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Books

THE illusion that publishers do not read MSS, and are not interested in the work of beginners, persists in the most extraordinary way, but it is an illusion none the less.

This was one of the points made by MR. STANLEY UNWIN in a recent Discourse at the Royal Institution, which has been recently published in booklet form*. It should be read by those authors and would-be authors (their number is fortunately decreasing year by year) who think that all publishers are leagued against them to wax fat at their expense and give them the minimum return for all their efforts.

Mr. Unwin quotes a case of a Professor of Philosophy, the sales of whose masterpiece had taken thirty years to cover the printing bill! The day that he received a cheque in respect of profits he retired from the Professorship that the writing of the book had secured for him—but the publisher had been out of pocket for 30 years.

A curious fancy, that it is hoped will not recur after the war, is that the value of a book is measured by its bulk. As Mr. Unwin says "The identical book which was 'poor value' when it bulked ½ in. was 'good value' when it was printed on fluffy paper which bulked 1 in., and the sad or amusing thing about it—take your choice which—is the chief difference between these two books is the amount of air left in the fluffy paper. It is rather like saying that the white of an egg is better value when beaten up . . . ."

How the unfortunate publisher has suffered during war-time in comparison with some industries is exemplified by the figures of the amount of paper allowed for the *whole* of the book publishing industry. As against 250,000 tons for newspapers, 100,000 tons for the Stationery Office (some of which is used in publishing books in direct competition with the book publishers), 50,000 tons for periodicals, the total amount on books is only 22,000 tons.

"And yet in the face of the above there are responsible officials who claim that books have been generously treated, because, forsooth, on a percentage basis the book publishers are favoured. What should we think of a Ministry of Food which boasted that on a percentage basis it had not reduced the diet of previously under-nourished people by quite as large a percentage as the over-fed?"

Books were among the first things to be made to suffer from the paper shortage, and restrictions were applied to the use of paper in books twelve months before they were made obligatory to other printed matter such as balance sheets and reports of Company meetings destined for the waste-paper basket.

In a letter to the *Daily Telegraph*,* MR. R. E. DANGERFIELD (Temple Press) puts forward a plea for the earliest relaxation of the restrictions on the trade and technical press, whose total paper consumption is less than 5,000 tons a year.

"In the U.S. the collective importance of the technical press has always been fully recognised both by the State and the industry. In Germany, too, before the war leading trade and technical journals were given every kind of official facility and encouragement, *because it was realised that this was the best means of drawing attention to the scientific and technical excellence of her products:* (The italics are ours).

Already the libraries on the continent will be thinking about replacing their lost and damaged stocks, to say nothing of our own depleted shelves. The early release of a small number of skilled men in the printing trades and a small quantity of the paper at present lavished on official forms would ensure that British technical books were among the first replacements to arrive.

* "Publishing in Peace and War," (G. Allen and Unwin) 6d.

* September 13th, 1944.

Since the above was set in type, the release of a small quantity of paper for books has been announced.

AN ELECTRONIC WATER-IN-PETROL DETECTOR

A new device which automatically prevents water being pumped from a petrol storage tank into the tank of an aeroplane or motor vehicle.

BASED on the fact that the electrical resistance of petrol differs from that of water the detector consists of an electronic valve circuit connected to a search probe in the storage tank. While the search probe is in contact only with petrol, the valve circuit holds closed a pair of switch contacts which control the power supply to the pump motor, thus permitting the petrol pump to work normally. As soon as the probe encounters water, however, a change in the valve circuit current causes the motor switch contacts to open, thus making it impossible for the pump to be operated.

The instrument automatically indicates the following conditions :—

Mains on—A blue pilot lamp.
Safe —A green pilot lamp showing that the pump is ready to operate.
Warning—A red lamp showing mains supply cut off from the pump.

Fig. 1. Exterior view of the control unit.

Fig. 2. The assembled tank probe unit together with component parts of the mounting plate and adjustable gland. This enables the probe to be simply adapted for varying depths of storage tank.

The main features of construction are :—

(*a*) A very robust flashtight case, with armour plate glass front, suitable for mounting near petrol pumps or in a hangar.

(*b*) Remote indicating unit for extension to control room or maintenance department, if needed.

(*c*) Very complete range of conveniently mounted spare valves and pilot lamps.

(*d*) Simple, compact chassis construction, readily removable as a complete unit for servicing.

A test switch operated by a push button, enables the working of the equipment (apart from the test probe in the tank) to be checked at any moment.

The equipment was designed and manufactured by Leland Instruments Ltd., 21 John St., London W.C.1, in collaboration with the Wayne Tank and Pump Co., Ltd., for incorporation in various aerodrome installations throughout Britain, and we are indebted to the Wayne Co. for permission to publish this note.

Fig. 4 (left). Indicator panel removed, to give access to valves. Spare valves and pilot lamps are carried on the chassis.

Fig. 3 (right). Armour plate glass cover removed, showing working fuses with spares in clips and indicator panel.

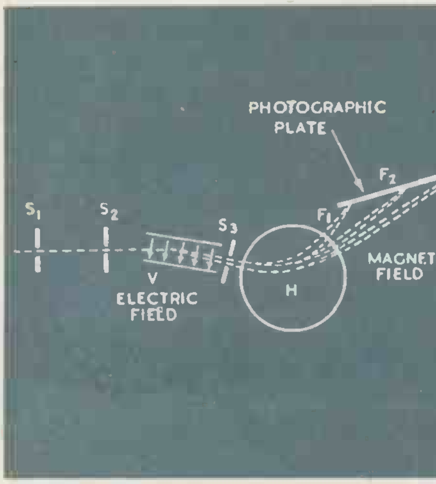

Fig. 1. Aston's first Mass Spectrograph.

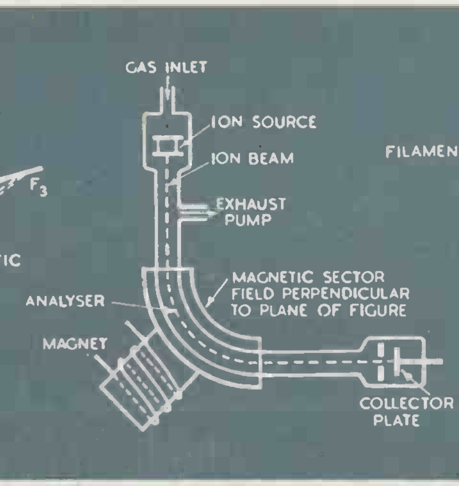

Fig. 2. Westinghouse Sector Field Mass Spectrometer.

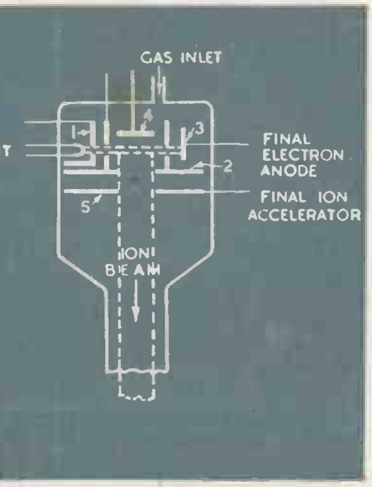

Fig. 3. Ion source, showing electron gun.

The Mass Spectrometer

A New Electronic Aid to Analysis

By E. D. HART, B.A.*

TO most engineers the words mass spectrometer have a distinctly academic ring. The association is immediately with complicated, cumbersome apparatus of glass and metal, useful only to the physicist in his laboratory. Yet such is the advance of modern electronics that the mass spectrometer is becoming a well known, if not a common instrument in some industrial fields, particularly in the United States.

With the mass spectrometer quick accurate checks on many laborious chemical analyses can be made, thus greatly speeding up routine day-to-day measurements. In some cases, however, the function performed by the mass spectrometer can hardly be done by any other means. At the present time, the instrument is finding its greatest industrial utility in the analysis of complex synthetic rubber compounds, such as the butadienes, in the analysis of the hydrocarbons used in the fuel oil and spirit industries and in the analysis of small amounts of gases in the presence of large quantities of another gas. All these are quite apart from its manifold theoretical and academic uses in pure research which do not concern us in this article. It is not proposed to cover the whole field of mass spectrometry, which would in any case, be impossible, but to describe briefly a modern industrial instrument and to point out its uses and future potentialities.

Historical Background

In order to appreciate the modern instrument a knowledge of the original instrument that was its forerunner is very desirable and a very much condensed description follows. Mass spectrometers and closely allied instruments have been known and used now for some twenty-five years. In 1919, F. W. Aston at Cambridge following upon work done by J. J. Thomson[1] and A. J. Dempster[2] on positive rays, constructed the first mass spectrograph (*-graph* because the instrument *records* on a photographic plate), and by its means confirmed the existence of an isotope† of neon.[3]

A diagrammatic view of the instrument is given in Fig. 1. A stream of positive ions under examination crosses the system from left to right. The parallel slits S_1 and S_2 reduce the ion stream to a very thin beam which enters an electric field E between the two plates following, which are slightly inclined to the beam. Within these plates the ion beam is spread out into an electric spectrum, the distribution along the spectrum not, as in a light spectrum depending upon frequency, but upon the mass of the different ions in the beam. Hence Aston's name "mass spectrograph." A portion of the divergent beam leaving the plates is selected by the diaphragm S_3 and passed through a field produced by a magnet which is represented by the circle in the sketch, the field being perpendicular to the paper. If the sense of this field is such as to deflect the beam in the opposite direction to that caused by the electric field between the two plates the beam will now converge and come to a focus, say, at F_1. Rays of ions of different masses will, however, be deflected through different angles and will focus at different points, say, at F_2, F_3. A photographic plate placed along F_1, F_2, F_3 will in this case receive three line images corresponding to the three different ions. We have then, found that there are three ions present in this particular example, and by measuring the distance of these lines from some fiducial point or by comparison with known lines, can find the relative masses of the three ions.

Many different and improved versions of this original instrument have been produced, and amongst the more modern ones may be quoted those of Bainbridge[4], Dempster[6], Bleakney[5], Nier[8, 9, 11, 13], Bleakney and Hipple[7] and Coggeshall and Jordan[14]. That of Nier may be exemplified as a modern type of instrument for physical and chemical research.

* Marconi Instruments, Ltd.

† *Isotopes*: elements having exactly the same chemical properties but different atomic weights.

An Up-to-Date Instrument

A recent edition of the instrument well suited to industrial and routine work instead of academic investigation has been developed by Dr. J. A. Hipple of the Westinghouse Research Laboratories, East Pittsburgh. This instrument, which has been already described in the American literature [12, 15, 16] will be treated here in some detail as being representative of modern practice.

This mass spectrometer (*-meter* since it *measures* the relative amounts of ions present, but does not record photographically) consists of a glass tube (Fig. 2) about a yard long bent through a right angle; this type of instrument is often called a $\pi/2$-radian instrument. Usually in mass spectrometers the tube is curved through 180° and they are thus called π-radian instruments. This, however, means either the use of a very large electro-magnet or a solenoid, of which both the prime cost and power consumption are high. By making use of a well-known principle that ions sent into a uniform magnetic field between V-shaped poles (a sector field) are subject to a focusing action provided the ion source, centre of curvature of the poles and ion collector lie in a straight line, it is possible to use a much smaller magnet whilst still obtaining good mass resolution. This is done in the Hipple sector field instrument.

At the top of the glass tube is the ion source. This consists of a fairly conventional type of electron gun assembly (electrodes 1, 2 and 3 in Fig. 3) arrayed at right angles to the main tube. The electron current is of the order of a few micro-amperes only and the accelerating voltage about 100. The gas to be analysed is admitted by a capillary leak above the gun and is ionised by impact in the electron stream, just below electrode 4. These ions are attracted through a long slit in electrode 2 by means of a small potential difference between 4 and 2, 2 being negative with respect to 4 as it is positive ions under examination. The ions are then further urged on and accelerated by another electrode 5 which is some 500-1,000 V. more negative than 2, and is usually earthed. Thus there are passing down the tube with some considerable velocity a sharply collimated beam of ions.

When the ions reach the curved part of the tube they enter the magnetic field which is perpendicular to the direction of the tube, and are deflected into curved paths. This deflection is exactly analogue to the deflection of electrons in an electromagnetically deflected cathode-ray oscillograph tube. It can be shown that the radius of curvature of the ion path is given by:—

$$r = \frac{c}{H}\sqrt{\frac{Vm}{150e}} \text{ cms.}\ddagger$$

where

H is the magnetic field in gauss.

V is the ion accelerating voltage.

m is the mass of the ion in grams.

e is the electronic charge (4.8×10^{10} esu).

and c is the velocity of EM waves (3×10^{10} cms. sec. $^{-1}$).

Thus for a given set of conditions of operation, *i.e.*, V and H fixed, the radius of curvature is given by:—

$$r = K.\sqrt{\frac{m}{e}} \text{ where } K \text{ is a constant}$$

since c is also constant. An ion can have more than one electronic charge on it giving values of m/e, $m/2e$, $m/3e$, etc., but if we assume singly charged ions to be the most plentiful and limit our consideration to those, we see that the radius of curvature depends only on the mass of the ion. By suitable arrangement of the curved part of the tube, it can be caused to act as a mass filter and pass only those ions of a particular mass.

This is achieved by making the length of the curved part great compared with its diameter and lining it with a conductor connected to the negative (earthy) side of the ion accelerating supply. Then for any one particular adjustment of V and H only one mass of ion will have exactly the same radius of curvature as the tube and will safely emerge from its lower end. Ions of less mass are deflected more, *i.e.*, have a smaller radius of curvature and go to earth on the upper side of the earthed shield in the tube. Ions of greater mass will have a greater radius of curvature and will be lost on the lower side of the earthed shield. In the instrument under description this earthed conductor is made of flexible Nichrome strips sprung into the tube and looking rather like flexible metallic gas tubing. Ions of one particular mass, then, will emerge from the bottom end of the earthed tube and after passing through a further diaphragm are caught in the collector in the far end of the tube. If a resistance is connected between this collector and earth the voltage developed across it is a measure of the ion current corresponding to a particular mass of ion and thus may be used as a quantitative estimate of the amount of ion present. This voltage may be applied to the input of an electrometer amplifier and a reading obtained on a galvanometer placed in the output circuit.

By calibrating the controls for V and H, or both, the instrument may be readily set up for any particular mass. The complete process of analysis is thus as follows. A suitable setting of V and H is fixed and the reading of the meter or other indicating device noted for ions of that particular mass. V and H are then adjusted for another mass and the second reading taken. This is repeated until all the ions known to be

‡ For derivation of this equation see mathematical appendix.

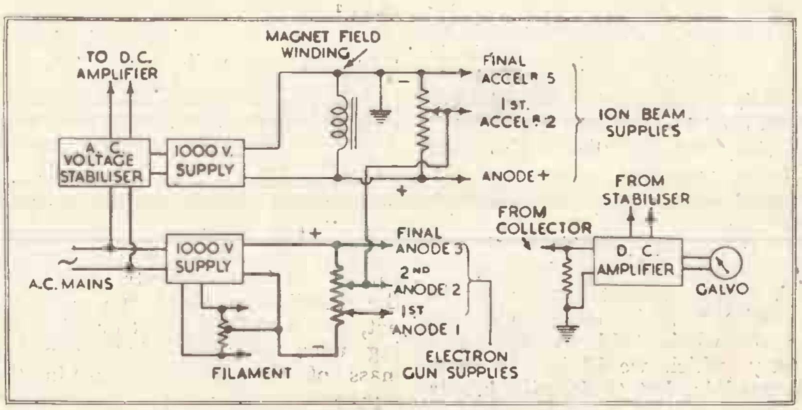

Fig. 4. Schematic circuit of power supplies.

present have been dealt with. The ion current of this mass spectrometer is of the order of $10^{-10}-10^{-15}$ ampere and the curvature of the ion path in the magnetic field has a radius of some 10–15 cms.* Since, as explained already, the selection of a particular mass of ion is done by adjustment of V and H, it follows that both of these supplies must be carefully stabilised and actually must be maintained constant to one or two parts in ten thousand.

In this typical instrument the magnet is wound for 100 Am at 1,000 V. supplied from an electronic regulator, and the ion accelerating voltage is tapped off a decade potentiometer in parallel with the magnet field supply (Fig. 4). This ensures that if the magnet current increases the accelerating voltage also increases and to some extent compensates for the increase. Other regulated power units supply the filament and HT voltage for the electron beam and the electrometer amplifier connected to the output collecting device. The gas pressure in the tube is very low, of the order of 10^{-4} mm. of mercury or lower and is maintained by continuous pumping. The gas under examination being admitted by the capillary leak is thus flowing continuously through the tube and we may assume that a constant number of ions is entering the magnetic analyser section. By integrating the readings of the electrometer over a period of time the amount of any particular ion per unit volume of gas can be determined.

In the Hipple instrument all the equipment: tube, magnet, several regulated power supplies, vacuum pumps and gas-handling apparatus are contained in a single cabinet mounted on wheels so that it may be readily shifted to the analysis site. All controls and meters are conveniently arranged on a horizontal panel, the gas-handling section being accessible through a trap door in the front.

A typical example of the output reading of a mass spectrometer is given in Fig. 5 which is the graph of ion current against ion mass for ordinary atmospheric nitrogen. Nitrogen as commonly found is a mixture of two isotopes having atomic weights of 14 and 15 (^{14}N and ^{15}N). When ionised by impact in the electron stream three or even more ions may be formed. Assuming only the three likely ones are formed they will be:—

* See mathematical appendix.

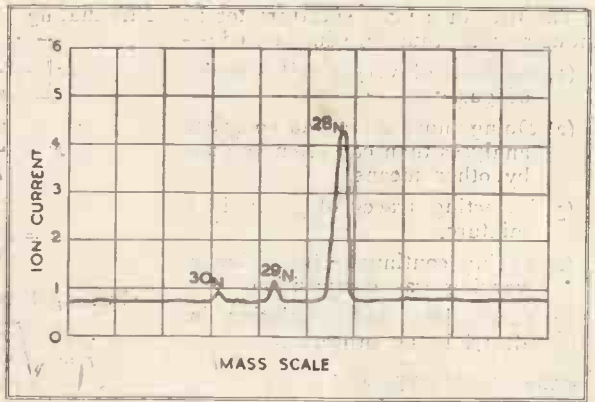

Fig. 5. Mass spectrum of Nitrogen.

$^{14}N^{14}N$ mass 28
$^{15}N^{15}N$ mass 30
$^{15}N^{14}N$ mass 29

Of these, mass 28 will be present in great abundance, mass 29 in considerably less and mass 30 to a very small extent indeed. Thus the three peaks of Fig. 5 are arrived at. Further peaks would be found at masses 14 and 15 if, for example, some of the gas were dissociated to the atomic state and not simply ionised.

Uses—Present and Future

It is clear from the foregoing description that the mass spectrometer finds a considerable use in the analysis of gases and gas mixtures. Although it can be used for the analysis of solids, the ion source has to be considerably more complicated and present applications are mainly confined to gases and vapours. Even with this restriction it has a wide field of use.

One of the best of its applications is in the analysis of very small samples of gas. The flow of gas through the instrument is very slow, only about 10^{-3} ml, measured at atmospheric pressure, per minute, so that the sample to be analysed need only be a fraction of a millilitre. The actual process of analysis, with a suitably calibrated spectrometer, is considerably quicker than any corresponding means of chemical analysis and a considerable saving of time can be secured in routine checks. The mass spectrometer, too, is not limited by a choice of reagents, in the constituents of the gas that can be detected as are chemical methods. Provided the mass of the ion is not such that it cannot be caused to traverse the curved analyser—and by adjustment of V and H a wide range of masses can be covered—its presence can be detected.

