ is controlled by the potentiometer in the cathode of $V11$. This is normally set so that the grid potential of the valve on test is zero in phase 1. It should be noted that $C2$ is not completely discharged as there is a change of D.C. level in the low impedance amplifier of Fig. 8 corresponding to the ratio of the two resistors in the cathode of $V8$.

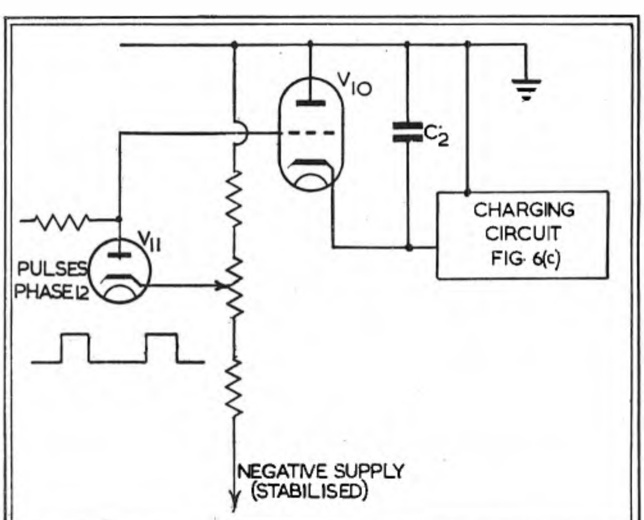


Fig. 9. Step waveform discharge circuit

Power Supplies

Owing to the presence of voltage and current wave forms of a complex nature, each of which has to be precisely determined, it is necessary to use low impedance power supplies to prevent interaction between circuits. Independently regulated supplies at +500 V, and +200 V, −200 V and −500 V provided the D.C. power for the various wave form generating circuits. The anode supply described above under static tests is switched so that its output is +500 volts when making visual tests, and this supplies all circuits requiring this voltage except the screen supply which is entirely independent and the anode supply to the main cathode followers which have their own supply.

In conclusion the authors wish to express their thanks to Messrs. Cinema-Television, Limited, for permission to publish the information contained in this article.

References

[1] A. J. Heinz van der Ven, *Philips Tech. Rev.*, March, 1940.
[2] W. E. Webking, *Electronics*, November, 1947.
[3] This circuit is similar to one suggested by G. Bocking, *Wireless Engineer*, December, 1942.

WINDING CAPACITANCE By N. H. Crowhurst. — *continued from page 419*

Referring these two values to secondary, turns factors are $1/2 + 1/6 = 2/3$ or $1/2 - 1/6 = 1/3$, giving capacitance values referred to whole secondary of 45 pF or 11 pF respectively.

A complete analysis would need to consider leakage inductance between each primary and each half secondary, and separate source and load impedances applied to each half. For this purpose, the primary and secondary shunt capacitances across each half would be 116 pF and 68 pF respectively, while the capacitance coupling would be 1,600 pF or 400 pF referred to half primary. The secondary shunt capacitances referred to the half primaries would be 610 pF.

Example 3

A direct coupled inter-valve transformer is arranged as at Fig. 4: $L_W = 1.5''$, $L_{MT} = 6''$, $T_D = 20$, $k = 1$ (air spaced); T_W (each whole winding) $= 0.2''$; Turns 4,000/12,000 c.t.

Distributed capacitance, using lower data sheet, $L_W = 1.5''$, $L_{MT} = 6''$, $T_W = 0.2''$, T (primary) $= 4{,}000$, gives $C_P = 400$ pF. Secondary, $T = 12{,}000$, gives $C_P = 225$ pF (or 450 pF per half secondary).

Interwinding capacitance, using upper data sheet, actual capacitance, $L_W = 1.5''$, $L_{MT} = 6''$, $T_D = 20$, $k = 1$, gives C_P just over 90 pF say 100 pF.

Vertical sectionalising will reduce the distributed component in each case, but will also vary the interwinding capacitance. Using the information in Table 1, the results may be tabulated as shown below.

In practice three sections for the primary and four or five sections for each half-secondary will be best, remembering capacitance reduction is more important in the secondary. By making the earthy end of primary and secondary at opposite ends of the vertical groups, interwinding capacitance coupling effects are minimised.

Number of Vertical Sections	Primary Capacitance			Half Secondary Capacitance		
	Dist.	Inter-winding	Total	Dist.	Inter-winding	Total
1	400	100	500	450	—	450
2	100	75	175	112.5	12.5	125
3	44.4	70.4	115	50	18.5	68.5
4	25	69	94	28	22	50
5	16	68	84	18	24	42
6	—	—	—	12.5	25.5	38

Binders for Fluorescent Screens

PARTICLES of phosphor materials employed as fluorescent screens for electric discharge tubes such as mercury vapour lamps and cathode ray tubes need to be firmly stuck to the wall of the tube in order that they remain in position during the life of the tube. It has been usual in the manufacture of these tubes to apply binders such as sodium or potassium silicate or boric acid either before, after or simultaneously with the deposition of the fluorescent material.

However, these binder materials are not always entirely satisfactory. The silicates depend for their adhesion properties on the presence of water, and during baking, an essential step in the evacuation process, they tend to flake off the walls of the tube; others such as boric oxide have undesirably high melting points — 577° C., which makes their use difficult.

It has been found that the beryllium fluoride glasses prepared by fusing together beryllium fluoride with alkali fluorides and other fluorides, are particularly suitable as binders owing to the low melting points available, the wide temperature range over which the glasses are soft, and also to the high transparency of these glasses to light in the ultra-violet region down to a wavelength of 2200 *A*.

An example of a suitable glass is that made by fusing together equal parts by weight of sodium fluoride and beryllium fluoride. This glass has a melting point about 160-170° C. If a glass with a higher melting point is required it can be obtained by using in the mixture other fluorides such as potassium, calcium, magnesium, and aluminium fluorides. It is desirable to keep the percentage of beryllium fluoride about 50 per cent of the mixture and also to have about 20 per cent of an alkali fluoride present.

The binder may be applied to the wall of the discharge tube in a number of known ways such as smearing the melted glass over the hot surface, spraying it in as a dry powder, as a suspension, or spraying it on as a solution of the constituent fluorides. The fluorescent material can be applied in similar ways either to the hot binder in soft or melted condition, or to the cold surface, to be followed subsequently by a heat treatment to cause firm adhesion between the fluorescent material and the wall of the tube. An alternative method that can be used, for example, in the manufacture of mercury or neon discharge lamps, where the exciting agent for the fluorescence is ultra-violet light, is to mix the fluorescent material with the binder and by melting the mixture within the tube cause it by suitable treatment to be coated evenly on the inside of the tube. Little diminution in the efficiency of excitation results from this coating process owing to the high transparency of the glass to ultra-violet light, and in fact the layer of binder may act as a protective coating. A further layer of binder may if desired be applied subsequently to the fluorescent material.

The exact degree to which the fluorescent material is embedded in the binder is sometimes of importance, particularly in avoiding halation effects. These glasses remain soft over a wide range of temperatures, and have low melting points, so that the extent to which the fluorescent material sinks into the binder after deposition may be readily controlled.

Also, if desired, in order to reduce halation effects further, the binder may be coloured by the addition of compounds such as cobalt fluoride, or alternatively a neutral light absorbing material such as graphite may be incorporated in the layer of binder between the fluorescent material and the glass wall of the tube.

—*Communication from E.M.I. Ltd.*

RESIN-BONDED FIBRES

RESINOUS insulating materials have widespread applications in the electronics industry, and in view of their increasing importance it should be of interest to follow the stages of manufacture of a typical product. "Tufnol"* has been selected for the purpose of this description.

The base from which the different varieties are made depends on the use required of the finished product. Paper is employed as a base for most general applications, but where mechanical strength and resistance to shock are required, a fabric base is called for. Both types will ultimately withstand temperatures from −183° C. up to about 100° C., but Tufnol with an asbestos base can be used up to as high a temperature as 200° C.

The manufacture of sheets begins with a roll of the fabric or other base being impregnated with a resinous bonding compound, which is then dried. High electrostatic potentials are generated on the sheets in the drying process, and have to be discharged by leakage conductors. The impregnated roll is then cut into 4-ft. squares. Depending on the ultimate thickness required—which may be from 1/64 in. to 9 in.—a number of these squares is placed between each pair of heating plates of a steam heated hydraulic press. After being subjected to a pressure from 150 to 1,000 tons, the sheets are baked to complete the setting of the resin.

The thinnest sheets are used for the manufacture of rod and tube, being rolled on to suitably shaped steel formers, and after removal of the formers from the rod material both rod and tube are processed in a second steam heated hydraulic press.

Careful inspection is carried out at each stage, and final tests are made, after all rough edges have been removed, before the finished product is ready for despatch.

Uses in the Factory

Although frequently taking the place of metals and other materials Tufnol is not to be regarded merely as a substitute. Its properties present definite advantages that commend it for particular uses. It can be machined accurately with ordinary engineering tools, and because of its toughness and resistance to ordinary wear it has many uses in the factory and workshop. Sheet up to 1/16 in. thick can be punched within the same limits as brass of a similar thickness. Rods and square and rectangular bars can be drilled and tapped in any direction without splitting.

Perhaps one of its most obvious uses in the workshop is in the making of drilling and routing jigs. Being so easy to machine, a considerable saving in time can be effected in making such tools, the lightness of which makes for greater ease in subsequent handling. This particular product weighs half as much as aluminium.

Gear wheels cut from Tufnol are used on all kinds of drives from clock and meter movements to gears for transmitting high horsepower; in fact, their horse-power capacity when fully shrouded (which is not normally necessary, however) is equal to that of machine-cut cast iron gears. Their resilience enables them to transmit the load smoothly with consequent silence in operation, and they absorb shock and thus prolong the life of the metal mating wheels.

Where non-metallic bearings are suitable for the work required, Tufnol bearings have long life and in suitable applications will have a longer life than bearings of any other practicable material. Considerable economies are effected since water lubrication is usually all that is required, and replacements are needed less often. In addition, shafts are not scored.

Moulded ball insulators are made for working potentials of 660 volts and are, in fact, proof-tested at 2.2 KV. They are suitable for use in any climate and, being designed for working loads of up to 2 tons, are practically unbreakable.

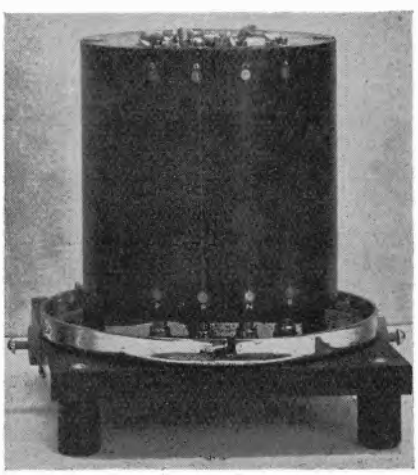


Fig. 1. Thermostatically controlled crystal oven (cover removed), made of Tufnol

Applications to Electronics

Among the more obvious electronic uses of this material are valve-holders, terminal boards, coil bases and coil formers. New types of life-testing equipment incorporating double-action Tufnol cams are used for applying endurance tests to electronic components such as plugs and sockets, potentiometers, switches and for flexing tests of cables. The photo shows a thermostatically controlled crystal oven (for frequency control apparatus) made of Tufnol. Heat-resisting Tufnol is being used, too, in many forms in R.F. heating apparatus, in transformer rectifier units and in thermal cut-outs.

Perhaps one of the most interesting uses is in the construction of the 1,000-ton proton-synchrotron at Birmingham University. The radial magnetic field for this equipment is produced by an electro-magnet energised by a current of 12,500 amperes flowing along 144 turns of laminated copper strip weighing 9 tons. Due to the heat generated, these turns have to be forced-air cooled at 15,000 cu. ft./minute and therefore have to be air-spaced as well as electrically insulated. 7,000 pieces of Tufnol strip are used for this purpose, having to withstand compressive stresses, due to electromagnetic forces, up to 480 lb. per square inch.

This brief survey can only touch on a few of the many applications known to the manufacturers, who are always glad to hear of any unusual uses of their product, or to give advice on possible applications.

* "TUFNOL" is the registered trade mark of Tufnol Ltd., Perry Barr, Birmingham.

CORRESPONDENCE

The Electronic Engineering Home-Built Televisor

Dear Sir,—I feel that I must draw attention to the undesirability and indeed danger of using unspecified components when building the Electronic Engineering Televisor.

I had the opportunity at Radiolympia of meeting a large number of constructors, the majority of whom reported having had excellent results with their Televisors.

Unfortunately there were a few who had not had the same good fortune. Careful questioning elicited the fact that the receivers had not been constructed strictly to detail, there being wide variations in the types of components used.

In some cases, scanning equipment designed for other receivers, principally commercial models, had been substituted, while in other cases different types of valves, transformers, and capacitors were employed.

It cannot be stressed too strongly that for optimum results, only the components which are specified should be used, since a considerable amount of work has been entailed in testing and ensuring that the components which are specified are suitable for the circuits and reliable in operation.

I should be most grateful if you would bring this information to the notice of your readers.