Another useful point is that a continuous record of the changing composition of the gas in, say, an annealing furnace, can be obtained and by suitable modification to the electrometer amplifier can be recorded. It is a short step from this to the automatic control of processes by means of the mass spectrometer. A portable instrument could be connected to measure continuously one particular constituent of the gas and the change of electrometer reading when the amount of this constituent alters used to initiate some regulating action to restore the original condition. The instrument may, in due course, become an important factor in automatic process control.

Because of the facility with which small traces of gases can be detected, the mass spectrometer is peculiarly well adapted to the study of outgassing and leakage rates of vacuum tubes, thermionic rectifiers, gas discharge lamps and similar devices. In all of these the gas pressure and composition determine how the device will operate and a rapid means of checking on the gas is a great aid.

In the United States at the present time, the instrument is used in the analysis of hydrocarbons, a difficult subject which has considerable bearing on the synthetic rubber, petroleum and general chemical industries. These applications are considerably more involved than the simple nitrogen analysis already described but the basic principle is the same, complicated by the fact that a large hydrocarbon molecule can give rise to many varied masses of ions. For a detailed study of this kind of application, attention is directed to the work done by Hoover and Washburn[10]. Further details will be found in a paper by Hipple, already quoted[11].

The uses of a mass spectrometer in industry may thus be summarised :—

(1) Analysis of very small samples of gas.

(2) Doing more rapid and complete analyses than can often be done by other means.

(3) Detecting traces of gases in a mixture.

(4) Giving continuous indication of varying gas composition.

(5) Controlling and regulating industrial gas processes.

Mathematical Appendix

The equation for the radius of curvature of the particle in the analyser may be derived thus :—

If a particle of mass m (grams) and charge e (e.s.u.) is accelerated by a potential difference V (e.s.u.) it acquires a velocity (cms.sec^{-1}) given by

$$\tfrac{1}{2}\, mv^2 = Ve \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

and if it now enters a magnetic field H (e.s.u.) perpendicular to its line of motion and moves in an arc of radius r (cms); by equating centrifugal force to the magnetic force

$$\frac{mv^2}{r} = Hev \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

Eliminating v from (1) and (2)

$$\tfrac{1}{2}m\left[\frac{Her}{m}\right]^2 = Ve$$

$$r^2 = \frac{2Vem}{H^2e^2}$$

$$a = \sqrt{\frac{2Vm}{H^2e}}$$

Putting V in volts and H in gauss :

$$r = \sqrt{\frac{2V}{300}\cdot\frac{c^2}{H^2}\cdot\frac{m}{e}}$$

where c is velocity of EM waves in cms.sec^{-1}

or
$$r = \frac{c}{H}\sqrt{\frac{Vm}{150e}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (3)$$

As an example, take a typical case, say of nitrogen ^{14}N.

$c = 3\times10^{10}$ cms.sec^{-1}

$H = 2{,}000$ gauss

$V = 1{,}000$ V.

$m = 28\times1.659\times10^{-24}$ gms (mol. wt. = 28).

$e = 4.8\times10^{-10}$ e.s.u.

then

$$r = \frac{3\times10^{10}}{2{,}000}\sqrt{\frac{1{,}000\times28\times1.659\times10^{-24}}{150\times4.8\times10^{-10}}}$$

= 12 cms. approx.

It can be seen that by varying H an inverse linear variation of r can be effected; thus the instrument can be calibrated in terms of r, *i.e.*, of m/e, and once calibrated can be set up for any value of m/e within its range.

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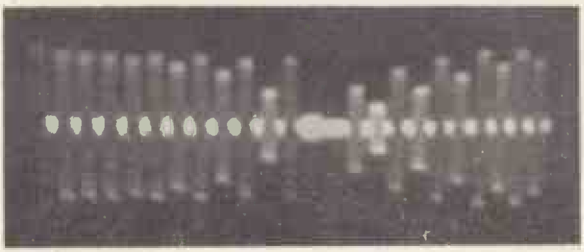
Cathode-Ray Armature Fault Finding Apparatus

by
W. W. Wilson, D.Sc.*



THE detection and location of winding errors in D.C. armatures are quickly effected by means of an apparatus designed by the G.E.C., consisting of a cathode ray oscilloscope, together with a bed-plate on which the armatures can be rotated one at a time by a motor running at about their normal speed. Two pairs of brushes are hinged above the bed, which can be lowered on to the commutator when the armature is in position. One pair are 180 (electrical) degrees apart and act as feeding points; while the others are arranged to bear upon adjacent or next-to-adjacent sectors, and are connected to the vertical deflectors of the oscillograph. A third pair rest on a contact cylinder revolving with the shaft, which short-circuits them once every revolution and thus triggers the time-base connected to the horizontal deflectors. This pair can be rotated bodily round the commutator so as to occupy any desired position.

When all the sections of the winding are sound, a series of parallel and equal ordinates are shown upon the oscillograph screen; but if any are faulty, this equality is disturbed, as in the figure. A dead short-circuited coil will have no voltage across it, and its ordinate will therefore be missing. An earthed coil is also shown by a missing ordinate, but its neighbours are shortened too, their heights tapering on either side down to the axis. A single very high peak marks an open-circuited coil, while sections with too many or too few turns will be respectively longer or shorter than the others. To detect a reversed coil, the brushes must be moved two sector-widths apart instead of one, when the faulty coil will give a null deflection with each of its sound neighbours.

Location of the faulty section is effected by rotating the time-base brushes until the abnormal ordinate comes at one end of the figure. The motor is then stopped and the armature is turned by hand until the trigger contacts are connected; when the pick-up brushes are bridging the defective coil.

The winding may be energised by direct current, but A.C. of audio frequency has the advantage of breaking down incipient faults with greater certainty. About 3 kc/s. was used for the test in the figure, giving two or more cycles per sector and causing the outlines of the record to be somewhat blurred. Incidentally, the latter shows an earth fault in a double-wound armature, which explains the double series of decreasing heights.

The above apparatus has reduced the time required for locating and analysing a faulty coil from about 10 minutes to a maximum of about one.

* The General Electric Co.

The Aniseikon

By Dr. W. SOMMER

Aniseikonia is a pathological condition in which the images which reach the consciousness through the two eyes are not of identical shape and size. This effect, although highly undesirable in the human visual system, is an efficient means of detecting moving objects in open or enclosed spaces.

THE Aniseikon is based on a twin photo-cell circuit first described by H. H. Raymond[1] for photo-voltaic cells, and A. W. Hull[2] for photo-emissive cells. The principle of the apparatus is shown in Fig. 1, using two photo-voltaic cells.

This circuit makes a balanced unit which is insensitive to fluctuations of the general illumination but is highly sensitive to changes in illumination from its special light source, the sensitivity being equal for day as well as night time. A binocular system projects the image of the space to be supervised or protected on to the light sensitive electrodes of the photocells. The aniseikonic effect is introduced by using optical systems of different focal length in each of the two oculars which results in the object being imaged at unequal sizes. The silhouetted image allows an area A-a to be illuminated, A being the whole of the cathode area, and a that part of it which is eclipsed by the image of the object. Introducing the factor α of aniseikonia, α may be defined as the ratio of the areas of the two images which are formed on the respective cells. Then, the illuminated areas on the other cell will be $A-\alpha a$. The indicating instrument will measure the ratio of these two illuminations or, more correctly, the ratio R of the two areas, *viz*, $R_1=\frac{A-a}{A-\alpha a}$. If now an object, for instance a burglar, or a condition such as a fire, alien to the initial set-up, makes its appearance in the space under supervision, the above relation will be disturbed. If b be the area of this new image on the one cell, and αb the image on the other, the ratio of the two active cathode areas will now be $R_2 \doteq \frac{A-(a+b)}{A-\alpha(a+b)}$. It is easily proved that $R_1 \neq R_2$ and therefore the equilibrium R_1, corresponding to the stationary condition, is disturbed and the pointer of the instrument moves from the position R_1 to R_2.

This movement of the pointer may be utilised to give an alarm by providing either a hole in the meter or a meter-relay. The hole must be at the point of equilibrium, *i.e.*, at R_1. It is being constantly covered by the target on the pointer. Whenever the pointer moves, an auxiliary light pencil strikes through this hole a third photoelectric cell which is in circuit with an electronic amplifier or any other means of controlling an alarm circuit. If a meter-relay of the Weston 705 type is used the power relay will be connected to its contacts. Figs. 2 a, b.

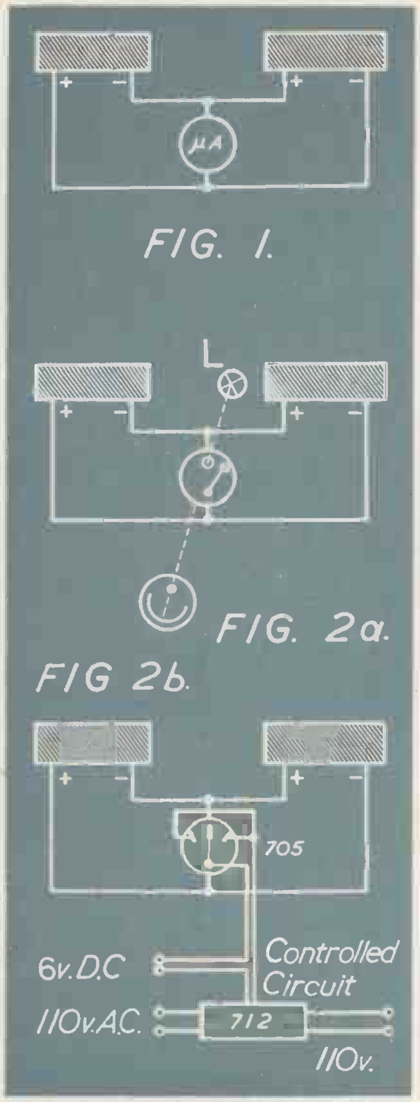


Fig. 1. Balanced photo-cell circuit using two photo-voltaic cells.

Fig. 2. Balanced photo-cell circuit with meter arranged to operate an alarm by uncovering an aperture in a second photo-cell circuit.

(b) A similar circuit with a Weston relay Type 705 to operate an alarm or control circuit.

The directed-beam system of photoelectric detection, as used in burglar alarms, etc., is inefficient because only a disturbance arising from across the windows, doors, or any other specially protected points is shown. Thus, it is a relatively simple thing for a burglar to defy the directed-beam system by entering the room where no protection is provided as, for instance, across the floor, or the ceiling, or any other parts of the room not under photoelectric control by the directed beam. The Aniseikon, while having the whole room under constant surveillance, leaves but one choice to the burglar, *viz*, to enter the room not at all.

The Aniseikon, as described so far, is able to detect objects or certain conditions alien to the original set-up. However, this apparatus cannot detect a moving object, the image of which was part of the original silhouette on the photoelectric cells, because the displacement of any part of the projected image—as long as it moves within the area of the cathode without changing its size, does not alter the ratio R_1. To detect an object starting to move about in a room where it has been before, it is necessary to introduce a grating which imitates the structure of the retina.

The retina consists of ten layers, in the third of which are embedded the photo-receptors. The image of an object, projected by the lens of the eye on to the retina, covers a certain number of these photo-receptors, each of which con-

[1] Horace H. Raymond, *Electronics*, Feb. 1933.
[2] A. W. Hull, *G. E. Rev.*, 32, 390, 1929.

veys a stimulus to the higher brain centres. If a change occurs in the position of the image other photoreceptors will be stimulated, and the result of the action is the perception of motion.

The physical interpretation and imitation of the physiological part of the eye, which is fundamental to the psychological perception of motion, led V. K. Zworykin to the invention of the iconoscope. Zworykin transferred the idea of separate photoreceptors to the realm of photoelectric cells. The iconoscope is an immensely enlarged "retina" with the relatively small number of 10,000 photocells to the square centimetre.

Another suggestion was made by A. Fitzgerald who put a screen of alternate black and white or opaque and transparent small areas—conveniently squares—between the cathode of the photoelectric cell and the projection image of the object. Using a two-cell circuit and complementary screens the image, having a maximum size not in excess of any of the small squares of the screen, will fall on a transparent square on the one cell, but on the corresponding opaque square on the other photo-cell, thus upsetting the balance of the two-cell circuit.

It is obvious that these elements, which constitute the screen, are to represent the retinal photo-receptors. The limiting factors of this invention are:—

(1) The difficulty of fixing the screens in such a position relative to each other that the elements are exactly in a complementary position;

(2) That objects, the images of which happen to be smaller than the elements due to the distance of the objects, may move over quite an appreciable distance in the field of view without being detected by the apparatus. This is due to the fact that the image is so small as to move within the bounds of an elementary square and, from an electrical point of view, the conditions of the instantaneous illumination on the photoelectric cells remain unchanged for a considerable time;

(3) That, by some coincidence, the image might be so positioned as to cover exactly as many transparent squares on the one cell as on the other and, therefore, the electrical equilibrium of the circuit is not disturbed.

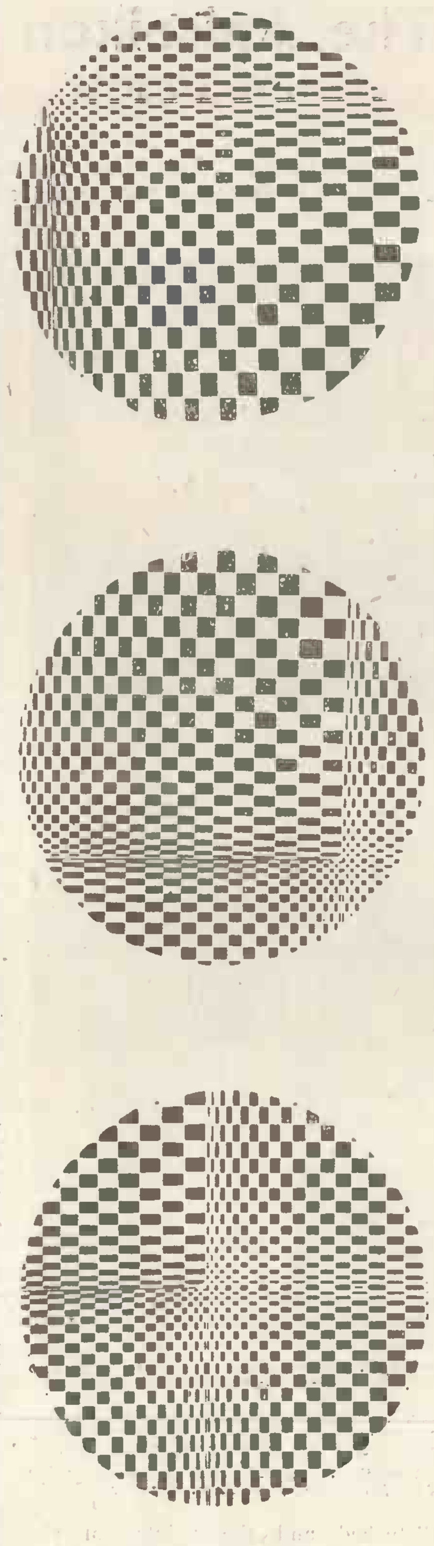


Fig. 3. The Aniseikon in combination with a grating. Any combination of two of these gratings will result in the aniseikonic effect, no matter what the position of the individual grating.

The Aniseikon, in combination with a grating, a type of which is shown in Fig. 3, is a foolproof device. The two gratings are not complementary—on the contrary they are widely different as to the size and shape of the elements and their relative position. The pattern of the two gratings is distinctly different. It will be useful to arrange generally for the small elements of the one grating to be where the large elements of the other screen are positioned, thereby enhancing the sensitivity of the device. There is limitation neither to size nor shape of the image and it is by no means conditional that the image must not exceed the area of a certain element.

As the size of the smallest element is kept down as much as possible in order to enhance the scope and range of the instrument it is necessary to calculate the permissible minimum size. The smallest current detectable by the best photoelectric cell plus high sensitivity amplifier is of the order of 10^{-18} to 10^{-19} amp. The question is as to what size the light sensitive cathode may be reduced in order to generate a photo-electric current i_{ph} when a certain sensitivity σ and a certain illumination J are characteristic for the cell.

The basic equation

$$i_{ph} = \sigma . J \quad \text{.......} \quad (1)$$

$$[\mu A] \rightarrow [\mu A\, Lm^{-1}]\, [Lm] \quad \text{.....} \quad (*)$$

may be transformed in the more convenient form

$$i_{ph} = \sigma . J' . A \quad \text{.......} \quad (2)$$

$$[\mu A] \rightarrow [\mu A\, Lm^{-1}]\, [ft.c.]\, [sq.ft.] \quad (*)$$

when it is considered that the footcandle is the illumination in lumens per square foot.

The critical area A_{crit}, able to generate the critical photocurrent i_{crit} will, therefore, be

$$A_{crit} = i_{ph\ crit} . \sigma^{-1} . J'^{-1} \quad \text{.......} \quad (3)$$

$$[sq.ft] \rightarrow [\mu A][\mu A . Lm^{-1}]^{-1}[ft.c.]^{-1} \quad (*)$$

Practical values are:—

$i_{ph.crit} = 10.10^{-12}$ amp.

$\sigma = 20$ $\mu A.Lm^{-1}$ (vacuum type emissive cell)

$J' = 50$ ft.c.

Hence the critical area is:—

$A_{crit} = 10.10^{-6}.20^{-1}.50^{-1} = 10^{-8}$ sq. ft.

The critical area of 10^{-8} sq. ft. equals 929 μ^2 which makes the side of the smallest square 0.03 mm.

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* The equations in square brackets are dimensional equations.

The illumination of 50 ft. c. on the critical area of 10^{-8} sq. ft. gives 50.10^{-8}Lm. A two-cell circuit*) easily measures a change in illumination of the magnitude of 25.10^{-6} Lm at as low a level of illumination as 10^{-4} Lm. An arrangement, having the above quoted critical characteristics, will respond to the illumination or eclipse of as small a square as the one of minimum size.

Illustrative List of Applications

The Aniseikon is readily applicable to a number of industrial problems as, for instance:—

Detection of cracks and flaws in material being manufactured in continuous sheets, rolls, rods, tubes, etc., as, *e.g.*, sheet metal, rubber, plastics, etc.

Of stains in paper, fabric, etc., moving at the usual speed in the making, re-rolling, or printing machines, or through the dyeing tubs, etc.,

Of objects or persons in a prohibited area or room; whether the object or person is stationary or moving; whether the object or person was hidden in the prohibited area or entered it later.

Protection of valuables, for instance, plans, precious stones for tools, instruments, etc.,

Of strong rooms or any enclosed spaces, safes, etc.

Of open spaces, power plants, gas works, etc.

Detection of Cracks, Flaws, Stains, etc.

The task of inspecting relatively big areas of a material, moving along on a conveyor belt or in a machine, raises appreciable difficulties for the designer of a scanning head. Soon it will be realised that another means than the usual type of scanner with or without microscopical or tele-optical equipment must be used if the inspecting device is to cope with the area as well as speed at which the material is moving. Here the Aniseikon will give first-rate service. It should be fitted with good-class lenses giving accurate images; if necessary, lenses of the wide angle type must be used. It is, however, not desirable to exceed an angle of 85 to 90 deg., because the difference of illumination between the centre and the edge would increase unfavourably.

* F. H. Shepard, Jr., *R.C.A. Rev.*, Oct. 1937.