Yours sincerely,

W. I. Flack

We should like to emphasise the remarks contained in Mr. Flack's' letter.

It has been brought to our notice that some home constructors are, for example, using not only unspecified components for the Home Built Televisor, but are making radical changes in the design by the substitution of ex-Government apparatus

While it is technically possible to use, say, a surplus 45 Mc/s. I.F. strip in the Televisor, a fully satisfactory picture cannot be obtained and we cannot accept any responsibility for the ultimate performance nor can we undertake any alternative designs.

Editor "E.E."

Membership of Learned Societies

Dear Sir,—Many and varied have been the comments made in the past about the mysterious questions asked by the Civil Service Commissioners on application forms for Government posts. May I comment further and quote from a recent "Official Appointments" notice observed in the daily press thus:—

"Instruments Engineer (Electronics) urgently required ... must either be Corporate Members of the Institution of Civil, Mechanical or Electrical Engineers or have passed examinations recognised as exempting from sections A and B . . . have had several years of experience in the field of electronic engineering, etc., etc."

This wording is typical of many advertisements for such vacancies in both the Electrical and Mechanical fields of Government employment which I personally have observed over recent months.

Surely officialdom can differentiate between the three professional institutions sufficiently to give each its pride of place in its own particular sphere of activity?

I know of few civil engineers who are qualified in electronics and I have yet to meet a member of my own Institute who is primarily engaged as a civil engineer unless such membership is an additional qualification subordinate to corporate membership of the "Civils."

Yours faithfully,

Gordon A. Spencer,
A.R.I.C., A.M.I.E.E.

The Design and Limitations of D.C. Amplifiers

Dear Sir,- The article on "The Design and Limitations of D.C. Amplifiers" Part I, in the issue of September 1949, shows that the authors are not aware of the work carried out in America by the Radiation Laboratory and published in book form by McGraw Hill. The type of valve selected for the first amplifying stage is the most important factor determining the performance of a D.C. amplifier. It seems[1,2,3] that the 6J6 is useless as the two halves are not well matched and drift is serious. By analogy the UA55 will also suffer from these defects. The best performance is apparently obtained from those twin triodes formed of two separate triodes in one envelope, the 6SL7GT being the best (the 6SU7 is a selected 6SL7GT). The new range of miniature valves 12AT7, 12AU7, 12AX7 may also be of value, but so far no tests have been published and as always with miniature valves oxidation of the valve pins may be a serious draw-back.

Yours faithfully,

T. V. Vernon,
Farnborough, Hants.

1. *Vacuum Tube Amplifiers, Radiation Laboratory Series*, Vol. 18, pp. 402, 445.
2. *Electronic Instruments, Radiation Laboratory Series*, Vol 21, p. 513, Section 16.6.
3. *Components Handbook, Radiation Laboratory Series*, Vol. 17, Section 14.3, pp 568-9

The Authors reply:

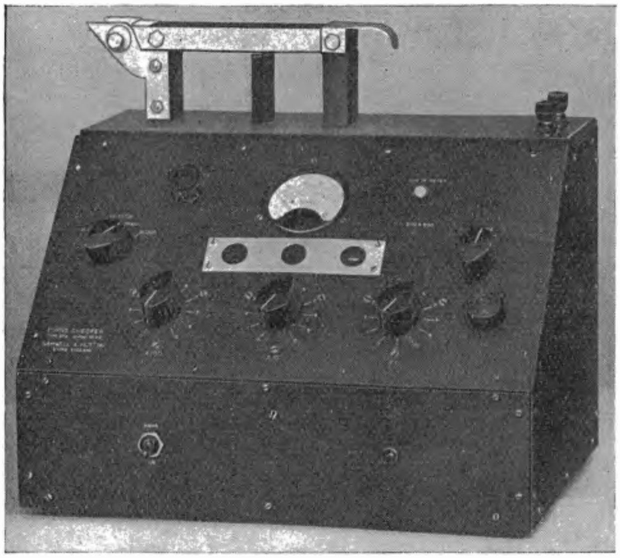
We think your correspondent makes rather sweeping statements: are there any figures to substantiate the relative performances of the various valves as a function of unbalance produced by a given change in heater current? At present the complete set of the McGraw Hill books is still not available here, and at the time our article was written none was available, so it is not surprising that we did not quote them.

Both the 6 (or 12) SL7, and the 6J6 have rather high grid currents, at least in some specimens. Careful selection of whatever type of valve is chosen is essential. It may be worth remarking that we have used 1634's with satisfactory results, the heater current of these is only 0.15 amp., and for that reason they are more convenient than 6J6's.

Variable Frequency R.C. Oscillators

It is regretted that there were two omissions from the formulæ for f and β printed in the letter from Messrs. Bacon and Clark in the October issue. The corrected formulæ read:

$f = (\tan \pi/n \sin \pi/n)/\pi CR$, and
$\beta = (\tan \pi/n \sin \pi/n)/\pi$.



Electronic

A monthly record of British elec-
accessories, compiled from information

Type 37A Turns Checker
(Illustrated above)

THIS instrument has been designed to provide an accurate means of checking the turns on field and armature windings of electric motors.

The coil to be tested is placed on a closed magnetic cored jig. The number of turns on the coil are indicated on a two-range meter calibrated 0—1,000 and 0—250 turns. This provides a quick method of sorting coils of similar physical shape. The ranges give 20 and 5 turns per division respectively.

For more accurate measurement a turns decade is provided, and when used in conjunction with the special detector, the turns on a coil may be measured to 1 turn or 1 per cent, whichever is the larger.

When using the decade, balance is indicated by means of lights showing if the decade setting is higher or lower than the coil under test.

The instrument, including the jig, is rigidly constructed and finished wrinkle black. The panel is machine engraved.

Price : £70 net. Size of jig, 1½ in. by ¾ in.

Samwell & Hutton, Combine Works, 1, Goodmayes Road, Ilford, Essex.

The Fielden Proximity Meter

THE Fielden Proximity Meter is a general utility instrument suitable for application to many problems in industrial control and measurements. The instrument may be applied to any problem which can be resolved into a minute change in electrical capacitance relative to earth. This change may be produced either from a minute mechanical displacement or from a change in dielectric properties.

The approach of any substance, conductor, insulator, solid or liquid, will change the capacitance of the terminating electrode, and this change is recorded on the meter. The *Set Zero* control knob enables the effective electrode capacitance to be balanced to zero at any value, and the other control knob adjusts the sensitivity of the equipment over a wide range.

The instrument, which is a self-contained mains-driven unit, is housed in a light aluminium case conveniently arranged for bench use. The length of special R.F. cable which joins the test probe to the instrument is terminated in a length of 4B.A. screwed rod, which facilitates the fixing of a suitable electrode to suit the user's application.

The instrument has now conventional power pack and is powered through a suitable transformer from "raw" A.C.

Fielden (Electronics) Ltd. Manchester.

Induction Tracer

A VERSATILE and highly sensitive, portable instrument for the tracing of unknown paths of cables and pipes, the tracing of cable faults and breaks in pipe lines, identification of cables, and depth determinations, by the induction method.

In use, an alternating current is injected at one terminal of the cable or pipe line under test. This gives rise to an alternating magnetic field surrounding the conductor concentrically. If the induction trace is now placed into this field, E.M.F.'s will be induced in the special coils with which the instrument has been provided, and after suitable amplification these E.M.F's are made suitable in a pair of headphones. The magnitude of the E.M.F. falls off as the radial distance between the conductor and coils increases.

The instrument is a self-contained portable unit comprising a wooden carrying case, two special detector coils, a combined l.t. and h.t. battery, a pair of piezo-electric headphones, and a three-stage amplifier.

Specification.

Dimensions of case : 12 in. by 12 in. by 6 in. wide.

Weight (complete) : 11 lb.

Power consumption : 200 mA at 1.5 volts, 0.35 mA at 69 volts.

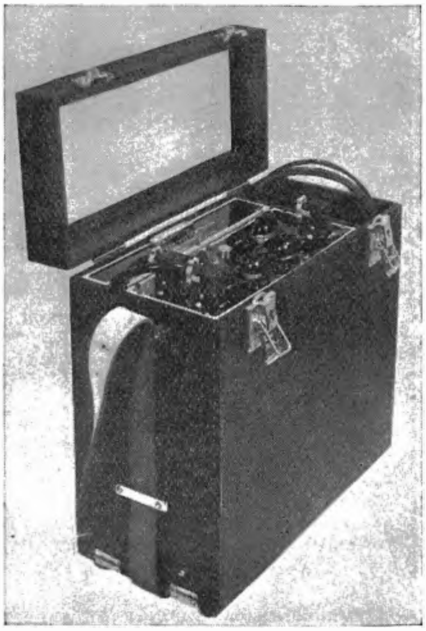
Valves : 3 Mullard type DAF 91.

Amplifier gain : 100 dB max. approx., ecxl. transformer.

Sensitivity : 1 mA at 1 Kc/s. at 50 feet approx.

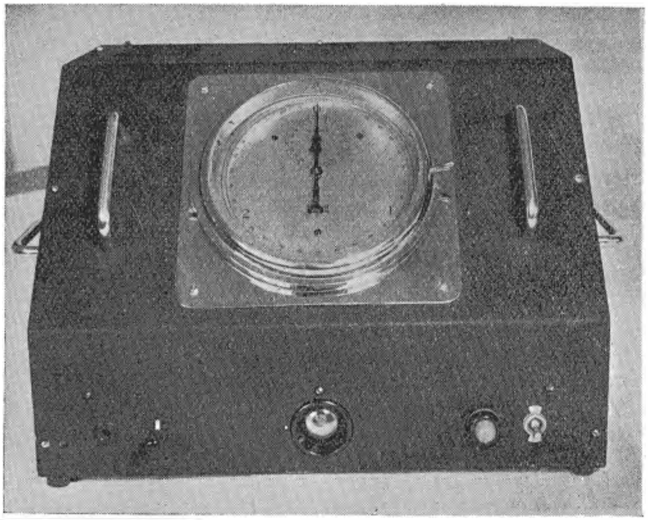
Selectivity : Linear, and tuned to 1 Kc/s. respectively.

Addison Electric Co., Ltd. 163, Holland Park Avenue, London, W.11.



Equipment

tronic apparatus, components and supplied by the manufacturers.



D.C. Motor Control Equipment

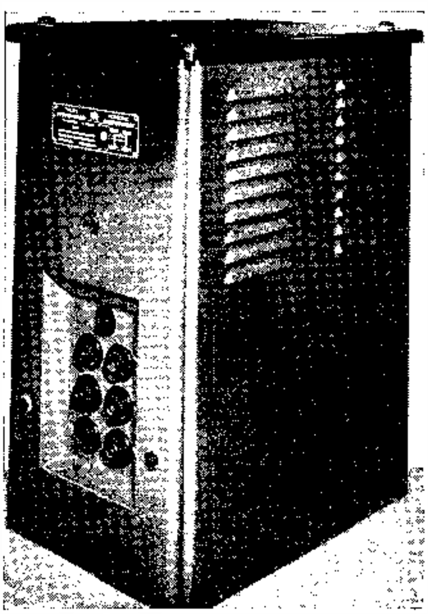
THYRATRON speed control equipment was shown at the Engineering and Marine Exhibition by both British Thomson-Houston and Philips Electrical Ltd.

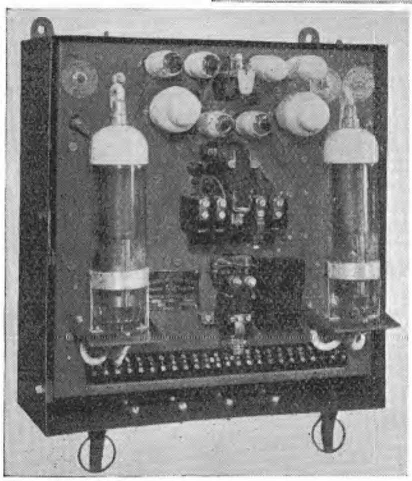
A general view of the B.T.H. "Emotrol" panel is shown on right. Panels are available from stock to give a speed range of 20 to 1 for 1, 3, 7½ and 15 h.p. motors, and can be supplied for motors up to 750 h.p. Normally speed regulation is kept within ± 2 per cent, but for special requirements this figure can be reduced to ±0.2 per cent operation from A.C. mains.

British Thomson-Houston Co. Ltd.
Rugby.

THE control unit of the Philips "Motronic" equipment is illustrated below. Other items, not shown, are a rectifier cubicle to supply the necessary power to the armature and field of the motor, and a push-button station which may be remotely situated. Typical applications are for motors used in wire and thread drawing plant, lathes (practically dispensing with gearing) and wind-up drives for film, cellophane, etc., where tension compensation is required.

Philips Electrical Ltd.
Century House, Shaftesbury Avenue,
London, W.C.2.