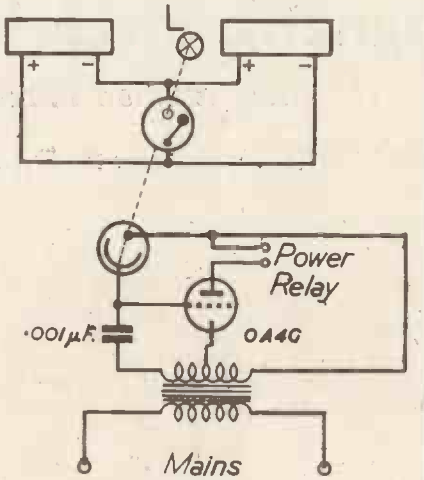


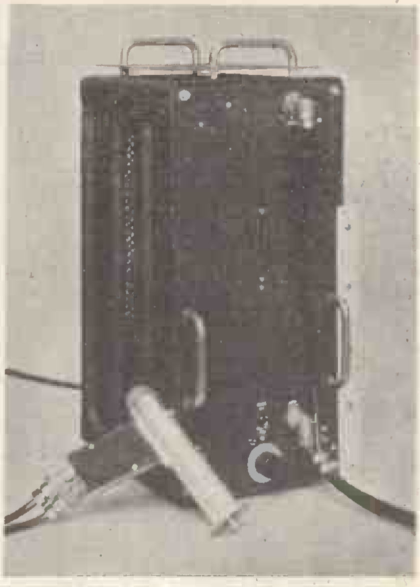
Fig. 4. Circuit of Fig. 2a in conjunction with a relay for industrial inspection work.

For inspection purposes rectangular photovoltaic cells of as big a size as available will give the best service. As a general rule the diagonal of the rectangle should equal or be nearly equal to the focal length of the optical system. The ratio of the focal lengths of the binocular system may conveniently be chosen between 1 : 1.25 to 1 : 1.50.

For industrial inspection of the above type a two-cell circuit is shown in Fig. 4. For high values of and relatively substantial changes in illumination this type of circuit will make a simple and reliable relay. When, however, changes in illumination are in the neighbourhood of 10^{-6} Lm or less at very low levels of illumination a more sensitive circuit must be used, for instance the one designed by F. H. Shepard, Jr. (*loc. cit.*).

The measuring instrument M is of the hole-in-the-meter type, having the hole at mark R_1. This hole corresponds to equal illumination on both cells. The target on the pointer covers up the hole barring the way for the light pencil from the lamp L to a third photoelectric cell, preferably of the emissive type. The relay circuit makes use of a cold cathode relay valve of the type OA4G. The relay circuit must be A.C. fed as otherwise the grid glow valve would show the here undesirable "lock-in" feature. The power relay counts or marks the flaws, stains, cracks, etc., scraps faulty sheet material, or gives a warning.

Spot Gluing with an H.F. Heating Gun.



THE high frequency gun makes it possible to apply heat locally to a synthetic glue so as to cause it to set rock-hard within a short space of time. The area heated by the gun is circular with a diameter of about ¼". The adhesive outside the heated spot is unaffected in properties, and if the correct type is used will eventually harden at shop temperature to produce a complete bond.

A radio frequency power of about 100 watts at 170 megacycles is supplied by a self-oscillator, which together with its power unit, is housed in a steel case 10" × 8" × 18" (see illustration). The oscillator weighs only 45 lbs. and is easily lifted therefore, by the carrying handles provided. The high frequency power is applied to the work by means of a gun connected to the oscillator by a flexible concentric transmission line. Tuning is accomplished by sliding a button on top of the gun which carries a lamp which is brightly lit by the high frequency current at the position of correct tuning.

The time required to cure the glue varies with thickness, but lines beneath 2 mm. veneers may be cured in 2 secs.

High frequency guns are available only for work of national importance and of high priority. All enquiries and requests for demonstrations should be made to the distributors—Messrs. Aero Research Limited, Duxford, Cambridge (Telephone: Sawston 167-8).

Magnetic Materials

2. *The Magnetisation Process*

By F. BRAILSFORD, Wh.Sch., Ph.D., A.M.I.E.E.*

2.1 Magnetisation of Polycrystalline Material

WHEN a piece of soft iron is magnetised by an increasing field, from the demagnetised condition up to saturation, it becomes apparent from the form of the magnetisation curve that two main mechanisms are involved in the process. A relatively small field strength, say about 10 gauss, is sufficient to raise the magnetisation to about two-thirds of its saturation value. The rate of increase of magnetisation with field strength then becomes much slower and a field of many hundreds of gauss is required to bring the material near saturation. The transition from one process to the other occurs in the region usually referred to as the " knee " of the curve. Curves plotted against magnetisation from careful measurements of hysteresis loss, produced either by an alternating or a rotational flux in magnetically soft materials, show similar discontinuities as described later. Such curves, obtained for polycrystalline material, represent the resultant effect of all the constituent crystals, and it is thus of interest to consider the magnetic properties of single crystals.

* Metropolitan Vickers Electrical Co., Ltd.

2.2 Magnetic Properties of Single Crystals

Large single crystals of metals may be produced by suitable technique. Honda and Kaya used the " strain and anneal " method in which they strained a rod of purified polycrystalline iron by about 3 per cent. and then maintained it at a temperature of 880° C. for several days. Oblate ellipsoidal specimens 2 cm. in diameter were cut from the large crystals which grew in the solid rod. Williams made large crystals of iron containing 3.85 per cent. silicon by slowly cooling the molten metal through the freezing point. In this case " picture frame " specimens, of which the largest was 1.72 × 1.23 cms. were cut from the single crystal with their four sides parallel to particular crystallographic directions.

The magnetisation curves obtained for iron are shown in Fig. 6 for the cube edge direction of the crystal, and for the cube face diagonal and long diagonal directions. These three crystallographic directions may be conveniently referred to by the Miller Indices [100], [110] and [111] respectively. It will be seen that an iron crystal is most easily magnetised in a [100] direction and that [111] is the most difficult direction. The curves obtained for 3.85 per cent. silicon-iron were of the same form and differ only in the field required to produce saturation and in the saturation value itself. Single crystals of nickel also show marked magnetic anisotropy but in this case [111] is the easy direction of magnetisation and [100] the most difficult.

When a ferromagnetic is magnetised, changes in its dimensions

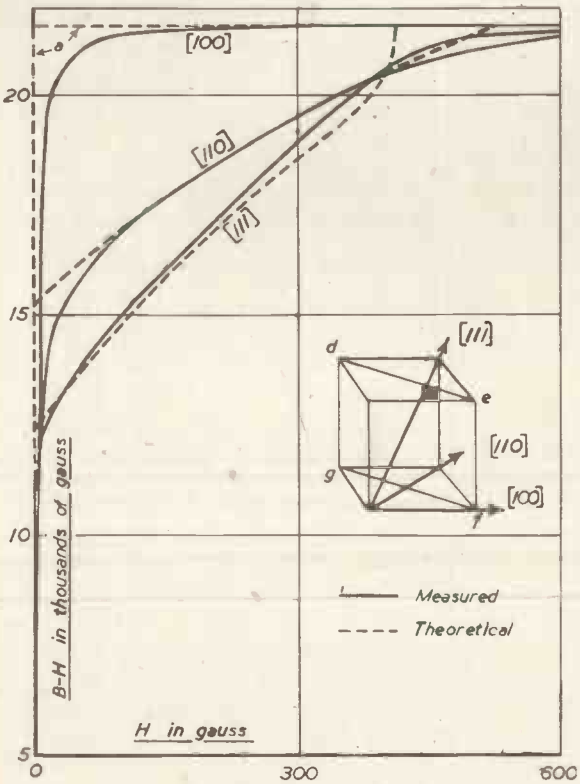
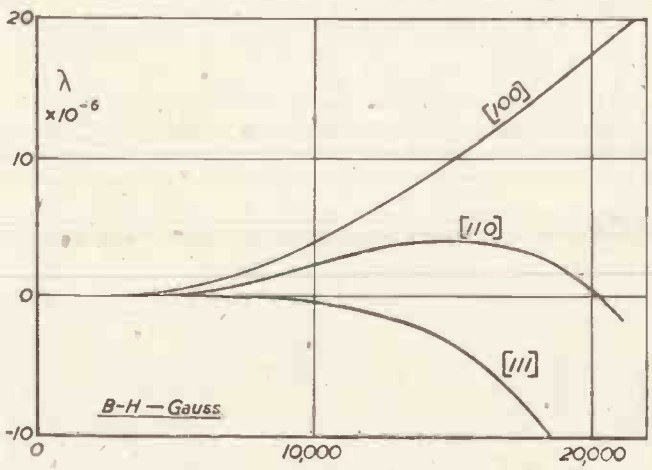


Fig. 6. (left). Observed and calculated Magnetisation curves for single crystal of Iron.

Fig. 7. Magnetostriction of single crystal of Iron



occur. This effect, known as magnetostriction, although small in amount, is of great theoretical and practical importance. The changes in length occurring in a single crystal of iron, when magnetised in turn in the same three crystallographic directions as before, are given in Fig. 7, from observations made by Webster. Thus a single crystal of iron magnetised to saturation in a cube edge direction extends by about 20 parts in a million, while in the [111] direction it contracts. Polycrystalline iron made up of randomly oriented grains has, as may be expected from these results, an intermediate magnetostriction curve similar in form to that for the [110] direction in Fig. 7. Nickel is simpler in its magnetostriction characteristics than iron, a contraction occurring for any crystallographic direction of magnetisation and thus also for the polycrystalline metal.

2.3 Effect of Internal Strains

Since a ferromagnetic changes its length when magnetised it is natural to expect that elastic changes in length brought about by an externally applied stress would also affect the magnetic properties. This is, in fact, the case and in general a material which extends on magnetisation has its permeability raised by an applied tensile strain, while one having negative magnetostriction, that is which contracts on being magnetised, has its permeability reduced by tension. In the case of nickel with negative magnetostriction, the permeability can be reduced to a low value by a high tensile strain. A striking example, due to Buckley and McKeehan, is shown in Fig. 8 for two nickel-iron alloys. With 85 per cent. nickel in iron the magnetostriction is negative and tension reduces the permeability, but in a 65 per cent. nickel-iron alloy magnetostriction is positive and the magnetisation curve is raised.

The effects mentioned are due to external strains applied within the elastic limit of the material. If a metal is "cold-worked" that is strained beyond the elastic limit, by any process such for example as bending, stretching, hammering or rolling, the grains become broken up and a complicated system of internal strains is introduced. It is well known that a magnetic material in this condition has low permeability and high hysteresis loss and that to restore its original magnetic properties a suitable annealing treatment, which relieves the internal strains and produces a recrystallisation of the metal, is required.

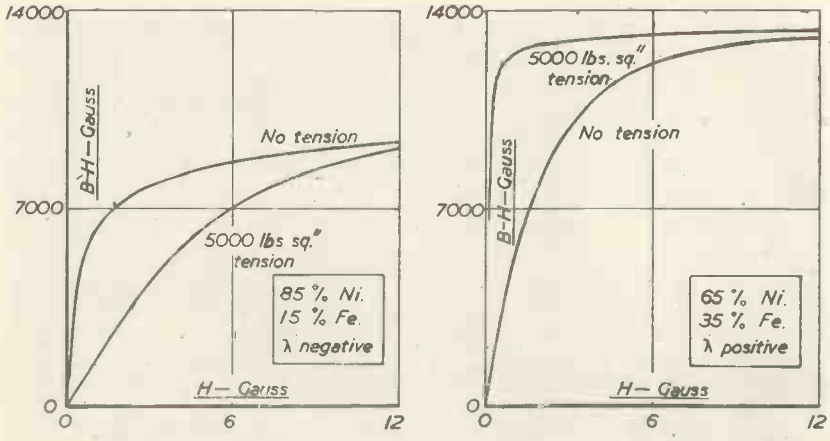


Fig. 8. Effect of tensile stress on materials with positive and negative Magnetostriction.

It is therefore apparent that both internal strains and the magnetostrictive properties are important factors in determining magnetic properties.

2.4 Magnetisation below the Knee

A theory which takes the factors of magnetostriction and internal stresses into account and relates them quantitatively to the initial permeability has been put forward by Becker. As already described any domain in a single crystal of iron will be spontaneously saturated to a saturation value I_T, and in a strain-free domain the direction of this magnetisation vector will be along any one of the six possible cube-edge directions without preference. For the direction in which I_T lies we may also deduce from Fig. 7 that the domain will have a magnetostrictive extension λ of about 20×10^{-6} per unit length. If now there is an applied tensile stress on the domain in a cube edge direction, the condition for least stored energy in the domain is satisfied for I_T directed along that particular direction. On the other hand if the stress is compressive I_T will take up a lateral cube-edge direction. If then we consider a strip along a [100] direction of a single crystal of iron having internal strains, then, according to Becker, we may assume that on the whole there will be as much compressive as tensile stress, and this on the average may be idealised as a sine wave of stress as shown in Fig. 9. Clearly then, the direction of the spontaneous magnetisation will be either along the strip or laterally as represented in the figure, and for no applied field the boundaries between domains will lies at positions of zero stress.

If now a field H is applied along the strip, then bearing in mind that I_T is by definition pole strength per unit area, the boundaries will be acted on by a force or pressure of HI per unit area tending always to move the various boundaries to increase the resultant magnetisation in the field direction. For example, the boundary at (a) will be moved to the right. In moving to a position such as (b) it is clear that, in the volume swept out, the magnetisation swings through a right angle. A magnetostrictive extension in this material then occurs against a compressive stress. Thus work has to be done by the applied field to move the boundaries and to magnetise the sample. If p is the compressive stress at (b) it is easily shown that the pressure-resisting movement of the boundary to the right is equal to $\frac{3\lambda}{2} p$, so that for a given applied field H the position of the boundary is determined by the equation

$$HI_T = \frac{3}{2} \lambda p$$

It is readily deduced from this that the initial permeability is given by

$$\mu_0 = \frac{8 I_T^2}{3 \lambda p_m}$$

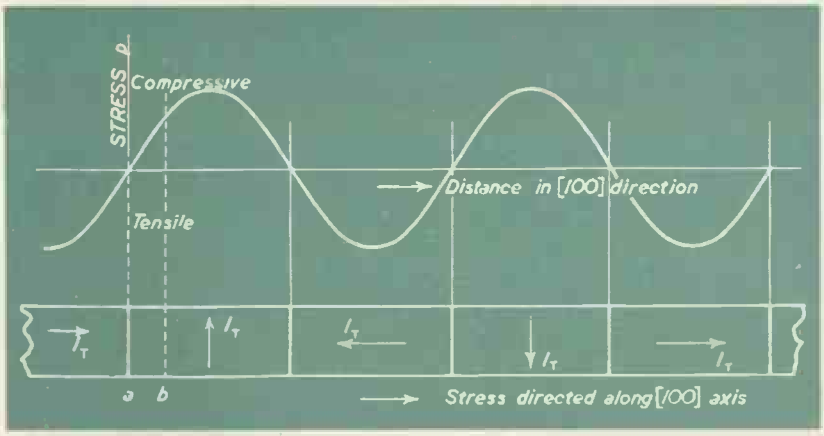


Fig. 9. Hypothetical stress distribution in a single crystal of Iron.

where p_m is the amplitude of the stress wave in Fig. 9. The above represents a reversible change of magnetisation without energy loss, as is indeed observed at low values of applied field strength.

As iron cools down after annealing it becomes ferromagnetic in passing through the Curie temperature, 770° C., and domains are formed which will be strained by the magnetostrictive effect. The order of the internal stress thus induced will be λE where E is Young's Modulus, though if in the cooling process these stresses are partially relieved, the value will be somewhat lower. If we write λE for p_m in the above expression we have a theoretical upper limit for μ_0 given by

$$\mu_1 = \frac{8 I_T^2}{3\lambda^2 E}$$

Substituting the appropriate values for iron in this equation, we have $\mu_1 = 9{,}800$. In ordinary soft iron, where there are other sources of internal strain than that under discussion, the initial permeability may be about 250, but Cioffi has obtained a value of 14,000 for very carefully treated iron which is of the correct order of magnitude predicted by Becker's theory, particularly as p_m may be, as suggested above, a little lower than λE.

We may assume that in an actual sample the internal strains will vary widely in magnitude from point to point so that the successive cycles of stress, shown equal in Fig. 9, will vary considerably in their peak values. Then if H is increased sufficiently to bring a boundary to the top of one of the lesser peaks the boundary will have reached an unstable position and will suddenly run forward. This would constitute an irreversible Barkhausen jump. There would be an energy loss in such a change appearing as heat or hysteresis loss in the material. The process of magnetisation for a cube edge direction would thus consist, as H was increased, in an increase, partly reversible and partly in a series of irreversible jumps, of the magnetisation until saturation was reached. For a very good crystal with low internal strains saturation would be reached for a comparatively low value of H so that, on the basis of this qualitative description, we might expect the magnetisation curve for the [100] direction of the crystal to be as shown at (a) in Fig. 6, where it may be compared with the observed curve.

If now H is directed at an angle to a cube edge direction as shown in Fig. 10(b), the same process will occur and saturation in the nearest cube edge direction to the direction of H will again occur for a comparatively low value of H. If the field is applied along a [110] direction, then clearly the magnetisation in the direction of H reaches the value of $\frac{I_T}{\sqrt{2}}$ and for the [111] direction $\frac{I_T}{\sqrt{3}}$

It will be noted in Fig. 6 that the observed single crystal curves have their knee close to these points which represent the end of the first process occurring during magnetisation.

2.5 Magnetisation above the Knee

The theory of the upper part of the magnetisation curve has been developed by Akulov and others. In a strain-free domain in iron with no applied field I_T will, as already stated, take up a stable position, or position of lowest potential energy, in a cube edge direction. On account of certain crystalline forces a torque is required to rotate the vector I_T out of this position. Thus as I_T changes its angular position in the domain the stored energy in the crystal changes and it may be shown that in a crystal with cubic symmetry this energy is given by the expression :—

$$E = K_0 + K_1(S_1^2S_2^2 + S_2^2S_3^2 + S_3^2S_1^2) + K_2(S_1S_2S_3)^2 \qquad \text{.............. (2)}$$

where K_0, K_1 and K_2 are constants and S_1, S_2 and S_3 are the direction cosines of the magnetisation vector with respect to three mutually perpendicular cube edges as coordinate axes. Now I_T may be rotated out of its cube edge direction by means of an applied field as shown in Fig. 10 (c) which represents the condition when H has been increased beyond the

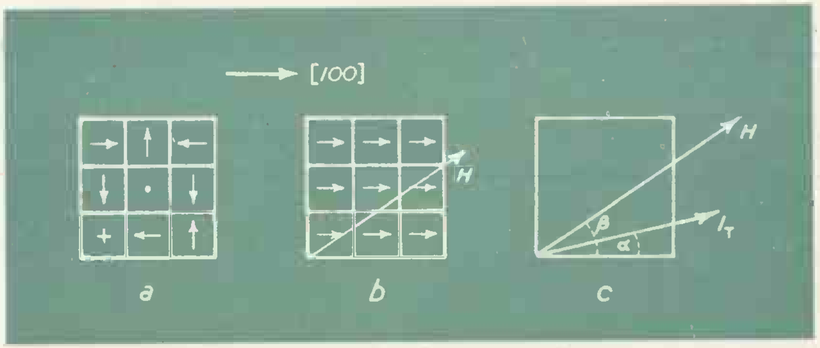


Fig. 10. Illustrating Magnetisation in a single crystal.

value required to complete the first process of magnetisation. If H is in the plane of the cube face then I_T will rotate in this plane. For a given H, applied at an angle β, I_T will rotate through some angle α as shown. Substituting for the direction cosines in equation (2) the energy equation becomes

$$E = K_0 + \frac{K_1}{8}(1 - \cos 4\alpha)$$

By differentiating we find the restoring torque per unit volume due to the crystalline forces acting to return I_T to the stable position is given by

$$L_{110} = \frac{dE}{d\alpha} = \frac{K_1}{2}\sin 4\alpha \quad \ldots\ldots\ldots (3)$$

The torque acting on I by the field H is given by $HI_T \sin(\beta-\alpha)$ so that for equilibrium

$$HI_T \sin(\beta-\alpha) = \frac{K_1}{2}\sin 4\alpha \quad \ldots\ldots (4)$$

Also the intensity of magnetisation I in the direction of H is given by

$$I = I_T \cos(\beta-\alpha) \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

By eliminating α between equations (4) and (5) we obtain a relation between I and H which is the equation of the magnetisation curve of the single crystal when magnetised at an angle β to a cube edge direction.