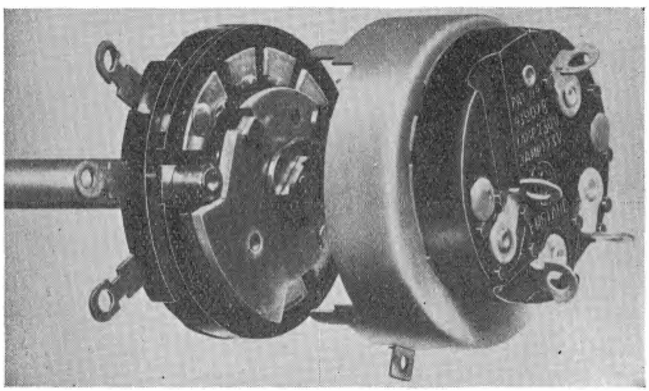


New Stud Potentiometer

(Illustrated on right)

INTRODUCED to meet the need for a neat, totally enclosed, improved substitute for the wafer switch and its externally connected resistance network, the Erie Stud Potentiometer has greater life and low contact resistance—features that also enable it to be produced rapidly at very low cost. The resistor elements can be supplied in the standard range from 10 ohms to 10 megohms ± 20 per cent. Types available are non-switch with nine steps and DPST switch with seven steps. Diameter 1$\frac{3}{16}$ in. (excluding tags). Bush sizes, 0.375 in. (32 T.P.I.) and 0.263 in. (32 T.P.I.).

Erie Resistor Ltd.
Carlisle Road,
London, N.W.9.



The Evans Quartz Crystal Clock

(Illustrated above)

THE Evans quartz crystal clock has been tested by the National Physical Laboratory as possessing a frequency instability from all causes of ten parts in a million. Thus, in timing events of one minute's duration, the instrument is accurate to one-twelfth of a millionth of a second.

Comprising a quartz crystal of low temperature coefficient (the frequency of which is reduced to 50 c/s. by a chain of electronic frequency dividers) and 1/100 second synchronous electric stop clock, the device is contained in a sealed, temperature-controlled cabinet of approximately the same size as a portable typewriter and is as easy to carry.

Plugged into normal A.C. main supply (200-230 volts), it is started and stopped by a key jack operated by any electrical device giving a simple "make" contact. The clock can also be started, stopped, or reset by hand. The instruments which are laboratory built, are not being sold but placed out on a rental basis. A full replacement and repair service will be maintained, users in the London area being given a three hour's replacement service.

G. R. Evans,
30, Mansfield Road,
Ilford, Essex.

BOOK

The Electronic Musical Instrument Manual

By Alan Douglas, VII. 143 pp. 106 Figs. Sir Isaac Pitman & Sons, Ltd. 1st. Edition, 1949. Price 18s.

THIS is a disappointing book. The first impression is admittedly a good one, created largely by the liberal use of illustrations and by the clean printing on good quality paper, but this impression soon fades. For the rather high price of 18s., the purchaser will expect a rather high standard of completeness and accuracy, but unfortunately there are far too many obscurities and ambiguities, peculiar phrasings and outright errors. These blemishes will confuse the novice and irritate the expert.

Although the author does not actually say so, he is really concerned only with electronic organs. This is probably the reason why there is no mention of such well-known instruments as the Theremin and the electric guitar.

Many of the diagrams are incorrect. Fig. 1 shows a sine wave in which the amplitude is indicated as being *twice* the maximum displacement: the frequency is carelessly shown as corresponding to $1\frac{1}{2}$ wavelengths. Fig. 51(B) is supposed to show a phase-splitter but something has obviously gone wrong in the draughting. Fig. 53 shows a push-pull amplifier without any connexion to the output cathodes. Fig. 23(B), an electron-coupled oscillator circuit, shows no negative H.T. terminal, a serious omission in this type of circuit.

Frequently there is lack of agreement between the drawings and the explanatory text. Fig. 15 shows a complete sine wave, but the text describes it as "one half cycle of the complete wave." The text also refers to "vertical lines" but they do not appear in the diagram. Fig. 23(A) shows a simple valve oscillator with battery bias, but the explanation of its mode of operation is incorrect; presumably the author meant to show a leaky-grid type of oscillator. The same passage refers to *R* and *K*, but these are not indicated in the diagram. In the same way, the reader will fail to find either the terminating resistance *Ro* in Fig. 35, or the transformer T^1 in Fig. 39, or the valve V^1 in Fig. 60(C), or the busbars *A* and *C* in Fig. 66.

On p. 50, it is said that "Fig. 37 shows two playing keys." The caption to this illustration, however, is "Valve Mixing Circuit," while the drawing itself shows neither keys nor valves.

Fig. 25 shows a simple neon-tube relaxation oscillator—a type familiar enough in the art of electronic music—but the author states that "The resistance must ensure a constant charging current, and a pentode valve is very suitable for this purpose." Clearly, he has confused this with the linear time-base in a cathode-ray oscillograph: a constant charging current is quite unnecessary in a musical oscillator, and it is a relief to find that the author has not enlarged upon this remarkable statement.

A very obscure reasoning appears on p. 42 in the description of the electrostatic type of generator (Fig. 30). Apparently the variable capacitance must not have any current flowing through it and yet it is relied upon to generate the tone voltage.

In Figs. 67 and 68 some rather unusual and unaccountable capacitor values are shown, e.g., 0.0234, 0.255 and 0.0937 (presumably μF), and in Fig. 92 the grid of the output amplifier valve is shown shunted to earth by a capacitor marked "50." By implication, this would have to be 50μF—an error with discouraging consequences.

On p. 64 there is a detailed description of Amplifiers Nos. 1 and 2, but there are no diagrams with these titles to be found anywhere. The reader must deduce for himself that the relevant circuits are those given several pages further on in Fig. 52 and 53.

Several equations are introduced into the text but the units are not always stated. For instance, what is the point of stating (as on p. 132) that the length of a circular (sic) steel bar to resonate at a frequency f is given as approximately $1075/\sqrt{f}$ without also stating the units?

On p. 18 the frequency ratio corresponding to a semitone is said to be $1:\sqrt[1]{2}$. This should of course be $1:\sqrt[12]{2}$. The velocity of sound in air is given as 1130 ft./sec. on p. 3 and 1056 ft./sec. on p. 79.

Innumerable little peculiarities in the text will annoy the careful reader. What, for instance, is "alternately-rectified A.C." (p. 71)? What is a "condenser amplifier" (p. 92)? The treatment of photoelectric cells (p. 44), the loading of an oscillator (p. 49), and impedance matching (p. 53) is almost completely confused. In describing the beat-frequency oscillator, the author states (p. 35) that "The increased sensitivity of this type of oscillator enables a somewhat wider frequency range to be covered." In describing the electrostatic string type of generator, he says (p. 92) "The pickups are of such an area that in every case this is a smaller than the

REVIEWS

wavelength of the required harmonic." On p. 70 he says that "high-gain amplifiers cannot be successfully operated from a D.C. source of 200/250 volts." Surely he means "high-power amplifiers."