When $\beta = \frac{\pi}{4}$ this relation gives the magnetisation curve in the [110] direction and this is given by

$$H = \frac{2K_1}{I_T}\frac{I}{I_T}\left\{2\left(\frac{I}{I_T}\right)^2 - 1\right\} \quad \ldots\ldots\ldots (6)$$

In a similar manner it may be shown that the restoring torque acting if I_T is rotated in the [110] plane of the crystal, represented by the diagonal plane d.e.f.g. in Fig. 6, is given by

$$L_{111} = \frac{K_1}{8}(2\sin 2\alpha + 3\sin 4\alpha) + \frac{K_2}{64}(\sin 2\alpha + 4\sin 4\alpha - 3\sin 6\alpha) \quad \ldots\ldots\ldots\ldots (7)$$

and the magnetisation curve for the [111] crystal direction is then given by the following rather lengthy expression:

$$HI_T = K_1\frac{\sqrt{2}}{3}\sqrt{1 - a^2(4a^2-1)} + K_1\frac{a}{3}(7a^2-3) - K_2\frac{\sqrt{2}}{18}\sqrt{1 - a^2(10a^4 - 9a^2 + 1)}$$
$$+ K_3\frac{a}{18}(23a^4 - 16a^2 + 1) \qquad \text{where } a = \frac{I}{I_T} \quad \ldots\ldots\ldots\ldots (8)$$

Taking $I_T = 1717$ $K_1 = 4.5 \times 10^5$ and $K_2 = 2.25 \times 10^5$ ergs/cc. for iron the theoretical magnetisation curves given by equations (6) and (8) are plotted in Fig. 6 in terms of (B−H). It will be seen that there is very good agreement between the theoretical and the observed magnetisation curves.

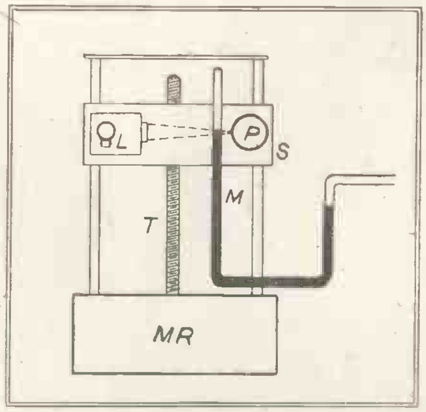
If a high field strength, sufficient to produce saturation is applied to a crystal, then no matter what its direction in the crystal, I_T will always be very nearly in line with H. Thus, if a disk, or preferably an oblate ellipsoid of revolution, is cut from a crystal in one of its crystallographic planes, and rotated in a strong field about an axis perpendicular to it and to the plane of the specimen, the angular position of I_T relative to a datum direction of the crystal is known. If the plane of the disk is a cube face, or (100) plane, the torque required to rotate the disk in the field is given by equation (3). Similarly, if the disk is cut from the diagonal (110) plane the torque acting is given by equation (7). By making measurements on single crystal specimens in this way the constants K_1 and K_2 may be determined and the shape of the theoretical and observed torque curves are found to be in excellent agreement. Such torque curves may also be observed in polycrystalline disks and from them useful information about the disposition of the grains in the material can be obtained, as will be described in the next section.

(To be continued.)

A Photo-Electrically Controlled Kymograph

It is well known that the usual method of recording pressure by a manometer moving a stylus on the smoked paper of a kymograph is open to objections, particularly if the energy available for operating the stylus is small.

The photo-electrically controlled kymograph devised by S. Feitelberg, of the Mt. Sinai Hospital, N.Y., has the advantage that the manometer fluctuations are not directly applied to the recording mechanism, and there is consequently no damping due to stylus friction.



The slide carrying the recording paper also carries a lamp L and photo-cell P, and engages a threaded brass rod T, driven by a reversible electric motor MR. The light from the lamp is interrupted when the manometer column rises, switching on the motor by means of a relay, and raising the slide until the beam is clear of the top of the column. The relay than reverses the motor and the slide is lowered until the beam is again interrupted. This oscillatory movement continues over a distance of 1-2 mm. at a rate of 2 per second. The slide follows the movement of the manometer at the rate of 20 mm. per second.

As the power for recording is supplied by the motor, the manometer column may be of small cross-section—an advantage when recording arterial pressure in small animals. The movement can also be amplified by electronic or mechanical means.

The Frequency Discriminator

by R. A. LAMPITT

THE frequency discriminator is a comparatively modern circuit which has only recently been finding its place in commercial radio receivers in this country. It can be used for two distinct purposes: first, as a detector in a frequency modulation receiver, and second, as a means of providing a control voltage in a system of automatic frequency control, used mainly on receivers employing an automatic tuning device.

As frequency modulation is not used in this country on a commercial basis, the discriminator has appeared only as a part of the automatic frequency control circuits used in a small number of the more expensive commercial receivers, and consequently its operation and capabilities are not well known to the average radio engineer. Information on this subject has been rather scanty, and it is the author's opinion that an article, which is not too mathematical and yet gives an account of the operation of such a circuit, is useful to service engineers and others who are interested in unusual electrical devices.

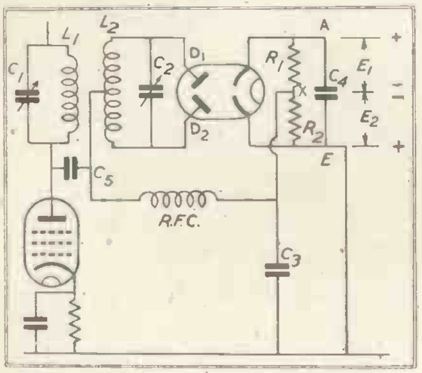


Fig. 2. Alternative frequency discriminator circuit due to Foster and Seeley.

The Simple Discriminator

The frequency discriminator is a circuit by means of which voltage is developed positive or negative with respect to earth. The sign and magnitude of this voltage are determined by the deviation about a fixed value of the input signal frequency. Such a circuit is shown in Fig. 1.

As is seen from Fig. 1, the intermediate frequency signals are applied to the discriminator via an I.F. transformer with two separate tuned secondary windings. The outputs from these windings are rectified by separate diodes D_1 and D_2, and the rectified voltages appear across the separate loads R_1 and R_2. These loads are connected together so that the voltages produced across them oppose each other, then the resultant voltage between A and B will be equal to their difference.

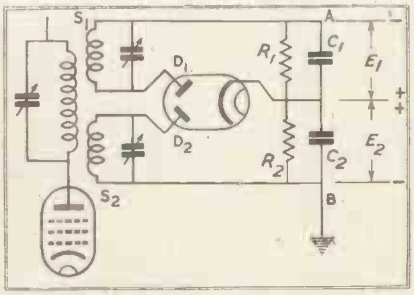


Fig. 1. Simple circuit giving a voltage output proportional to frequency deviation.

In practice the cathodes of the two diodes will be joined together, so that it is possible to use a double-diode with a single cathode as in the diagram.

The two I.F. transformer secondaries are tuned one slightly above, the other below the correct intermediate frequency, so that when the signal is at its correct frequency, each diode anode will have the same value of voltage applied between it and the common cathode. The rectified voltage across R_1 and R_2 will consequently be equal when $R_1 = R_2$. R_1 and R_2 are shunted by C_1 and C_2 respectively, so that there will be a large D.C. component across each resistor, and since E_1 and E_2 are equal, the p.d. between A and B will be zero.

If the frequency of the I.F. rises or falls, one of the tuned secondaries will be nearer to resonance than the other, so that the signal on its diode anode will be larger. Consequently, the voltages developed across the corresponding loads will be unbalanced and a potential will appear between A and B. This potential at A may be positive or negative with respect to B depending on whether the I.F. rises or falls. That is, if S_1 is considered to be tuned to a higher frequency than the correct I.F., and S_2 to a lower frequency, then if the I.F. rises, S_1 will develop a larger signal than S_2, and E_1 will be larger than E_2, so that A will be negative with respect to B. Should the I.F. fall, then S_2 will be nearer to resonance than S_1, and consequently E_2 will be greater than E_1, and A will be positive with respect to B.

If B is connected to earth, then the potential at A will be positive or negative with respect to earth. This potential can be used as a control voltage if the circuit is to be used in a system of automatic frequency control; or, if it is used in a frequency modulation receiver, this voltage will represent the A.F. component of the signal, and may be passed on to an A.F. stage for further amplification. This circuit, however, is seldom used in practice and in its place we have a circuit which works on a different principle, and which has several advantages over the one already described.

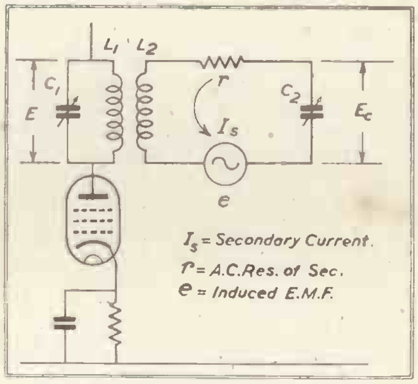
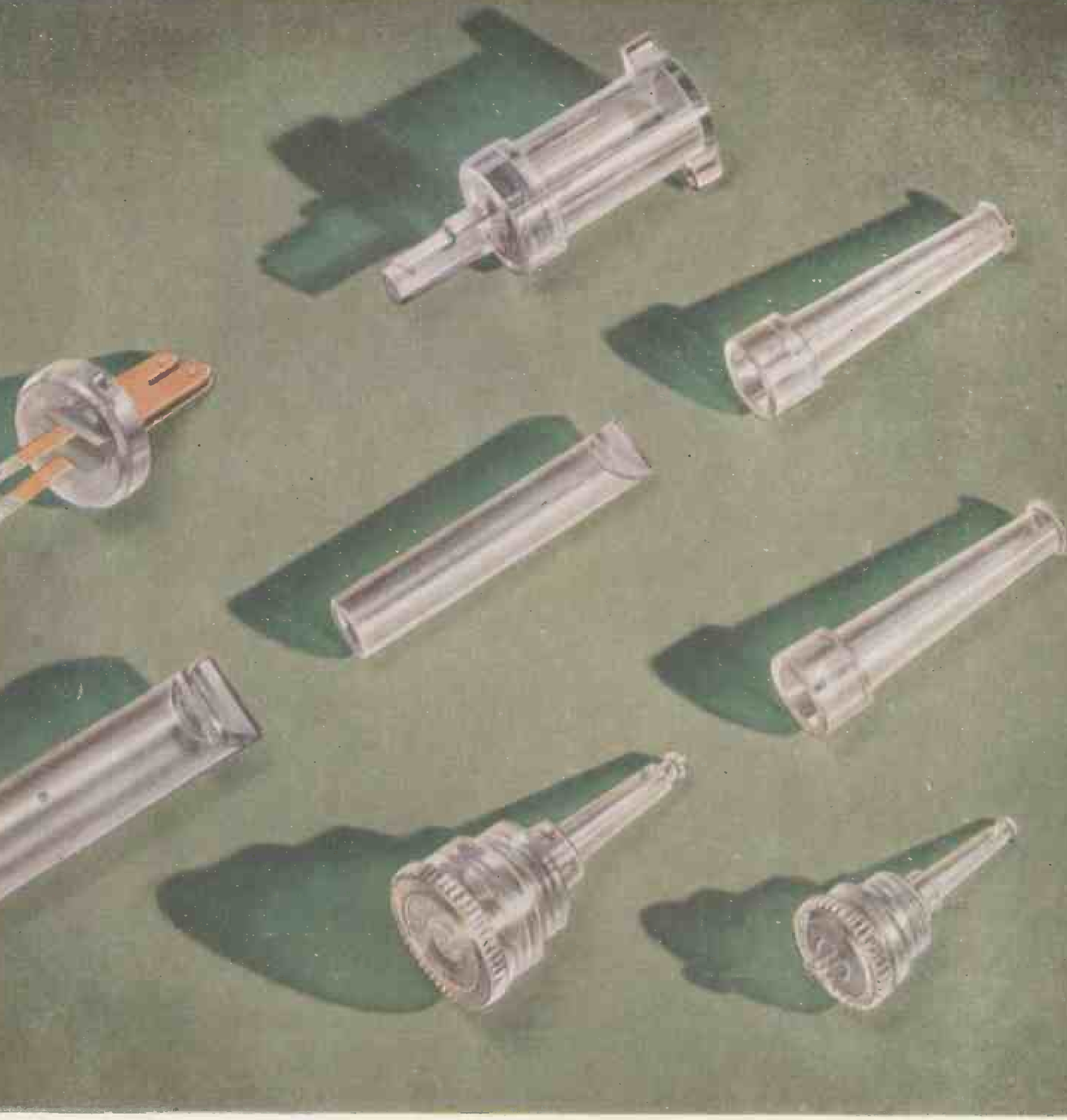


Fig. 3. Equivalent circuit of Fig. 2.

The Foster-Seeley Circuit[1]

From Fig. 2 it is seen that there is only one secondary winding on the I.F. transformer, and this is tuned in the normal way to the correct I.F. The obvious advantage is that the circuit is much easier to adjust than the previously described apparatus and incidentally the only difference between the normal I.F. transformer and that shown, is that the latter has a centre tapped secondary. This secondary has its ends connected to two separate diodes whose loads are R_1 and R_2 respectively, and the "reservoir" condenser C_4 is common to

(*Continued on p. 201*)



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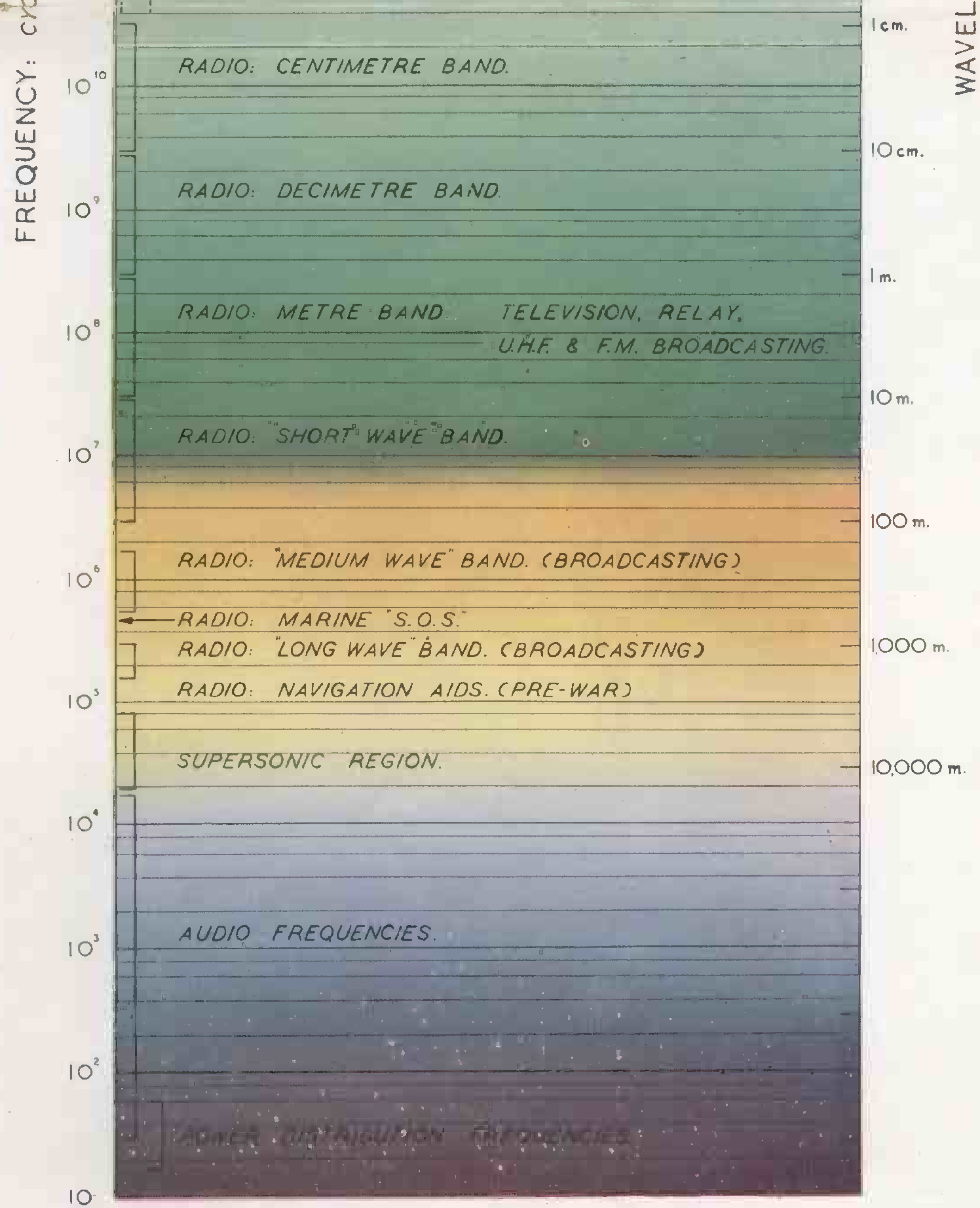
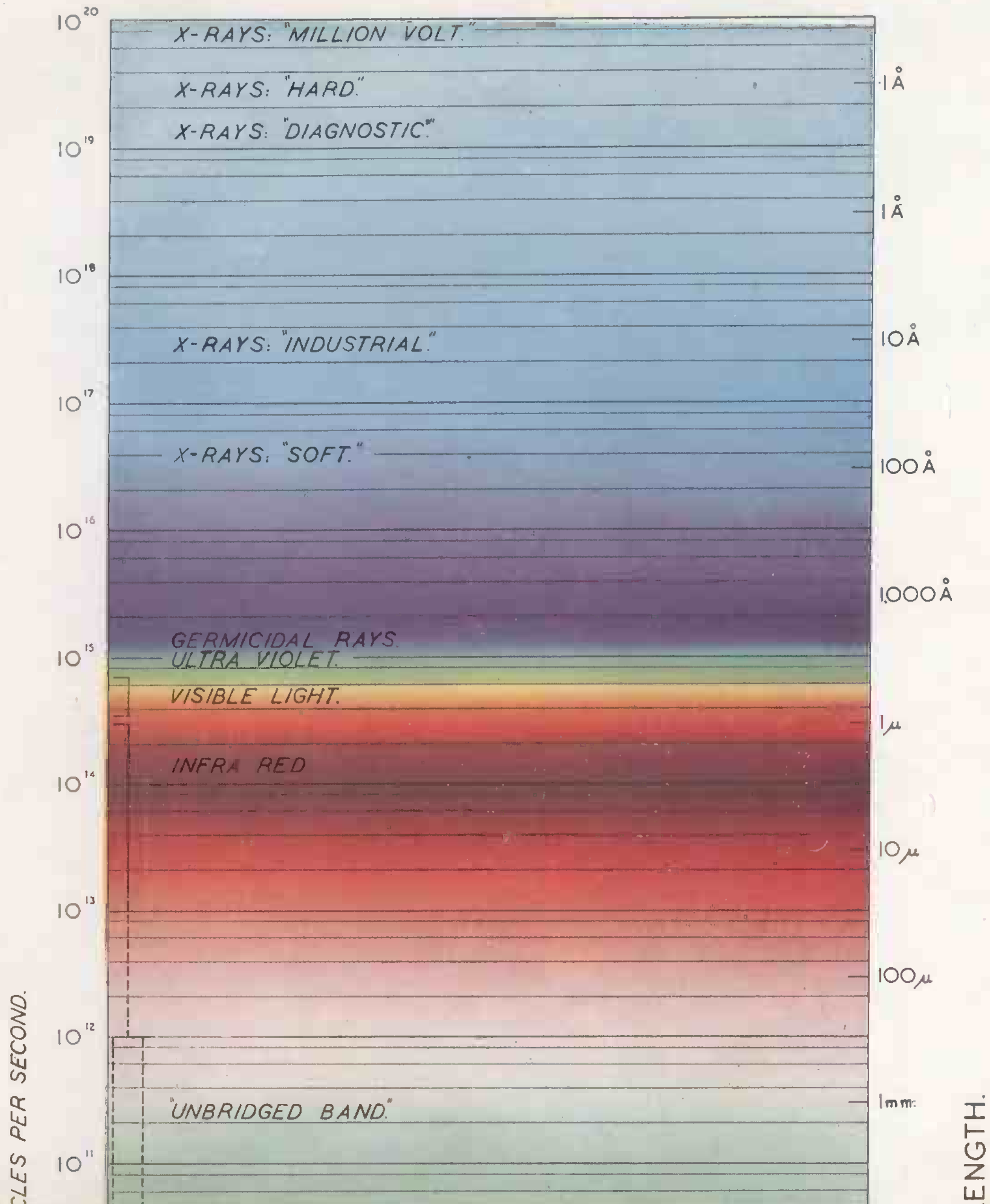


1 micron (μ) = 10^{-4} cm.   1 Ångstrom (Å) = 10^{-8} cm.

This chart is reproduced by permission from a Report issued by the British Institute of Radio Engineers.

THE ELECTRO-MAGNETIC SPECTRUM



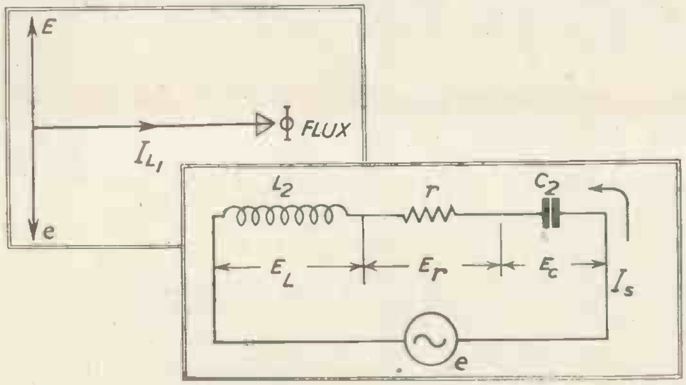


Fig. 4. Vector relation between *E* and *e* of Fig. 3, and (Fig. 5), part of the circuit redrawn to show the components of the voltage *e*.

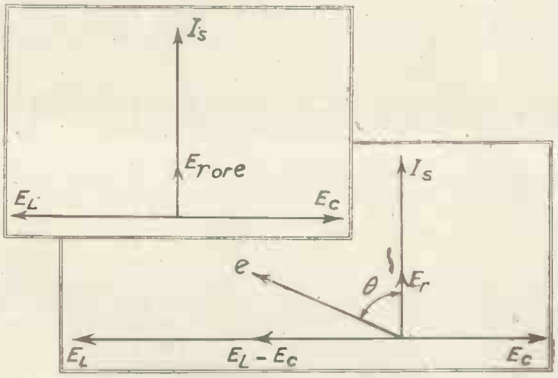


Fig. 6. Vector relationship between the voltages of Fig. 5.

Fig. 8. Vector diagram for signal frequency above the resonant frequency.

both. It will be noticed that the signal voltage which appears across the primary is passed through the condenser C_5 to the centre tap of the secondary, in addition to which an E.M.F. is induced into the secondary in the usual way. Half this induced voltage is applied to each diode anode in opposite phase as in the case of a full-wave rectifier. The signal via C_5 is applied to each anode in the same phase and from this point of view the two valves appear to be in parallel. These two voltages are applied simultaneously so that the rectified output of each diode depends upon the phase relationship between the primary and half secondary voltage being applied to it.

Phase Relations

In order to understand this it is necessary to consider the phase relationship at resonance between the voltage produced by induction and that applied directly via C_5. Since the primary of the I.F. transformer is in the anode circuit of the previous valve, the signal voltage E will appear across the tuned circuit (Fig. 3). Now the current through L_1 will lag on E by approximately 90°; this current will set up a magnetic field around the coil, the flux being in phase with the current. This flux will link with the turns of the secondary and induce an E.M.F. e into it. The E.M.F. induced is proportional to the *rate of change* of flux; therefore e will lag on Φ by a further 90°, so that e and E are 180° out of phase. (Fig. 4.)

Since e is injected *into* the secondary, this circuit becomes in effect a series-tuned circuit, and a voltage equal to Qe appears across C_2 (where Q is the magnification factor of L_2).

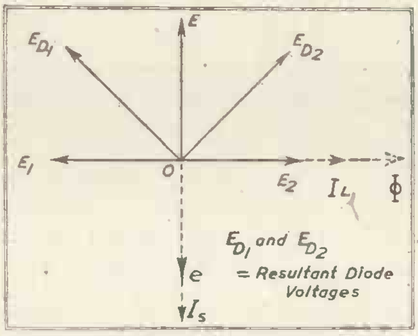


Fig. 7. Resultant diode anode voltages.

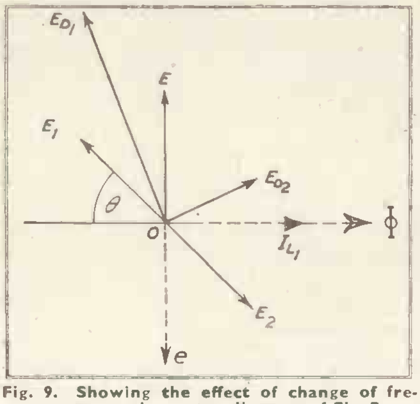


Fig. 9. Showing the effect of change of frequency on the vector diagram of Fig. 7.

This voltage will lag the current through the circuit by 90°, and since e is the vector sum of all the voltages, E_L, E_r, and E_c, and E_L equals E_c at resonance, then e will be in phase with I_s (Fig. 6), and E_c will lag on e by 90°.

Now that it has been established that the voltages across the primary and secondary are 90° out of phase, it is obvious that the diode voltages produced by this induced e.m.f. will be 90° out of phase with the applied voltage E. As these voltages are also 180° out of phase with respect to each other then one will lead E by 90° while the other will lag by the same amount. As the resultant diode anode voltages will be the vector sum of E and E_1, and E and E_2 respectively, they will be equal in amplitude (Fig. 7). Consequently, the rectified voltages appearing across R_1 and R_2 will be equal, and since they are connected in opposition, the control voltage will be zero. If we neglect any voltage drop across the diodes, then the rectified voltages will be approximately equal to E_{D1} and E_{D2} respectively, and the control voltage will be equal to the arithmetic difference between the two vectors.

Effect of Frequency

When the signal frequency rises above the resonant frequency, the induced E.M.F. e will now be applied across a series circuit which is "off resonance," and since the inductive reactance will then be greater than the capacitive reactance (Fig. 8), E_L will be greater than E_c. The vector sum of E_L, E_c and E_r will now lead I_s by an angle θ, where the value of θ depends on the deviation of frequency from the resonant frequency. In other words, E_c will lag e by $(\theta + 90°)$ and Fig. 7 now appears as Fig. 9.

From Fig. 9 it will be seen that E_{D2} and E_{D1} are unequal, so that the resultant control voltage at A with respect to earth will be positive in sign and equal to $E_{D1} - E_{D2}$ approximately. If the frequency of the signal falls *below* resonance, then the capacitive reactance of C_2 will be greater than the inductive reactance of L_2 and the vector E_1E_2 will swing in the opposite direction, so that E_{D2} becomes greater than E_{D1}. In this case the control voltage at A will be negative with respect to earth.

In practice, of course, when the frequency of the signal changes, the vector E_1E_2 will swing in sympathy about the point O, and the voltage will change from positive to negative or *vice versa*.

If the discriminator is used as a detector in a frequency modulation receiver, the voltage which appears between A and E will be the audio-frequency component of the signal; and will be passed on to one or more A.F. stages for amplification. It should be noted, however, that in the case of A.F.C., the changes in voltage are comparatively slow and consequently the values of the components used will be different.

Fig. 10 (a) and (b) shows the simplified circuit of the discriminator showing that the two diode detectors are in parallel from the point of view of the directly applied voltage *via* C_5.

Fig. 10 (a) shows the circuit minus the secondary coil L_2 and condenser C_2. The R.F. choke and condenser C_3 are also omitted. C_5 and R_2 act as a diode load for D_2 so that when a signal is applied from the primary L_1C_1, the anode end of R_2 is driven negative owing to the anode current of D_2 on each positive half cycle of the supply. This is common practice, the only difference in the whole circuit being that two diodes are connected in parallel across the same supply, and the earthy ends of each load are isolated from a D.C. point of view by the condenser C_4. It is obvious that as the same supply is connected to both, the D.C. potentials appearing across R_1 and R_2 will be the same, provided, of course, that R_1 equals R_2. In this case, the difference in D.C. potential between the cathode ends of each load will be zero. When an additional signal is applied *via* L_2 and C_2, however, the voltages across R_1 and R_2 will differ depending upon the phase relationships of the two signals. Fig. 10 (b).

The R.F. choke inserted in series with the diode loads prevents serious damping of the primary and also tends to prevent any phase change of the voltage applied to the diodes *via* C_5, so that the control voltage remains zero upon the reception of a signal at resonant frequency. It also serves, in conjunction with C_3, as an R.F. filter preventing the development of R.F. voltages across the diode loads.

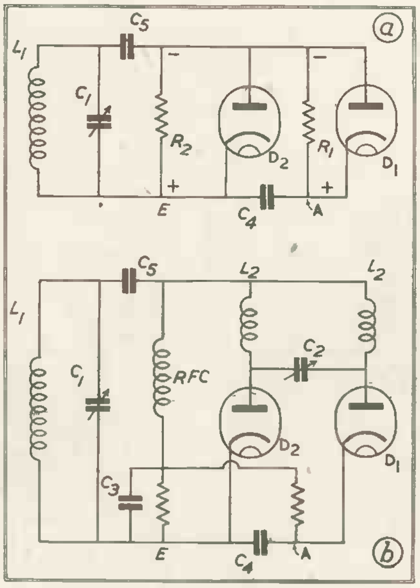


Fig. 10. **(a) Simplified circuit showing diodes in parallel (b) The same circuit with the addition of L_2 and C_2 (see Fig. 2).**

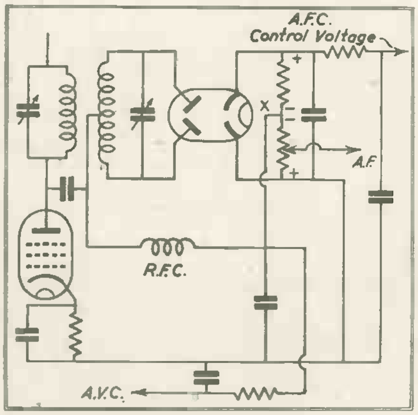


Fig. 11. **Circuit used for providing A.V.C. to compensate effect of signal strength on A.F.C. Audio frequency can be tapped from R_1 and R_2 as shown.**

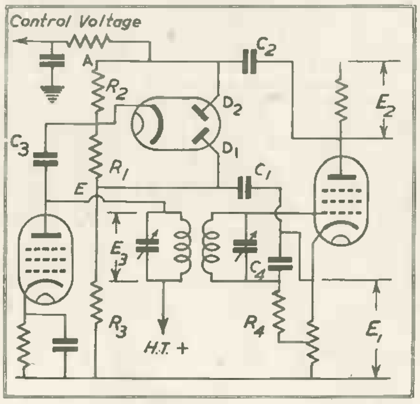


Fig. 12. **R.C.A. frequency discriminator avoiding the use of a centre-tapped secondary.**

The discriminator, as well as being used as a source of control voltage for A.F.C. in a superheterodyne receiver, may also be employed as the second detector and as a source of A.V.C. control voltage.

Provision for A.V.C.

As the signal strengths vary owing to fading, etc., the voltages across the loads R_1 and R_2 will vary in sympathy, but as these voltages vary simultaneously, their difference will remain constant at zero, provided, of course, that the receiver is accurately tuned, *i.e.*, that the input to the discriminator is at the correct intermediate frequency. If, however, the receiver is off tune, then a control voltage will be produced which will shift the frequency of the local oscillator until the I.F. is almost correct. This in turn will reduce the control voltage which will tend to detune the receiver again. In practice, the control voltage is modified by the change in oscillator frequency and vice versa instantaneously and the whole system settles down to a state of equilibrium. The set is always *a little* off tune (unless it has been adjusted manually) and there is always a small P.D. between A and earth. Now, if the signal strength varies, the control voltage will vary in proportion, and the tuning of the receiver will be modified slightly in consequence. A system of A.V.C. will reduce this effect to a large extent. As E_1 and E_2 are proportional to signal strength also, either of these may be used for A.V.C., and since the voltage at X is negative with respect to earth, then the A.V.C. bias may be taken from there as shown in Fig. 11.

The amplitude of the signal is also varying at an audio-frequency due to the modulation, and in consequence, the A.F. component is found to appear across R_1 and R_2. This A.F. may be tapped off for further amplification, and in this way the discriminator may be used as a second detector. Fig. 11 shows the complete arrangement.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The Valve Phase Splitter [2]

Although efforts have been made to reduce the damping effect of the diodes, it is of course, impossible to eliminate it entirely from the arrangements already described. A second disadvantage lies in the difficulty of constructing an accurately centre-tapped secondary.

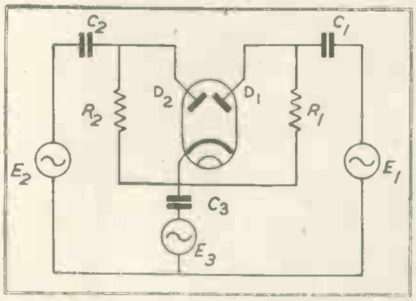


Fig. 13. Equivalent circuit of the R.C.A. discriminator.

To overcome these disadvantages, the Radio Corporation of America introduced a discriminator for use with A.F.C. using an ordinary I.F. transformer, the secondary of which is fed into a valve acting as a phase splitter (Fig. 12). This valve takes the place of the centre-tapped secondary, and also, as the grid is biased sufficiently to prevent the flow of grid current, the I.F. transformer is not damped in any way. C_4 and R_4 are merely for grid decoupling. The two out-of-phase voltages are applied *via* C_1 and C_2 to the diodes D_1 and D_2 and the rectified voltages appear across R_1 and R_2. The control voltage appears between A and E, and as before, it is equal to the difference between E_1 and E_2. Point E must be at earth potential from a D.C. point of view so that the voltage at A varies with respect to earth. This is done by earthing the point E through a resistance R_3 which must be of high value to avoid earthing or short circuiting the signal E_1. The voltage E_3 being applied between earth and the cathode *via* C_3, appears in series with both E_1 and E_2 and is therefore common to both diodes. The resultant diode anode voltages will be the vector sum of E_3 and E_1, and E_3 and E_2 respectively, so that from this point the operation of the circuit is the same as before. The equivalent circuit is shown in Fig. 13.

1 D. E. Foster and S. W. Seeley, *Proc. I.R.E.* March (1937).

2 *Electronics, Television and Short Wave World*, March (1941).

Measuring Flash Bulb Intensity with a C.R.O.

by K. S. ANKERSMIT *

A NEW application of the oscillograph is the measurement of the behaviour of photographic flash bulbs. The time is already far behind that the only reliable way to fire a flash bulb consisted of opening the shutter, firing the bulb and closing the shutter. Electrical and mechanical devices have been constructed to fire the bulb under well regulated circumstances, timing the reaching of the peak of maximum intensity to coincide exactly with a shutter action of often less than 1/100th of a second. But all these devices are in vain if the bulb itself is not reliable and uniform in its action.

One of the most frequent faults of the flash bulb is the loss of part of the oxygen through damage or faulty construction resulting in excessive lag or even complete failure to fire. It was therefore necessary to measure the intensity curves of a batch of rather old flash bulbs before using them. This it was felt could only be done by the oscillograph.

Method

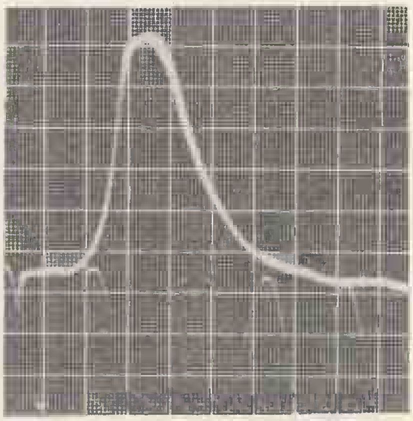
The flash bulb was made to flash in a light-tight housing placed in front of a special type of photo-electric cell and separated from the latter by a neutral density filter of adjustable value. The output of the cell was fed to the deflector plate of a double beam oscillograph, where it produced a vertical deflection of a horizontal transient. The second beam was used as a time marker from the 50 cycle mains, so that the distance between two peaks corresponds with a time lag of 20 milliseconds. In order to facilitate reading of the photographic records this time marking was adjusted to coincide exactly with the millimetre calibration of the abcissa on the graticule.

Difficulties

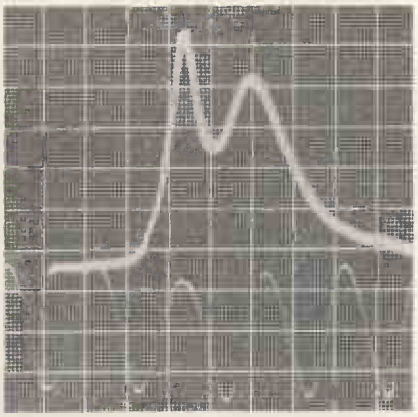
Two problems required special consideration: the exact degree of intensity reduction by the neutral density filter and the synchronism between the closing of the electrical circuit through the flash bulb and the start of the single stroke transient on the oscillograph screen. In the first case a middle course had to be found between cut-off peaks and insignificant vertical deflection, whilst asynchronism in the second case led to photographs with only a part of the intensity curve portrayed.

* The Technica Camera Repair Company.

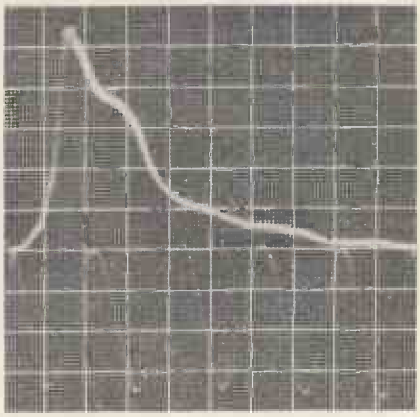
Oscillograms of Flash Intensity.



No. 1. A good curve, although the time lag is considerably longer than the 5msec. allowed for this type of bulb.



No. 2. A still longer time lag, with two peaks of intensity.



No. 3. A very short time lag (peak of intensity reached in 13 msec.) but an irregular curve. Such curves are fortunately rare, or precision synchronisation would be impossible.

Tensor Algebra

and its Application in the Solution of Network Problems

By C. F. DAVIDSON*

THE solution of network problems by means of the mesh equations presents no undue difficulty when the number of meshes is small, but considerable labour is entailed in setting up these equations when the number of meshes is large, also care must be taken to see that the correct sign is given to any mutual impedances that may be present. Both of these difficulties are avoided by the use of tensor methods since no mesh equations need be set up, and by means of a sign convention introduced later the signs of the mutual impedances are automatically inserted. The method will be applied to the solution of a simple two-mesh network and then extended to a more general three-mesh network, the latter example showing the procedure to be followed in determining the performance of any n-mesh network.

Tensor Algebra

In the solution of network problems by tensor methods we shall only be concerned with the algebraic, as distinct from the differential, properties of tensors.