The list of references is spoiled by the sparseness of its details, and it is a pity that no mention has been made of such important papers as the one by Winch and Midgley (J.I.E.E., June 1940). With a single exception, all the papers referred to are more than 10 years old.

The index is inadequate and ill-balanced.

A book with as many faults as this one has cannot be recommended. Especially in the field of electronic music where non-technical musical readers may be trying to absorb the details of circuit design, accuracy and clarity of expression are vital, and this is where the book leaves so much to be desired. If the publishers can be persuaded to issue a second edition, the author should take the opportunity to make a thorough revision: it is badly needed.

S. K. LEWER.

Technical Dictionary

By Hans Thali, Volume II, German-English-French. 311 pp., 1948. (H. Thali & Co., Hitzkirch, Switzerland). Price 35s.

IN the Report on the Scientific Information Conference of the Royal Society 1948 it was stated that "there is a great need for bilingual glossaries of particular subjects (e.g., German-English Glossary of Electronics)." Although the book under review is a dictionary and not a glossary, i.e., it does not give an explanation of the technical terms, it will serve the purpose of a glossary to some extent or, at least, can do that if used together with a modern monoglot glossary of electronics. e.g., that of Cooke and Markus. This is due to the fact that of the total of 24,000 entries 1,800 are specialised expressions adopted by the International Electrical Commission and the International Committee on Illumination respectively, and a further 2,000 entries are those used in the "Vocabulaire téléphonique international." These entries are marked with special symbols.

The first volume containing the English-French-German version appeared first in 1946 and in a second edition in 1947, and was at that time recommended as "a useful addition to the radio engineer's library" (*Electronic Engineering*, 1947). Compared with this the number of entries has been extended from 13,500 to 24,000 word places while the size of the book was increased from 277 to 311 pages only. This was made possible by using smaller but still very clear type so that the items per page could be increased from an average of 60 to about 80. The table of chemical elements, and the conversion tables contained in the first volume are not repeated in the second.

The dictionary, although mainly concerned with electrical engineering, radio, television and telecommunication, includes also the most important terms of acoustics, illumination, mathematics, materials, optics, heating, etc.

A few small points may be mentioned in which the English or German expressions are not those most frequently used. "Zählen" might be translated better by "count" than by "number." "Nachbarortsverkeher" is usually expressed here by "toll traffic," although "junction traffic" is apparently used in the international telephonic vocabulary. The word "Walzlager" appears to be of Swiss usuage, while in the Reich "Walzenlager" is used more commonly for "roller bearing" and "Wälzlager" comprises both ball and roller bearings. It may be doubted whether "mehrstellig" is adequately rendered by "multiple."

But these are minor blemishes which may well be corrected in a second edition and which in no way impair the great value of this very useful and thorough piece of work. The book is well produced and the author-publisher may be thanked for, and congratulated upon this welcome addition to the electronic engineer's tools.

R. NEUMANN.

Introductory Radio—Theory and Servicing

By H. J. Hicks. VIII, 393 pp. with a Teacher's Manual of 42 pp., 259-48 illustrations. 1949. McGraw-Hill Publishing Co. Ltd. Price 34s.

THIS book is principally written to serve as a guide for teachers in courses dealing with the servicing of radio and television receiving sets. But it may also be used as a first introduction to radio theory for home study, and only a very slight amount of mathematical knowledge is required for its understanding. Throughout, the principal stress is laid on practical aspects.

A brief introductory chapter deals with the elements of magnetism and electricity, and a number of problems are given for computation. No problems are given for the other chapters, but in the teacher's manual some

BOOK REVIEWS *(continued)*

"quizzes" will be found suitable for reviewing the material contained in the respective chapters.

In the second chapter useful practical hints are given for the soldering of connexions, and then the construction of simple receivers is described in detail. So the student is led to do practical work from the start. It will be noticed that frequently expressions are used in the text which are explained only in a later part of the book. But as the index is carefully written the reader will have no great difficulty in finding out what is meant.

The third chapter gives a clear account of vacuum tubes, with their characteristics and the methods for obtaining them. The purpose of screen grid and suppressor grid, and the influence of the spacing of the turns of the control grid on the cut-off and the amplification factor, are explained.

The next two chapters deal with audio amplifiers and power supplies. Comparative diagrams are given of the different kinds of amplifier couplings, and a clear graph shows the operational conditions for the various amplifier classes. Full- and half-wave rectification and the principles of filter circuits are explained. Special sections deal with trouble hunting and the elimination of hum due to faults in the power supply.

The next two chapters describe and illustrate the straightforward and the superhet A.M. receivers and the F.M. receivers with their accessories. It is quite characteristic for the way in which A.C. theory is interspersed in the various chapters of the book that expressions like reactance, impedance, lag and lead are explained not before they are required in dealing with FM receivers.

The 8th chapter is the longest and probably the most useful for the servicing of receiving apparatus. It deals with the test equipment and the general methods used for trouble hunting. Among other equipment the C.R.O. and the tube voltmeter are explained.

Special chapters are devoted to public address systems, aerials and television, and in the last chapter some additional information is given on phototube circuits, the design of radio transformers and of demonstration boards, which are not only useful for demonstration purposes but also as objects for practical class-work of the pupils.

A large number of appendices gives further useful information. In the table of formulæ on page 332 that for calculating the resistance of a given length, cross-section and material as well as a table of specific resistances is missing although these may be found, of course, in every electrical pocket book. This also applies to some of the other tables given in the appendix.

The author being an American, the apparatus described and the valve types are those of American manufacturers. But this should not lead to difficulties as a valve manual or equivalent table may be used, and every dealer of radio equipment will be able to propose suitable British valves if the characteristics of the respective U.S.A. type are given to him. The "commercial frequencies" given on page 28 are those used in the U.S.A.

Some minor points may be mentioned which might be revised in a second edition. The brief paragraph on push-pull amplifiers gives some statements which might well be explained in some greater detail. The terminals in Figs. 35 and 36a are not designated in the same manner and the explanation of Fig. 42 (c) is not very clear. No explanations are given in the text referring to Figs. 112 and 133.

The book is well produced and can be recommended to teachers, students and practical servicing technicians.

R. NEUMANN.

Wireless World Diary, 1950

Wireless World Diary, 1950. Published on October 12th, 1949, at 3s 4½d. (including Purchase Tax) by Iliffe & Sons Ltd. Size 4¼ in. by 3¼ in. wide. 80 pages of reference material—plus the usual Diary pages of a week to an opening.