Tensor algebra is a generalisation of vector algebra, and the subject is best introduced with a reference to the transformation of the components of a vector due to a transformation of co-ordinates.

Let $A_x(x,y,z)$, $A_y(x,y,z)$ and $A_z(x,y,z)$ be the components of a vector in the x,y,z, directions of an orthogonal Cartesian reference frame OXYZ, and let $A_x(\bar{x},\bar{y},\bar{z})$, $A_y(\bar{x},\bar{y},\bar{z})$ and $A_z(\bar{x},\bar{y},\bar{z})$ be the components of the same vector in the $\bar{x},\bar{y},\bar{z}$ directions of a reference frame O$\bar{\text{X}}\bar{\text{Y}}\bar{\text{Z}}$ formed by rotating OXYZ through an angle θ about OZ, the direction of rotation being clockwise when looking from O to Z.

The following relations then hold among the two sets of co-ordinates:—

$$\bar{x} = x \cos\theta + y \sin\theta$$
$$\bar{y} = -x \sin\theta + y \cos\theta$$
$$\bar{z} = z.$$

It readily follows that the components, A_x, A_y, A_z, and $A_{\bar{x}}$, $A_{\bar{y}}$, $A_{\bar{z}}$ are transformed according to the law

$$A_{\bar{x}} = A_x \cos\theta + A_y \sin\theta$$
$$A_{\bar{y}} = -A_x \sin\theta + A_y \cos\theta$$
$$A_{\bar{z}} = A_z$$

Thus we have a set of quantities in the co-ordinates (x,y,z) which are related to a similar set of quantities in the co-ordinates $(\bar{x},\bar{y},\bar{z})$, and the law of transformation of these quantities is identical with that of the co-ordinates.

Tensor algebra deals with transformations similar to the above, the co-ordinates or variables being transformed linearly. The transformations are, however, of a much more general character. In the following analysis we shall use the indicial notation which will now be explained.

Suppose we are given a set of n numbers, then we may denote them by the same letter distinguishing them by means of indices, as for example

$$a_r = \overbrace{\begin{array}{|c|c|c|c|} \hline a_1 & a_2 & \cdots & a_n \\ \hline \end{array}}^{1 \quad 2 \quad \longrightarrow r \longrightarrow \quad n}$$

which may be written more compactly as

$$a_r \ (r = 1, 2, \ldots n.).$$

Alternatively we could write the index as a superscript instead of a subscript, and we should have

$$a^r \ (r = 1, 2, \ldots n).$$

A set of numbers which depends on one index is known as a system of the first order. A system of the second order depends on two indices, each varying from 1 to n, and will therefore contain n^2 components; it may be one of three forms

$$a_{rs},\ a^r{}_s,\ a^{rs}\ (r, s = 1, 2 \ldots n),$$

which may be written in the form of an array, as for example:

$$a_{rs} = \begin{array}{c|cccc} & 1 & 2 & \cdots & n \ (s) \\ \hline 1 & a_{11} & a_{12} & \cdots & a_{1n} \\ 2 & a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & & \vdots \\ n \ (r) & a_{n1} & a_{n2} & \cdots & a_{nn} \end{array}$$

In a similar manner we may have systems of any order, a system of the third order being written in any one of the four different forms

$$a_{rst},\ a^t{}_{rs},\ a^{st}{}_r,\ a^{rst}\ (r, s, t=1, 2 \ldots n),$$

but systems of order higher than the second require more complicated arrays if they are to be displayed in full. A single quantity independent of indices is said to be a system of order zero. We shall not be concerned with systems of order higher than the second.

Suppose now that we have two systems, one a_r and another b^r, we shall frequently be concerned with sums of the type

$$\sum_{r=1}^{n} a_r b^r = a_1 b^1 + a_2 b^2 + \ldots\ldots + a_n b^n.$$

If we now make the convention due to Einstein that whenever an index is repeated in a single term the sigma sign may be omitted, the above expression may be written more concisely as

$$a_r b^r = a_1 b^1 + a_2 b^2 + \ldots\ldots + a_n b^n.$$

It should be noted that a repeated index can be any letter, for example,

$$a_m b^m = a_p b^p = a_r b^r.$$

An index which is not repeated in a single term is known as a free index and must still be given the range of values 1 to n. Thus

$$a_r b^{rs} = a_1 b^{1s} + a_2 b^{2s} + \ldots + a_n b^{ns} \quad (s = 1, 2, \ldots n).$$

Having become familiar with the above notation we can now proceed with the study of tensors.

Suppose the variables $x^1, x^2, \ldots x^n$, are transformed into a new set of variables $\bar{x}^1, \bar{x}^2, \ldots \bar{x}^n$ by the linear transformation

$$\begin{aligned} \bar{x}^1 &= c^1{}_1 x^1 + c^1{}_2 x^2 + \ldots\ldots + c^1{}_n x^n \\ \bar{x}^2 &= c^2{}_1 x^1 + c^2{}_2 x^2 + \ldots\ldots + c^2{}_n x^n \\ &\text{etc.} \\ &\vdots \\ \bar{x}^n &= c^n{}_1 x^1 + c^n{}_2 x^2 + \ldots\ldots + c^n{}_n x^n \end{aligned}$$

$$i.e., \quad \bar{x}^r = c^r{}_m x^m.$$

* Post Office Research Station.

Let $c=|c^r{}_m|$ denote the determinant of the transformation which we shall assume is not zero, and let $C^m{}_r$ be the cofactor of $c^r{}_m$ in the determinant c, divided by c.

Then

$$c^r{}_p C^p{}_m = C^r{}_p c^p{}_m = \delta^r{}_m$$

where $\delta^r{}_m$ is the Kronecker delta, which is zero if r is not equal to m, and $+1$ if r is equal to m.*

We can solve the system of equations

$$\overline{x}^r = c^r{}_m x^m$$

as follows :—

Multiplying both sides of the above equation by $C^n{}_r$ we have,

$$\overline{x}^r C^n{}_r = c^r{}_m C^n{}_r x^m = \delta^n{}_m x^m = x^n$$

since $\delta^n{}_m$ is zero except when m is equal to n.

Hence we have

$$x^n = C^n{}_r \overline{x}^r.$$

In the above equation no confusion will arise if the index n is changed to m since the components of x^m are the same as the components of x^n when m and n are given the same values; it is frequently necessary to do this. Thus the above equation may be written

$$x^m = C^m{}_r \overline{x}^r.$$

This result will be found useful later.

A tensor is defined as follows: A tensor is a system of numbers or functions whose components obey a certain law of transformation when the variables undergo a transformation, in this case a linear transformation.

A system of order zero which has the same value $\overline{a}$ in the new variables $\overline{x}^r$ as it had in the old variables x^m, is called a scalar or invariant, or a tensor of order zero. Hence "a" is an invariant if

$$\overline{a} = a$$

Consider a system a^m of order one in the variables x^m and a system $\overline{a}^r$ in the variables $\overline{x}^r$ such that

$$\overline{a}^r = c^r{}_m a^m,$$

then a^m is said to be a *contravariant* tensor of order one, contravariance being indicated by using the index as a superscript. Obviously the variables themselves are the components of a contravariant tensor of the first order.

If we have a system a_m in the variables x^m and another $\overline{a}_r$ in the variables $\overline{x}^r$ such that

$$\overline{a}_r = C_r{}^m a_m$$

then a_m is said to be a *covariant* tensor of the first order, covariance being indicated by using a subscript. A tensor of the first order is sometimes known as a vector. A double system a^{mn} which transforms according to the law

$$\overline{a}^{rs} = c^r{}_m c^s{}_n a^{mn}$$

is known as a contravariant tensor of the second order.

A system $a^m{}_n$ which transforms according to the law

$$\overline{a}^r{}_s = c^r{}_m C^n{}_s a^m{}_n$$

is known as a tensor of the second order of covariance one, and contravariance one. A typical system of the third order of contravariance one and covariance two would transform according to the law

$$\overline{a}^r{}_{st} = c^r{}_m C^n{}_s C^p{}_t a^m{}_{np}$$

We shall not be concerned with tensors of higher order than the second.

If we add (or subtract) the corresponding components of two tensors of the same number k of contravariant indices, and the same number m of covariant indices, the quantities so obtained are the components of a tensor of the same kind. This follows immediately from the equations of transformation of components of tensors.

The product of two tensors is a tensor whose order is the sum of the orders of the two tensors. If we multiply the components of a tensor which is contravariant of order k and covariant of order m, by the components of another tensor which is contravariant of order k' and covariant of order m', the quantities obtained constitute a tensor of contravariance order $k+k'$ and covariance order $m+m'$.

Let $a^m{}_n$ and b^p be two given tensors then

$$\overline{a}^r{}_s = c^r{}_m C^n{}_s a^m{}_n$$

and $$\overline{b}^t = c^t{}_p b^p$$

Hence $$\overline{a}^r{}_s \overline{b}^t = c^r{}_m c^t{}_p C^n{}_s a^m{}_n b^p$$

which shows that $a^m{}_n b^p$ constitutes a tensor, contravariance of order two and covariance of order one. The operation of contraction must now be considered. Let $a^m{}_{pq}$ be a mixed tensor and suppose we make the indices m and q the same, remembering that the repeated index m has to be summed from 1 to n, we see that the new system has its order reduced by two since

$$\overline{a}^r{}_{st} = c^r{}_m C^p{}_s C^q{}_t a^m{}_{pq}$$

Putting t equal to r we have

$$\overline{a}^r{}_{sr} = c^r{}_m C^q{}_r C^p{}_s a^m{}_{pq} = C^p{}_s \delta^q{}_m a^m{}_{pq} = C^p{}_s a^m{}_{pm}$$ from the properties of the Kronecker delta. Thus $a^m{}_{pm}$ is a covariant tensor of the first order.

The following theorem, known as the *quotient law*, is most important. If we are given the relation

$$a(m, n, p) b^{np} = d^m$$

where d^m and b^{np} are known to be tensors, then $a\ (m, n, p)$ is a tensor and is to be represented by $a^m{}_{np}$ for

$$\overline{a}\ (r, s, t)\ \overline{b}^{st} = \overline{d}^r = c^r{}_m d^m = c^r{}_m a(m, n, p) b^{np}$$

Now $\overline{b}^{st} = c^s{}_n c^t{}_p b^{np}$

$$\therefore \overline{b}^{st} C^u{}_s C^v{}_t = c^s{}_n C^u{}_s c^t{}_p C^v{}_t b^{np} = \delta^u{}_n \delta^v{}_p b^{np}$$

$= b^{uv}$ from the properties of the Kronecker delta. The above equation may be written

$$b^{np} = C^n{}_s C^p{}_t \overline{b}^{st}$$

Hence we have

$$\overline{a}(r, s, t)\ \overline{b}^{st} = c^r{}_m C^n{}_s C^p{}_t a(m, n, p)\ \overline{b}^{st}$$

and therefore

$$\overline{a}(r, s, t) = c^r{}_m C^n{}_s C^p{}_t a\ (m, n, p)$$

which shows that $a(m, n, p)$ is a triple tensor and is correctly represented by $a^m{}_{np}$.

(To be continued.)

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* Thus, when r is given a particular value in the range 1 to n, say 2, and m takes values from 1 to n, we have $\delta^2{}_2 = 1$ and $\delta_1{}^2$, $\delta_3{}^2$, $\delta_4{}^2$ .... $\delta_n{}^2 = 0$.

"Scale Distortion" and Visual Analogies

By PATRIC STEVENSON

". . . . . those who with preposterous intelligence grumble at their fate, complaining that their brains are too dependent on their stomachs, or that their knee-joints are clumsily fashioned, and their toes unsightly and useless; they might even emulate the bold proficiency of Helmholtz who asserted that, if he the creature had only been the Creator, he would have supplied mankind with a better eye."

—Robert Bridges in the Preface to "Milton's Prosody"

(Oxford University Press, 1921).

ALTHOUGH, or perhaps because, the mention of "scale distortion" never fails to arouse discussion amongst those interested in high fidelity reproduction, it seems to the writer that there is a good deal of misunderstanding on the question. In particular, comparisons between photographic enlargement or reduction and abnormal volume in electrical reproduction are apt to be used without enough thought as to whether or not the subjects are precisely analogous. "If," says the voice of supposedly common sense, "the tonal balance of music reproduced at a lower volume level than the original is so terribly distorted as the experts maintain, it would be logical to assume that a passport photo must be printed life-size. It is unreasonable to assert that unless a reproduction is life-size it is of necessity distorted."

In reply to such a view one of the experts[1] writes :—

> . . . ." Now, that is just where the mistake comes in. There is no inherent reason why a portrait two inches high should not correctly represent to scale a six-foot man. Photographic reduction or enlargement does not necessarily distort. But a volume control, which appears to perform the corresponding service for sound, does. It is as if in the process of photographically reducing a man's body 10 times, the head were to diminish 30 times and the feet 100 times."

What exactly is meant by the correct representation to scale of a six-foot man? Suppose we measure all parts of a man with extreme accuracy and make a two-inch drawing of him, strictly in proportion to these measurements, on squared paper. We then have what can truly be called an accurate representation to scale of a man, but it is something which human eye has never seen. It will, in fact, be an orthographical projection (like an architect's designs for the front, back, and sides of a building), made on the assumption that the eye can be simultaneously opposite every part of the object. A figure or building far away from us, viewed perhaps through a telescope, will approximate to these proportions; but at shorter distances the human figure (and, *a fortiori*, the building) will appear very different to the orthographical projection.

Let us next consider photographic reduction. Imagine a photograph of a man standing twelve feet from the camera. The man appears as nine inches high. Now when we hold this photo at a comfortable focal distance such that, supposing it to become transparent, the represented figure would exactly coincide with the actual man were he standing twelve feet away, we see the figure in correct proportion. The picture itself inevitably falls into perspective, and this perspective coincides with the reality[2]. Looked at nearer or farther than this ideal distance, perspective—resulting from the constitution of space—will introduce some degree of distortion. Now suppose this print is reduced by straightforward "photographic reduction" to passport size. The man is now two inches high, but still retains the relative proportions of a figure seen at a distance of twelve feet. If this is what is implied by a passport photo correctly representing to scale a six-foot man, well and good. But the writer cannot agree that the mechanical process of reduction is here free from distortion, for by no natural means can we see a man as approximately passport-photo size *exhibiting the proportions of a figure twelve feet from us.* Figures measuring two inches high when traced on to a transparent picture plane held at any normal focal distance, would be in the neighbourhood of forty to fifty feet away, and show very different proportions to those obtaining at a range of twelve feet.

It appears, therefore, that photographic reduction cannot be instanced as an intrinsically distortionless process to which the effect of reproducer volume control should aspire. On the contrary, it is *liable to introduce distortion*, creating a result which, however pleasing it may be, is unlike anything which human eyes could see in reality[3]. It is the distortion introduced which has to be emulated; and, in fact, the passport-size reduction we have considered is closely analogous to an orchestral reproduction, at less than normal volume, in which the tonal balance perceived by the average ear at the intensity level existing in the hall, has been preserved by suitable electrical distortion, *i.e.* bass and treble boost. Those who argue on these lines thus hit on the right analogy for the wrong reasons and so confuse the subject as much as if they had chosen the wrong analogy for the right reasons. Distortion can only mean a departure from what is normally perceived by the senses of a healthy (and sober) human being; and when the effect of normal perception is called "scale distortion" (". . . . it exists equally in direct listening to a performance")[4], and an effect of abnormal perception is held to be free of "scale distortion," it is time to call a halt and endeavour to clear away the mists of confusion which have gathered round the question through the misuse of the word "distortion" in this context. (The reason for the Bridges quotation prefixed to this article may by now be growing clearer). A. S. Evans[5] was fully justified in referring to the preposterous mental aberrations which this dreaded term is apt to produce in the minds of quality enthusiasts, But as J. R. Hughes pointed out[6], Evans was completely incorrect in saying that the "scale distortion" (alteration in balance) perceived when we vary our distance from a real orchestra "is *automatically corrected by . . . the ear.*" Actually it is *caused by the ear*, and is the mode under which homo sapiens is obliged to experience auditory sensation. As such it should not be called "distortion," any more than the fact that perspective alters the relative proportions of a building depending on our distance from it is called "distortion." An effort should therefore be made to do

[1] *See* "Scale Distortion," by 'Cathode Ray,' *The Wireless World*, September 24th, 1937.

[2] Strictly speaking this would only be true of a drawing. The artist draws horizontal lines as horizontal and vertical lines as vertical, thus allowing for the right perspective being added when his picture is seen from the correct distance. See Chapters V and VII of "What is Art?" by D. S. MacColl (Pelican Book, No. A62).

[3] It is agreed that normally the distortion introduced by photographic reduction is much less than in volume reduction. But this does not invalidate the argument.

[4] *The Wireless World*, February, 1942 (letter).

[5] *ibid* January 1942.

[6] *ibid* February 1942. (letter).

away with the expression "scale distortion." The term "aural perspective" or "audio-perspective" is suggested as a substitute[7]. Unless the snob-appeal of a box in the theatre is too great, we pay in proportion as a seat is kind to the visual and aural perspective it affords of a performance.

It is thus clear that much of what has hitherto been called "scale distortion" is no such thing; it is the natural way our ears respond to auditory stimuli of varying intensity. Receivers with "cooked" response curves designed to counteract this misnamed phenomenon are, in fact, introducing another form of the very thing they are supposed to abolish. If soft reproduction which retains the tonal balance peculiar to a loud performance is not a type of "scale distortion" it is not known what is. To avoid further misunderstanding it is suggested that the term "orthophonic" be applied to reproduction which retains at all volume levels different from that normally chosen as giving the best tonal balance at the actual performance, the characteristic balance of the latter. It is as if the listener were given the power to hear the aural equivalent of an orthographical projection at different volume levels.

Parallels between photographic enlargement and reproduction at supernormal volume need not be gone into here. High fidelity then ceases, and —as Mr. P. G. A. H. Voigt has said— "the ear hears extra bass, most objectionable on speech . . . it is then legitimate to cut some of this so as to obtain a less unreal effect."

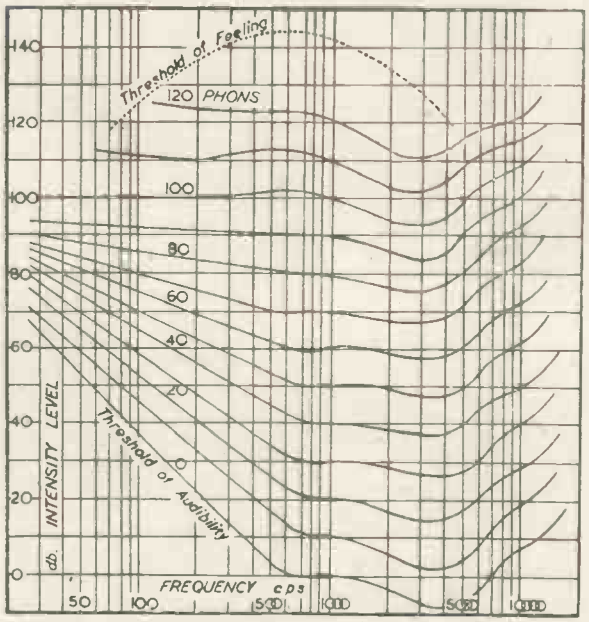
As a final word, some data in tabular form relating to actual and reproduced music. The figures have been derived from the familiar series of equal-loudness contours shown in Fig. 1, and this further exposition may throw a little more light on the matter.

Imagine a wide-spread chord for full orchestra played *fortissimo* (*ff*). The balance has been adjusted by the conductor so that no constituent note preponderates over any other note. The volume of sound reaches a level of 90 phons. Decibel and phon values for three representative notes are given in the first column of Table 1.