THE reference pages of this diary, now in its 32nd year of publication, contain information, mostly technical, of the kind that every wireless man needs, but can seldom memorise. The data is that most widely useful in the design and maintenance of radio equipment. In addition there are general reference pages giving a summary of existing regulations affecting the wireless user (including a page on the new Wireless Telegraphy Act) addresses of radio organisations, etc.

Compiled by the technical staff of *Wireless World*, the section includes a large selection of useful formulæ, abacs for easy graphical estimation of such things as coil windings and circuit constants, lists of unit abbreviations, definitions and classifications, with a number of miscellaneous circuit diagrams. In addition to general revision of the reference pages, the valve base tables have been entirely re-organised, and connexions for over 500 valves are now given in more convenient form.

Data for television and extra-short-wave aerials has been revised to meet the projected new B.B.C. services.

NOTES FROM THE INDUSTRY

Appointment of Chief Scientist to the Ministry of Supply

The Minister of Supply has appointed Mr. H. M. Garner, C.B., to be Chief Scientist of the Department, in succession to Sir Ben Lockspeiser.

For the last three years Mr. Garner has been Principal Director of Scientific Research (Air) in the Ministry of Supply.

Constitutional Changes at the University of Bristol

From the beginning of September, the Society of Merchant Venturers were no longer responsible for the administration of the Engineering Faculty and the College, and the title ceased to exist. The administration of the Faculty is now carried on as for the rest of the University, and is entirely separate from that of the College.

The College is now known as the College of Technology, and owned by the Bristol Corporation; while part of it, which is leased to the University, is known as the University Engineering Laboratories.

At the same time as these changes took place, the existing Department of Commerce of the Merchant Venturers Technical College became an independent college, also under the control of the Corporation of Bristol, known as the College of Commerce, Bristol.

Amateur Radio Exhibition

The Third Annual Amateur Radio Exhibition organised by the Inc. Radio Society of Great Britain, will be opened at the Royal Hotel, Woburn Place, London, W.C.1, at 2.30 p.m. on Wednesday, November 23rd, 1949, by Lord Sandhurst, O.B.E.

Included in the representative gathering are the following concerns: Standard Telephones & Cables, Ltd.; G.P.O. Engineering Dept.; Webb's Radio; Quartz Crystal Co.; Radiocraft, Ltd.; Oliver Pell Control, Ltd.; Telegraph Condenser Co., Ltd.; E. J. Philpott's Metalworks, Ltd.; Salford Electrical Instruments, Ltd., Iliffe & Sons, Ltd.; Denco (Clacton), Ltd.; Taylor Electrical Instruments, Ltd.; Cyril French, Ltd.; Alfred Imhof, Ltd.; Automatic Coil Winder & Electrical Equipment Co., Ltd.; Air Ministry; Southern Radio & Electrical Supplies; Sangamo Weston, Ltd.; *Electronic Engineering*; New Era Publishing Co., Ltd.; General Electric Co., Ltd.; Woden Transformer Co., Ltd.; E.M.I. Sales & Service, Ltd., and Short Wave Magazine, Ltd.

Admission will be by catalogue issued free to members. Non members may purchase a catalogue at the door (price 1s.), or obtain a copy in advance from the Radio Society of Great Britain (price 1s. 3d. post free).

India

The United Kingdom Trade Commissioner in Madras reports that a Madras firm, Messrs. Radio & Electricals, Ltd., of 1/29B Mount Road, Madras, is seeking agencies on behalf of United Kingdom firms. Messrs. Radio Electricals, Ltd., are particularly interested in (a) Radio receivers; Transmitters; (b) Domestic Electrical Wiring and Lighting Accessories; (c) Power Transformers, H.T. Switchgear and Insulators. They are interested in low price rather than luxury lines.

The firm would propose to act on a commission basis and would cover the whole of Southern India, including the States of Mysore, Hyderabad, Travancore and Cochin; also the adjoining provinces of Orissa and Central Provinces.

The firm is considered to be of good commercial standing and a reliable contact for United Kingdom firms.

Firms interested are requested to contact Messrs. Radio & Electrical, Ltd., direct, and advise the Board of Trade of any action taken in the matter, quoting reference number CRE(IB)-24444/49.

The Osram Valve and Electronics Department

The General Electric Co., Ltd. announce that the department previously known as the Osram valve department will in future be known as the Osram valve and electronics department.

The reason for the change is that the department has widened its scope to deal with the rapidly expanding world of electronics. It will now handle the sales and technical inquiries in connection with transmitting and receiving valves, electrometer valves, magnetrons, television and industrial cathode-ray tubes, photocells and auxiliary apparatus, voltage stabilisers, current stabilisers (barretters), visual tuning indicators, neon indicators, thyratrons, ionisation gauges, Geiger-Muller tubes and lighting arrester vacuum tubes.

New Depot for Aerialite, Ltd.

Messrs. Aerialite, Ltd., of Castle Works, Stalybridge, Cheshire, have opened a new depot at 44-45 Suffolk Street, Birmingham, to serve the Midlands. In the new depot it was proposed to stock a large range of their products, including Ashton cables and flexibles, Aerialite automobile cables, and radio and television aerials.

Change of Address

The Mica Directorate moved recently from Horseferry House, Thorney Street, London, S.W.1, to Empire House, St. Martins le Grand, London, E.C.1. (Telephone: CLErkenwell 7931).

Publications Received

Radio for Merchant Ships

Performance specifications for compulsorily and voluntarily fitted radio telephone equipments. *H.M. Stationery Office, price 6d.*

The Electron Microscope

This is a brochure issued by the Plessey Co., simply describing Electron Microscope techniques and containing a full specification of their own instrument. From *The Plessey Co., Ltd., Ilford, Essex.*

Leak "Point One" Amplifiers

A booklet containing descriptions of high performance amplifiers manufactured by *H. J. Leak and Co., Ltd., Brunel Road, Westway Factory Estate, London, W.3.*

Preliminary Data of Wearite Magnetic Recorder "Tape Deck"

A leaflet issued by *Wright and Weaire, Ltd., 138 Sloane Street, London, S.W.1.*

Electrical, Radio and Television Components

A 19 page catalogue containing particulars of new radio and electrical components produced by *Mullard Electronic Products, Ltd., Century House, Shaftesbury Avenue, W.C.2.*

The Aluminium Courier (Electrical Issue)

This issue of the quarterly publication is devoted to activities in the electrical trades. The Aluminium Courier is mainly addressed to users and prospective users of aluminium and its alloys.

The Aluminium Development Association, 33 Grosvenor Street, W.1.

The Somerford Range of Transformers and Chokes

An easy-reference catalogue of their products, post free from *Gardners Radio, Ltd., Somerford, Christchurch, Hants.*

Electric Wiring Systems

This British Standard Code of Practice publication (No. CP 321.101) makes recommendations for safe and efficient installations of power, lighting and heating circuits in buildings. Price 4s., post free, from *British Standards Institution, 24/28 Victoria Street, S.W.1.*

Electrolytic Capacitors

A description of all radio and industrial capacitors manufactured by *British Electrolytic Condenser Co., Ltd.*, a subsidiary of *The Plessey Co., Ltd., Ilford, Essex.*

NOVEMBER MEETINGS

The Institution of Electrical Engineers

Unless otherwise stated, all meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Radio Section

Date: November 16. Time: 5.30 p.m.
Lecture: "Some Considerations in the Design of Negative Feedback-Amplifiers."
By: W. T. Duerdoth, B.Sc.(Eng.).
Date: November 28. Time: 5.30 p.m.
Discussion: "Achievement of Reliability in Radio Equipment."
Opened by: G. W. Sutton, Ph.D., B.Sc., and F. E. McGinnety, M.Sc.

The Secretary, Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Cambridge Radio Group

Date: November 1. Time. 8.15 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Lecture "Some Recent Advances in the Design of High-Energy Electron Accelerators."
By: D. W. Fry, M.Sc.

Secretary: G. E. Middleton, M.A., University Engineering Laboratory, Cambridge.

Mersey and North Wales Centre

Date: November 7. Time: 6.30 p.m.
Held at: Liverpool Royal Institution, Colquitt Street, Liverpool.
Lecture: "The Motor Uniselector and the Technique of its Application in Telecommunications."
By: W. H. Grinstead, M.B.E.

Secretary: A. V. Milton, 12 Bevington Hill, Liverpool 3.

North Eastern Radio and Measurements Group

Date: November 7. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: "Some Considerations in the Design of Negative Feedback-Amplifiers."
By: W. T. Duerdoth, B.Sc.(Eng.).

Secretary: G. A. Kysh, Cariol House, Newcastle-on-Tyne 1.

North-Western Radio Group

Date: November 16. Time: 6.30 p.m.
Held at: The Engineers Club, Albert Square, Manchester.
Lecture: "Hot-Cathode Thyratrons: Practical Studies of Characteristics."
By: H. de B. Knight, M.Sc.

Secretary: A. L. Green, 244 Brantingham Road, Chorlton-cum-Hardy, Manchester 21.

Rugby Sub-Centre

Date: November 29. Time: 6.30 p.m.
Held at: The Electricity Showrooms, High Street, Rugby.
Lecture: "Magnetic Amplifiers."
By: A. G. Milnes, M.Sc.(Eng.).
Lecture: "The Theory and Design of Magnetic Amplifiers."
By: H. M. Gale, B.Sc.(Eng.), and P. D. Atkinson, M.A.

Secretary: J. H. Walker, M.Sc., Ph.D., A.C. Engineers Dept., The B.T.H. Co., Ltd., Rugby.

The Institution of Post Office Engineers

Date: November 15. Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.
Lecture: "Some Aspects of Telephone Engineering Practice in Germany."
By: N. V. Knight, B.Sc., A.M.I.E.E.
Date: November 23. Time: 5 p.m.
Held at: Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1.
Lecture: "The Engineer as an Administrator."
By: C. J. Gill, A.M.I.E.E.

Local Secretary: W. H. Fox, A.M.I.E.E., Engineer-in-Chief Office, (T.P. Branch), Alder House, London, E.C.1.

British Institution of Radio Engineers

London Section

Date: November 17. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Gower Street, London, W.C.1.
Lecture: "Measurement of F.M. Transmitter Performance."
By: D. R. Willis.

Merseyside Section

Date: November 2. Time: 7 p.m.
Held at: Accountants' Hall, Derby Square, Liverpool.
Lecture: "Electronics in Aircraft Design."
By: A. L. Whitwell.

Scottish Section

Date: November 3. Time: 6.45 p.m.
Held at: The Heriot Watt College, Edinburgh.
Lecture: "The Performance and Stability of Permanent Magnets."
By: A. J. Tyrrell.

North-Eastern Section

Date: November 16. Time: 6 p.m.
Held at: Neville Hall, Newcastle-on-Tyne.
Lecture: "Dielectrics."
By: Mrs. E. Laverick.

The General Secretary, British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1.

Radar Association

Date: November 1. Time: 7 p.m.
Held at: Albert Tavern, Victoria Street, London, S.W.1.
Monthly Meeting.

Hon. Secretary, Technical Committee: J. C. Warren, 57 Gallows Hill, Kings Langley, Herts.

The Television Society

All meetings, unless otherwise stated, will be held at the Cinema Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.

Programme Group

Date: November 3. Time: 7 p.m.
Lecture: "Television of the Future."
By: Maurice Gorham.

Constructors' Group

Date: November 16. Time: 7 p.m.
Lecture: "The View Master—a new receiver for the Home Constructor."
By: W. I. Flack (Fellow) (T.C.C., Ltd.)

Main Society

Date: November 25. Time: 7 p.m.
Lecture: "Modern Developments in Television."
By: Dr. Leonard Levy.

Lecture Secretary: T. M. C. Lance, 35 Albemarle Road, Beckenham, Kent.

Midlands Centre

Date: November 7. Time: 7 p.m.
Held at: Lecture Hall (1st Floor), The Crown Restaurant, Corporation Street, Birmingham.
Lecture: "The Relaying of Broadcasting and Television."
By: L. E. C. Hughes, Ph.D., A.M.I.E.E.
(Joint meeting with the Institution of Electronics)

Hon. Lecture Secretary: W. Summer, A.Inst.P., F.T.S., F.Inst.E., 31 Beech Road, Bournville, Birmingham 30.

Inc. Radio Society of Great Britain

Date: November 18. Time: 6.30 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.
Lecture: "The Radio Control of Models." (Demonstration).
By: Lt. G. C. Chapman, B.A., R.N., and Peter Cummins, A.M.I.E.E.

Hon. Secretary: James W. Mathews, New Ruskin House, Little Russell Street, London, W.C.1.

British Sound Recording Association

London Meeting

Date: November 25. Time: 7 p.m.
Held at: Royal Society of Arts, London.
Lecture: Loudspeakers.
By: G. P. Briggs.

Birmingham Meeting

Date: November 26.
Time: 3 p.m. and 7 p.m.
Held at: Imperial Hotel, Temple Street, Birmingham.
Lecture and Demonstration: Sound Recording and Reproducing Equipment.
By: L. E. C. Hughes, Ph.D. A.M.I.E.E.