Now imagine this chord played *piano* (*p*). Each player, judging by ear, so reduces the volume of sound from his instrument that the same even balance is retained at the new low level of 60 phons. The equivalent db. values appear in column 2 of the table, only that at 1,000 c/s having fallen a numerically-equal number of db. corresponding to the general 30-phon drop. The bass players have automatically reduced their intensity by as little as 12 db. clearly showing the necessity for a big increase in the relative intensity of the lowest notes in order to preserve the required balance. The 10,000 c/s harmonic has fallen by 28 db.

If, however, the original 90-phon chord is not reduced to 60-phons by the human agency of the players, but by a mechanical volume control which can only respond to a db. scale, what is the ear's verdict? Column 3 shows that the bass in the reproduction is 49 phons, and the extreme treble 12 phons below the values necessary for correct balance! Column 4 completes the picture by illustrating the result of reproducing the actual *piano* chord (2) with the intensity of all its constituent notes reduced by 30 db. The 50 c/s note is now completely inaudible, being some 24 db. below the threshold of audibility, whereas the high note has fallen 8 phons lower than the middle frequencies. Some idea of the actual reduction in volume can be gained by remembering that the decibel is a logarithmic unit, and hence 10 db. means ten times the intensity, 20 db. one hundred times the intensity and so forth. The impression of a decrease in loudness depends, therefore, not on the amount by which the intensity has been reduced, but on the ratio in which it has fallen. Transmitter volume-compression, which boosts the quiet passages and reduces the intensity of loud ones, will naturally mitigate to some extent the disagreeable result of reproduction at low volume levels.

Fig. 1. Equal loudness contours.



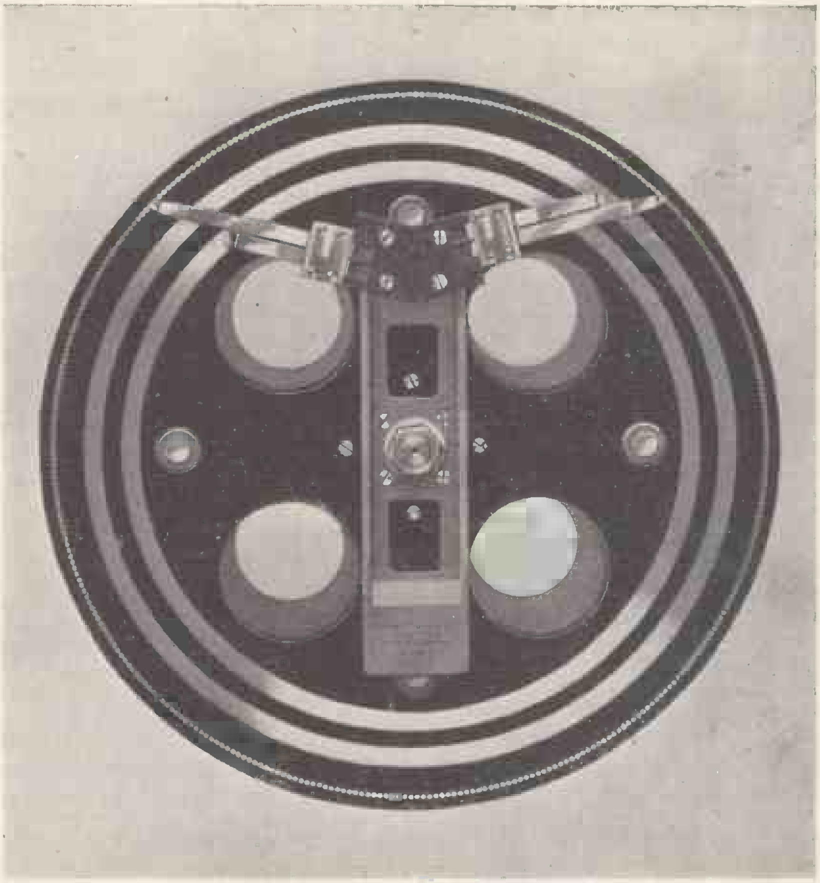
[7] I am aware that the term "auditory perspective" has been used to denote the illusion of space brought about by stereophonic reproduction. Yet since the size of an object, or the space occupied by an orchestra, does not *constitute* the visual or aural perspective as the case may be, but merely *modifies* it, I feel the term is somewhat misapplied. Would it not be better to narrow down the connotation of "aural perspective" to a meaning precisely analagous to its visual counterpart, describing the result of stereophony as "space effect" and the departure from reality brought about by reproduction through a mon-aural channel as "point-source distortion?"

TABLE I. Showing that orchestral dynamics follow a different law to volume controls.

Column No.	Orchestra or Reproduction	General Level in Phons or Decibels	50 c/s		1,000 c/s		10,000 c/s	
			Db.	Phons	Db.	Phons	Db.	Phons
1	Orchestra *ff*	90 Phons	93	90	90	90	101	90
2	Orchestra *p*	60 Phons	81	60	60	60	73	60
3	Reproduction of 1 *p*... ...	60 Db.	60	11	60	60	60	48
4	Reproduction of 2 *pp* ...	30 Db.	30	(—24Db.)	30	30	30	22

Some Modern Components and Accessories

Some of the products illustrated in this review are only available for priority orders, but in all cases the manufacturers will be pleased to give further particulars to industrial firms and engineers who are interested.

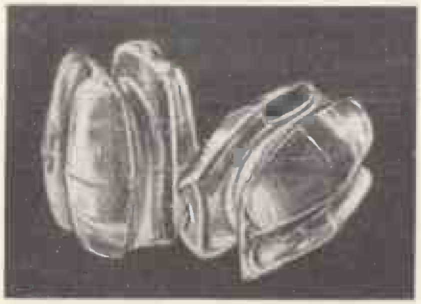


Rotary Stud Switch

The rotary stud switch type D-198-A, shown in the photograph, was designed to meet a special need. It has 360 contact studs with an angular spacing of 1 degree. The studs are continuously traversed by a two-pole brush assembly with 90° spacing between the poles. The resistances associated with the switch form a potentiometer of which the resistance conforms to a sine law; thus when a constant potential is applied to the ends of the potentiometer and the brushes are rotated at constant angular velocity, two sine wave potentials, spaced 90° apart in time appear at the switch terminals.

Each of the 360 resistance elements comprising the potentiometer is non-reactively wound on a small bakelite card and adjusted to within 0.1 per cent. of its nominal value. The brass contact studs which are 0.0937 in. in diameter, are mounted on a substantial insulating board 12½ in. diameter; the stud circle is 12 in. diameter and the gap between studs only 0.011 in. To prevent wear of the studs the tips of the laminated phosphor bronze brushes are set obliquely to the direction of motion.

Messrs. Muirhead and Co., Ltd., Elmers End, Beckenham, Kent.



Engraving on Metal

The "Actograp" electric pen is an instrument for engraving on every type of metal by means of a small continuous arc struck between the special writing point and the metal. It is similar in form and handling to a fountain pen, and is fitted with renewable and sharpenable writing points. The pen operates from D.C. or A.C. supplies of 2-6 volts, and a special transformer is available giving two strengths of current from 240 or 110 v. mains.

The No. 1 outfit is for light duty and costs £2 11s. with transformer. No. 2 outfit is for heavy duty and costs £5 7s. 6d. with multi-tapped transformer. Both outfits are complete with flex, clips, etc. The knack of writing uniformly and accurately is soon acquired, and the outfit should prove very useful in toolmakers work for identifying parts, etc.

Electric Spot Soldering

Intense local heat for spot soldering can be obtained by means of the "Lorsol" arc electrode connected to a low voltage transformer similar to the one used in the "Actograp" engraver. An advantage of the carbon electrode is that current is only flowing during the actual soldering process, resulting in economy over the continuously heated soldering iron.

The instrument holds two carbon electrodes, which are replaceable, and is supplied complete with spare carbons, solder and transformer, leads and clips, for £5 15s.

Lorant and Co., Ltd., 98-100 Croydon Road, S.E.20.

Pyrex Insulators

The use of Pyrex is an insulating material for aerials and lead-in bushings has several advantages over similar materials, notably in the dielectric strength, which is 35 kV. per 100 mils.

It has a low thermal expansion and the power factor is 0.38 per cent. at 3 Mc/s. The illustration shows a shackle insulator manufactured by Messrs. Jobling & Sons, and sold by Berry's (Short Wave), Ltd. Spacers and standard aerial insulators are also available.

Berry's (Short Wave), Ltd., 25 High Holborn, W.C.1.

Moulded Tubular Condensers

B.I. Moulded tubular condensers are manufactured in a wide range of capacities and for working voltages up to and including 6,000 D.C. They provide the most effective solution in those cases where minimum size and weight are important considerations. They carry full Inter-Service type approval and are included in the interim schedule of I.S.C.C. preferred types.

Manufactured in three sizes, these condensers can be obtained with soldering tags at each end, or alternatively, with one soldering tag and a stud for base fixing.

British Insulated Cables, Ltd., Prescot, Lancs.

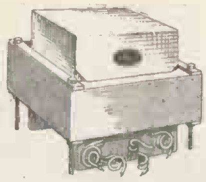
High Stability Carbon Resistors

In addition to the normal range of values, these resistors can be supplied in values down to 10 ohms. and up to 5.1 megohms on special inquiry.

Resistors are supplied to within ±5 per cent., ±2 per cent., or ±1 per cent. of the nominal value. The finish is tropical grade to comply with W.T. specification K 110. The age stability under tropical conditions as stipulated by the above specification is 1 per cent. for values up to 30,000 ohms. and 2 per cent. over 30,000 ohms. This is, therefore, the maximum permanent change in resistance to be expected during the life of a resistor when operating in the tropics.

Welwyn Electrical Laboratories, Ltd., 70 Bridge Road East, Welwyn Garden City, Herts.

Temperature Coefficient	¼w. (ohms)	½w. (ohms)	1w. (ohms)	2w. (ohms)
.02 — .03% per °C. ...	10 — 51K	10 —100K	10 —200K	10 —390K
.03 — .04% per °C. ...	51K—100K	100K—200K	200K—390K	390K—820K
.04 — .07% per °C. ...	100K—1M	200K—2M	390K—3.9M	820K—5.1M



Mains Transformers

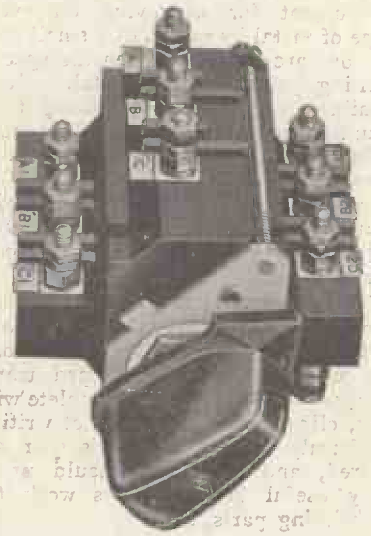
A special type of mains power transformer designed by the Radio Instrument Co. is suitable for use with 6L6 and 807 valves. The rectifier winding allows the use of 4 v. or 5 v. heaters. The transformer is shrouded and arranged for sub-chassis mounting. This company also manufacture transformers for receiver replacements, intervalve coupling, and A.F. output in addition to carrying stocks of components and speakers.

The Radio Instrument Co., 294 Broadway, Bexley Heath, Kent.

"Diamond H" Switches

These switches, of which a specimen is shown in the photograph, have a totally enclosed mechanism in a moulded plastic case and conform to service requirements for tropical use. The dimensions are constant throughout the range except for depth. Other features are the legible marking of the connecting tags and the provision for one-hole or two-screw fixing.

Ratings are as high as 250 v. 10 amps., of 1.7 v. 15 amps., and a wide variety of circuit switching can be arranged.



Technical Brochure No. 76 can be obtained from the makers:

Diamond H Switches, Ltd., Gunnersbury Avenue, W.4.

Precision Test Meters

This company manufactures precision universal test meters of which the Type E.44 is shown in the photograph.

As the type number suggests, the meter has 44 ranges—from 200 mV. D.C. to 1,000 v. D.C. and A.C., 1 mA. to 10 A. D.C. and A.C., resistances from 0.5 ohms. to 1 megohm., and power from 0–4 mW. with a 4,000 ohm. load.

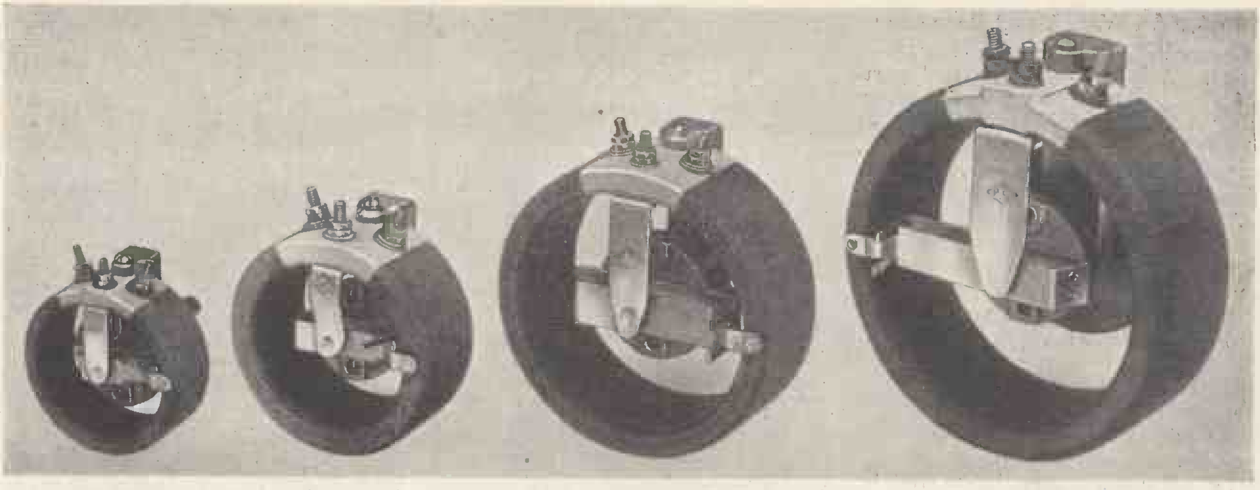
A characteristic feature is a well-made polished mahogany box, with removable lid, the dimensions being 11¾ in. by 10¼ in. by 6 in. deep. The internal construction is of high quality, the jewels being spring-loaded, and all resistors wire-wound and non-inductive. Automatic cut-out protection is provided and the circuit is broken if voltage is applied to the current range.

The voltage drop on the 1 mA. range is exactly 200 mV., enabling special shunts or series resistances to be used if required. The current consumption on all ranges is 1 mA.

Model E.45 with a lower range of 100 mV. D.C. is also available.

Both meters are of superior workmanship and are precision instruments. Particulars and prices from

Electrotest, Ltd., 17 Paradise Road, Richmond, Surrey.



Toroidal Potentiometers

The potentiometers illustrated are wound on massive ceramic formers to a resistance tolerance of ±5 per cent. Closer limits can be supplied if specially required. All models can be wound graded, and can be adapted for bench mounting or double or triple ganging.

Wattage Ratings: 25, 50, 100, 200.

Resistance Ranges: 12—30,000 ohms in 200 w. size.

12—25,000 ohms in 100 w. size.

12—14,000 ohms in 50 w. size.

10— 8,000 ohms in 25 w. size.

Max. depth behind panel: 2 3/16 in. (largest) to 1 1/8 in.

All models pass R.A.F. K.110 test and are approved for tropical conditions.

The company specialise in toroidal windings and invite inquiries for 360° windings of this type.

P.X. Fox, Ltd., Hawksworth Road, Horsforth, Yorks.

Butt Wire Welding Machine

This machine has been expressly designed for use in the lamp, valve, and wire making industries. The electrodes are mounted on a welded steel frame with steel panelled sides fitted with adjustable arm rests for the operator. The wire carriage is ball-bearing and the copper jaws have a vernier adjustment to ensure accurate positioning of the wires. The finished welds are ejected into a catch tray fitted with an adjustable eye shield.

Speeds of 500 to 900 welds an hour may be obtained, depending on the skill of the operator. The standard machine handles wire from .026 in. to .125 in. and can be supplied for wires down to .012 in. if required.

Atlas Engineering Co., 3 St. James's Square, S.W.1.

When enquiring about any of the products described, it would be appreciated if this Journal was mentioned as the source of the information.

Compact Galvanometer Scale

The Hilger "Galvoscale" projector enables a galvanometer with a normal scale distance of 2 metres to be used on a bench area 2 ft. by 1 ft. without loss of sensitivity. The complete assembly is mounted on a cast base and the galvanometer mount is spring suspended to damp out vibration. The projector is designed for use with the Tinsley F.878 Galvanometer.

Adam Hilger, Ltd., 98 St. Pancras Way, N.W.1.

Walter Switches

The illustration shows two types of wafer switch manufactured by this company. Type B.T. is a compact switch measuring approximately 1¼ in. overall diameter by ¾ in. behind panel and provides single pole switching up to 12 positions, 2-pole up to six positions, and 4-pole three positions. Blades and contacts are heavily silver plated.

Type 40 multi-pole rotary switch is designed for assembly in banks with various arrangements in each bank: 12 position single-pole to 3 positions 6-pole.

In both types of switch the positioning device is positive and smooth in action. The bank wafer is of bakelite and the centre disk is located on a double-flatted shaft to avoid play developing during the life of the switch. The finish is to Spec. D.C.D./WT.1000.

A comprehensive specification chart is issued by the manufacturers on which customers can indicate their special switching requirements.

Walter Instruments, Ltd., Earls Court Exhibition Buildings, Earls Court, S.W.5.

Taylor All-Wave Signal Generator

The All-Wave Signal Generator, Type 65A, is a mains operated portable equipment covering a frequency range from 100 kc/s. to 46 Mc/s. It is designed for general r.f. test work, ganging and alignment of tuned circuits, and as an r.f. standard. A 400 c/s. signal is also available for a.f. testing.

There are seven controls on the panel of the generator as follows:

(a) Main Frequency Control.
(b) Range Switch.
(c) Coarse Attenuator.
(d) Fine Attenuator.
(e) Modulation and Mains Switch.
(f) Audio Output Control.
(g) Mains Voltage Adjustment.

The frequency range is covered by six wavebands. Five of these are fundamentals and the sixth is a harmonic of the fifth.

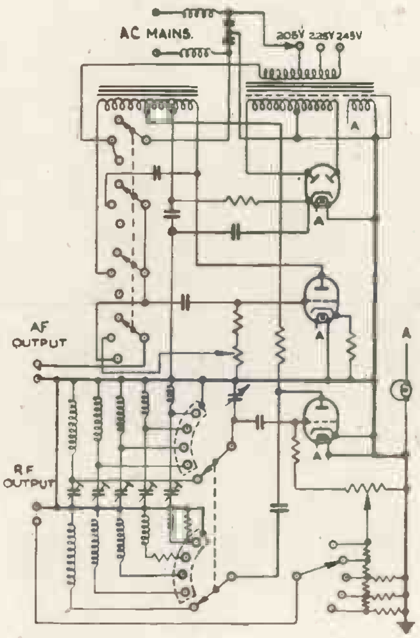
Band	Frequency covered
1 ...	100—300 kc/s.
2 ...	300—900 kc/s.
3 ...	900—2,700 kc/s.
4 ...	2.7—8 Mc/s.
5 ...	8—23 Mc/s.
6 ...	16—46 Mc/s.

The average accuracy of calibration is 2 per cent. on all frequency ranges.

The output is continuously variable from 1 to 100,000 microvolts, controlled by two attenuators. These are directly calibrated in microvolts, the coarse control having five positions marked ×1, ×10, ×100, ×1,000 and ×10,000, and the fine control is marked from 0 to 10. The output is approximately equal to the product of the readings of both controls. The output impedance is 20 ohms. on the three lowest output ranges and is higher on the two higher ranges.

The selector switch gives a choice of two positions:—

(1) *INT. MOD. and 400 c.p.s.* In this position the modulator valve oscillates at 400 c/s. and modulates the R.F. Oscillator to a depth of approximately 30 per cent. At the same



time, 400 c/s. output is available at the right-hand output socket.

(2) *EXT. MOD. and C.W.* In this case the modulator valve acts as a choke coupled amplifier, and by plugging into the right-hand socket a source of audio input, the R.F. oscillator will be modulated. Alternately, the instrument can be used on this switch setting to give unmodulated R.F. output.

The size of the instrument is $12\frac{1}{2}$ in. by $8\frac{1}{2}$ in. by 6 in. and weight is approximately $10\frac{1}{2}$ lb.

Messrs. Taylor Electrical Instruments, Ltd., 419-424 Montrose Avenue, Slough, Bucks.

Solder Creams and Solder Paints

Solder creams and paints contain solder in powder form intimately mixed with flux and embodied in a suitable medium. They provide a simple method of applying solder which for many purposes has superseded hot dip tinning or the use of solder in stick form. In tinning operations, the cream is brushed on the parts to be treated, which are then heated until the solder melts and forms an adherent coating.

"*Fryolux*" *solder paint* (*active*) very rapid in tinning action, non-greasy; for dipping or spraying it can be thinned down with water if necessary. Approved M.A.P. for general soldering, but not for electrical work

"*Alcho-re*" *solder cream* (*non-corrosive*) safety cream for electrical, radio and delicate instrument work. The residue flux is harmless and cannot cause corrosion or acid action under any circumstances. Officially approved M.A.P. on W/T list 1,000, and releasable A.M. 705.

"*Fryolene*" *solder cream* (*non-corrosive*) suitable on brass, copper, chrome, nickel, iron and steel. It is not recommended for use on tinplate, terneplate, or for electrical duties.

"*Fryolux*" *solder cream* (*active*) somewhat similar to "Fryolux" paint above mentioned, but slightly greasy in consistency. It cannot be thinned down as in the case of the solder paint.

Information sheet No. 50 gives general details.

Fry's Metal Foundries, Ltd., Tandem Works, Merton Abbey, London, S.W.19.

Masteradio Vibratorpacks

Masteradio Vibratorpacks are complete H.T. power systems for use on either 6 or 12 volt accumulators (input voltage should be stated when ordering). No H.T. smoothing chokes are fitted or electrolytic condensers but R.F. noise suppression filters adequate for normal use such as operating broadcast receivers or L.F. amplifiers are included. Typical output is 300 volts, 100 mA., and overall efficiency 85 per cent.

The Standard Vibratorpacks occupy a space $5\frac{3}{8}$ in. by $4\frac{1}{2}$ in. by $5\frac{3}{8}$ in. high, and weigh only approximately 6 lb. These packs are designed to deliver their outputs as unsmoothed D.C., but can also be supplied as complete units with smoothing.

The "B" type Vibratorpacks can alternatively be supplied without rectifying valve, their outputs being A.C. with a frequency of 115 c/s.

Masteradio, Ltd., Vibrant Works, Rickmansworth Road, Watford.

OCTOBER MEETINGS

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

Institution of Electrical Engineers

London Section

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

Ordinary Meeting

On October 5, at 5.30 p.m., the Inaugural Address as President will be given by Sir Harry Railing, D.Eng.

Radio Section

The next meeting of the above section will be held at 5.30 p.m., on October 11, when the Inaugural address as Chairman will be given by H. L. Kirke, Esq.

On October 25, at 5.30 p.m., a lecture will be given by Professor Willis Jackson, D.Sc., D.Phil., and J. S. A. Forsyth, B.Sc., entitled "The Development of Polythene as a High-Frequency Dielectric."

Informal Meeting

The next meeting will take the form of a Discussion on "The Engineer's part in certain Post-War Problems," and will be held on October 23, at 5.30 p.m. The Discussion will be opened by the President.

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

Students Section

A "Brains Trust" Meeting will be held on Monday, October 16, at 6.30 p.m.

The panel is composed of:

Sir Stanley Angwin, Sir Noel Ashbridge, Sir John Kennedy, Dr. C. C. Paterson, Mr. A. G. Ramsey, and Mr. J. W. J. Townley. Question Master: Mr. C. C. Barnes (Section Chairman).

Section Secretary: R. G. Stefanelli, 19 Effingham Lodge, Surbiton Crescent, Kingston, Surrey.

Institution of Electronics

North-West Branch

A meeting will be held at 6.30 p.m., on Friday, October 27, at the Reynolds Hall, College of Technology, Manchester. Dr. J. A. Darbyshire will lecture on "Hot Cathode Mercury Vapour Rectifiers."

General Secretary: L. F. Berry, 14 Heywood Avenue, Austerlands, Oldham, Lancs.

Institute of Physics

Electronics Group

At a meeting to be held on October 31, at 5.30 p.m., in the Rooms of the Royal Society, a lecture will be given by S. Rodda, B.Sc., F.Inst.P. (The Cosmos Manufacturing Co., Ltd.), is entitled "Beam Tetrodes."

Group Secretary: A. J. Maddock, M.Sc., F.Inst.P., Messrs. Standard Telephones and Cables, Ltd., Oakleigh Road, London, N.11.

Brit. I.R.E.

London Section

On October 19, the Annual General Meeting will be held (postponed from September 1). Members only.

Midlands Section

The next meeting will be held on October 25, at the University of Birmingham. A paper will be read by Dr. H. Moss (Messrs. A. C. Cossor, Ltd.) on "The Electron Gun of the Cathode Ray Tube."

The Television Society*

An Extraordinary General Meeting for Members only will be held on Saturday, October 28, at the Institution of Electrical Engineers, Savoy Place, W.C.2., at 2.30 p.m.

This will be followed by a paper: "New Types of Test Gear for Television Production," by P. D. Saw (Mervyn Sound & Vision Co.), with demonstrations. Visitors are invited to this meeting, which commences at 3.30.

Lecture Secretary: G. Parr, 43 Shoe Lane, E.C.4.

General Secretary: O. S. Puckle, 8 Mill Ridge, Edgware, Middlx.

Association for Scientific Photography*

The next meeting of the above will be held on October 14, at the Caxton Hall, Westminster, at 2.30 p.m. Two papers will be read: (1) Cinemicrography of Crystal Growth," by H. Emmett, F.R.P.S., and (2) "Cinemicrography in Biological Research, by R. M. Weston, M.A., F.R.M.S.

The Secretary: Association for Scientific Photography, 34 Twyford Avenue, Fortis Green, London, N.2.

CORRESPONDENCE

Coding Components

SIR,—Mr. Hurran's proposition for coding components, as outlined in your Editorial (July 1944) is of great interest as a time and labour saving device. For some years past I have been using a similar scheme for making notes on electrical circuits and found it extremely helpful. Of course, even greater advantage could be derived from what I would call an indicative coding system if it formed part of the information supplied by the makers of electrical instruments in their various instruction and service sheets. A pictorial representation of a resistance panel with the resistances all bearing their code numbers or signs according to, say, Mr. Hurran's scheme, would then convey about all the information one wishes to have on a panel.

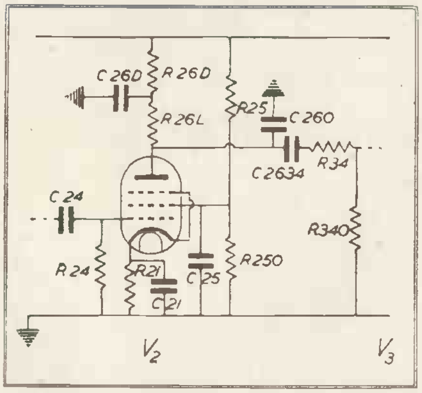
It appears to me that on the whole, it is not necessary to indicate the electrical function of a part directly by its code sign as the circuit position of the element will leave the investigator in no doubt as to that point. My code sign is therefore, mainly based on the position of the element within the circuit with which it is associated and consists of :

(1) An initial letter (C, R or L) denoting the nature of the component in the usual manner, taking no account of its circuit position.

(2) A first digit relating to the number of the valve with which the element is associated. The numbering of valves, has, of course, to follow the progress of the function which the circuit is made to perform.

(3) A further digit refers to the electrode of the valve, to which the element belongs. For numbering electrodes there is the existing system of the Automatic Coil Winder Co., used with many of their Avo Valve Testers, fitted with rotary switch units for the selection of electrodes, and as this way of numbering is known to quite a few engineers, there is no reason why it should not be adhered to. The numbers in question are :

0 Chassis.
1 Cathode.
2, 3 Heater.
4 Grid.
5 Screen grid.
6 Anode.
7 Auxiliary grid.
8, 9 Diode anodes.



(4) In order to avoid ambiguity, it is sometimes useful to add a further digit indicating where the respective circuit element terminates. Thus, in a potentiometer supply, the screen of the 3rd valve R350, will be the resistance returning to chassis, while R35 will obviously be the one which terminates on the H.T. line.

When several resistances belonging to, say, the anode circuit of the same valve are connected in series, they can be best distinguished by a suffix letter ; L for load or D for decoupling could be used conveniently and without putting an extra strain on one's memory. Similarly, B for bypass and C for coupling can be used as suffixes, where necessary.

As to the objection that with the introduction of some system into coding, " yet another table of symbols will have to be memorised by the engineer, I should say that this will not be a table to increase, but to decrease, the burden on the engineer's memory. The Chinese, whose memory is badly overburdened by something like 5,000 symbols of word-writing, could not reasonably complain over the introduction of yet another 26 symbols, which would be necessary for a switch-over to the use of our more economical alphabet.

The coding of constituents of a resistance—capacitance coupled pentode amplifier is given above as an example.

Yours faithfully,

M. L. TELCS, Ph.D.

Aeronautical and General Instruments Ltd., Croydon.

Editorial Note

With reference to Mr. Pennell's letter (September issue, p. 170), several correspondents have written to point out that the standard abbreviation for " micro " is μ and not *m*, and that the abbreviation for Farad is F and not *f*, which is frequency.

Mr. H. T. Stott (Messrs. A. F. Bulgin) advocates the omission of the comma in writing large numbers, and the insertion of a space, *e.g.*, 10 000 instead of 10,000, as is the practice in some technical journals. He also considers $\mu\mu$ for " micromicro " cumbersome, and does not approve of " K " for a prefix for thousands of ohms.

In thanking all correspondents for their trouble in writing, we may point out that the B.S.I. in the Glossary of Electrical Engineering Terms (B.S. 205 : 1943) recommend p or $\mu\mu$ for micromicro-, and "k" for kilo-, an accepted, if inconsistent, prefix. Our own policy is to follow the B.S.I. recommendations except where conditions (including the author's personal tastes) indicate a close alternative with good reason.

When we have more time and staff to correct MS., the B.S.I. Symbols will be adopted throughout. In the meantime, authors would assist us by referring to B.S. 205 and B.S. 403 when preparing articles.

Cathode Ray Tube Traces

Errata

The following minor errors, mainly typographical, have occurred in the series of articles "Lissajous Figures" concluded in the last issue. Please make the necessary corrections to the original pages.

Article 1. (*June*, 1944).

Page 24, col. ii. Under " Special Case," para. 2, for " an even multiple thereof " *read* " an even multiple of $\pi/2$."

Article 2. (*July*, 1944).

Page 65, col. i. Under " Case (2) Simple Lissajous Figures," para. 2, for—

" corresponding to a variation of θ from α to $2\pi + \alpha$."

read

" corresponding to a variation of θ from α to $2\pi p + \alpha$."

Page 65, col. ii, para 2. For "and the lines $y = -B$ . . . ." read " and the lines $y = +B$, $x = +A$."

Article 4. (*September*, 1944).

Page 112, col. ii, para 4. For " double harmonic term in the ' Y ' axis " *read* " double harmonic term in the appropriate axis."

ABSTRACTS OF ELECTRONIC LITERATURE

INDUSTRY

Polythene and its use as a Dielectric
(E. G. Williams)

The author outlines the principal physical, chemical and electrical properites of polythene, and gives details of its present uses as a dielectric. Outstanding properties are its low specific inductive capacity and its low power factor.

—*P.O.E.E. Jour.*, Vol. 37, Part 2, July, 1944, p. 40.

New Crack Detector—R.F. Apparatus

A brief description is given of apparatus of new design for detecting cracks in metals which is being marketed by Salford Electrical Instruments, Ltd. It depends for its action upon skin effect and with appropriate choice of frequency surface cracks of extremely shallow depth can be detected. Wire, strip or bar stock can be examined in continuous lengths at any speed up to 1 ft. per second by passing through a suitable coil connected to the radio frequency generator. Crack indication may be by lamp, bell or meter calibrated to give depth of crack for any particular material. Ferrous or non-ferrous materials from 0.05 in. to 2 in. dia. or width may be examined and cracks from a minimum depth of 0.0005 in. upward can be detected.

—*El. Rev.*, 28/7/1944, p. 125*

An Electronic Defectoscope
(A. Gozelik et. al.)

For continuously testing steel rails a detector is passed over them at fairly high speed, the variation in magnetic field strength close to the surface of the detector being measured electrically.

For this purpose, a special valve consisting of a straight wire hot cathode placed at the centre of a semi-cylindrical anode is employed. The glass bulb has a flat top, the cathode being in close proximity to its internal surface and facing the concave surface of the anode. The latter is connected to the grid of a normal amplifying valve the anode current of which is measured on a milliammeter or cathode ray oscillograph. The grid bias and loading resistances of the circuit are such that when the detector valve is in a constant magnetic field, the anode current of the amplifier is zero. On passing the flat glass top of the detector over the specimen under examination, any variation of field strength from this normal distribution changes the path of the electrons in the detector and thus alters the grid voltage of the amplifier with the result that the recorder operates.

—*Met. Ind. Rev., U.S.S.R.* Vol. 19, No. 7, 1939.†

Non-Destructive Testing of Non-Ferrous Semi-finished Metal Products by new Magnetic Induction methods.
(W. Schirp)

The magnetic induction method for the inspection of non-ferrous metals depends on the fact that the apparent resistance of a coil fed with high-frequency alternating current and surrounding the specimen varies with the dimensions and electrical conductivity of the latter. The method is primarily suited for tubes, rods or profiles of nominally constant cross-section which can be passed through the coil. Flow rates as high as 1 m/sec. can be maintained through the apparatus, which normally is provided with two test coils forming the opposite arms of a Wheatstone bridge. An EMF of sonic frequency is applied and the out of balance current after amplification can be observed on a cathode-ray oscillograph and will operate an electronic relay as soon as certain limiting values are exceeded.

When testing for consistency of dimensions or constitution (hardness or heat treatment, type of alloy, etc.) the specimen under investigation passes through one of the coils while the other surrounds a stationary reference sample. Dimensional errors are separated from those due to heat treatment, etc., by changes in phase displacement of the cathode ray record. The sensitivity of the inspection is not sufficient to record cracks or other internal faults (inclusions).

Such faults are detected by passing the specimen through both coils in succession, the coils being placed in close proximity to each other. Under these conditions, changes in dimension or constitution of sample (unless they are abnormal) will affect both coils equally, each crack or fault on the other hand giving rise to two discontinuities in the record (a crack smaller than the longitudinal dimension of the coils is recorded twice as it passes through the two coils while for longer cracks, the beginning and end of the fault is recorded). It is obvious that by duplicating the circuits and recorders and employing three search coils spanning the specimen while a fourth surrounds the standard, the fault testing can be carried out simultaneously with inspection for dimensions and heat treatment.

—*E. T. Z.* Vol. 64. No. 31/32. 12.8.43, pp. 413/44.†

THERMIONIC DEVICES

Electronically Controlled Dry-Disk Rectifier
(A. Rosenstein and H. N. Barnett)

The various types of dry-disk rectifier and their characteristics are reviewed. The basic elements of the regulated rectifier consisting of a specially-designed filter, a source of constant d.c. potential, a high-gain d.c. amplifier, thyratron-controlled saturating reactors and the selenium-oxide-rectifier disks with their associated transformer, are described and the filter design, saturating circuit and performance discussed. It is claimed that extremely close control is possible with the circuit given, which is relatively simple.

—*El. Engg.* January, 1944, pp. 21-23.

Electron Microscope Determination of Surface Elevations and Orientations
(R. D. Heindenreich and L. A. Matheson)

The methods of determining object thickness in electron microscopy are briefly reviewed. Uncertainties in interpretation of surface replicas from a consideration of intensities alone are discussed and three different replicas of etch figures in pure aluminium are presented. The analysis of the stereoscopic method and the derivation of an equation relating the parallax of image points in stereo micrographs to the elevations in an object are given. A new cartridge for obtaining stereo micrographs at an angle of 10° and for making measurements as small as 150 ± 50 A is described. Exmples illustrating different orientations of pearlite in steel and the scratches on a polished steel surface are given.

—*Jour. App. Phys.* May, 1944, p. 423.*

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

† By courtesy of R.T.P. Section, M.A.P.


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THE ALL-GLASS TECHNIQUE
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BOOK REVIEWS

Heaviside's Operational Calculus Made Easy

T. H. Turney, Ph.D., M.Brit.I.R.E. 96 pp. (Chapman and Hall, 10s. 6d. net.)

A chatty colloquial style is adopted in this book, which is modelled on Silvanus Thompson's "Calculus Made Eeasy." Readers are likely to be sharply divided into those who like it and those who are irritated by it.

The author has set himself the task of explaining the meaning and purpose of Heaviside's operator and unit function to the student of limited mathematical training and with little or no knowledge of the exponential function. An elementary knowledge of calculus is however assumed. The first chapter discusses the application of differential calculus to inductance and capacitance. A valuable feature of this chapter is a table showing the shapes of the current waves in inductances and capacitances for different input voltage wave shapes. Chapter 2 deals with the Heaviside operator and unit function and shows how the former can be treated as a normal algebraic function; a note might be included to the effect that "D" is sometimes used in place of "p" for the operator. The solution of the damped oscillatory circuit and exponential expressions for sine and cosine are given in the next chapter and again the author would be advised to stress at this stage that "j" is the electrical engineer's symbol for "i." The infinite and distortionless cables form the subjects of Chapters 4 and 5. The relationship between the work of Heaviside and Fourier is brought out in Chapter 6 and further elaborated in Chapter 7.

A statement at the beginning of Chapter 6 that analysing a square wave into sine wave components gives a "fundamental sine wave, which is bigger than the square wave" is incorrect. The actual amplitude of the author's square wave is 2E so that the ratio of fundamental to square wave amplitude is $4E/\pi$ to 2E. Neither chapter will prove easy for the student of limited mathematical knowledge. One of the rare misprints occurs on page 44 $\epsilon^{(-1i-)t}$ should be $\epsilon^{(-1-i)t}$.

K.R.S.

A Guide to Cathode-Ray Patterns

Merwyn Bly (Chapman & Hall, 8/6 net).

This book is a collection of sketches of typical cathode-ray tube traces with short descriptive captions.

Each chapter is also prefaced by notes on the method of obtaining the traces and the conditions under which they were obtained. The types covered are: Lissajous figures, Modulation Patterns, L.F. and H.F. Response, Resonance Curves, and Valve characteristics.

The book should be handy for beginners in 'scope work, as Mr. Bly would say.

CLASSIFIED ANNOUNCEMENTS.

The charge for miscellaneous advertisements on this page is 12 words or less 4/- and 4d. for every additional word. Box numbers (4 words) plus 1/- extra. Remittance should accompany advertisement. Cheques and P.O.'s payable to Hulton Press Ltd., 43 Shoe Lane, E.C.4. Press date—15th month for following issue.

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5,000 .5 MF/600 volts D.C. condensers 2" wide, ¾" deep, 4½" high. All in new condition. Best offer required for immediate sale. Box No. 5037, G.T.C., 21/41, Wellington Road, London, N.W.8.

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