# ELECTRONIC & RADIO ENGINEER

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## In this issue



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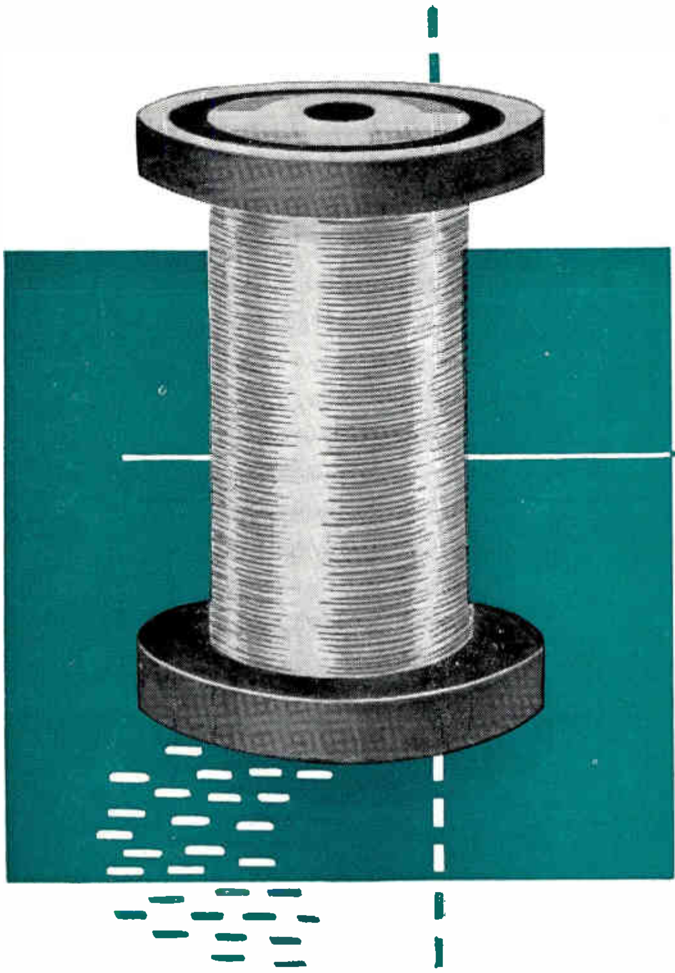
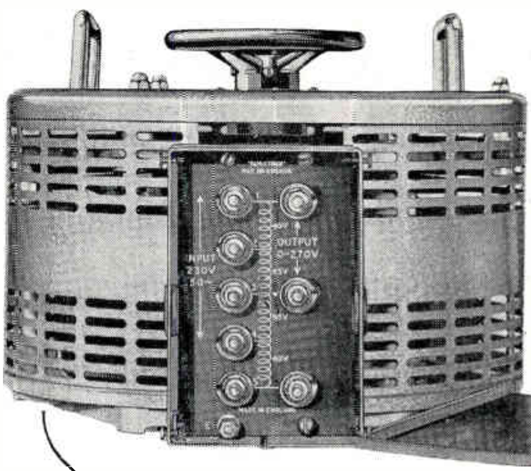
MAY 1957 Vol 34 *new series* No 5





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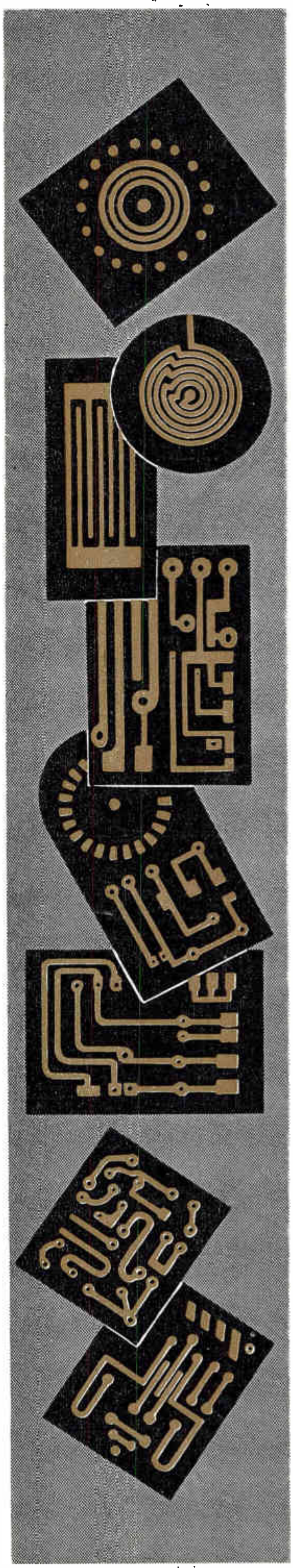

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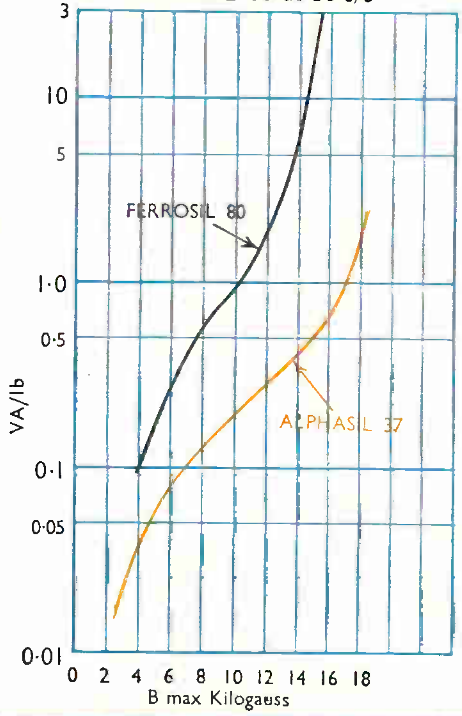


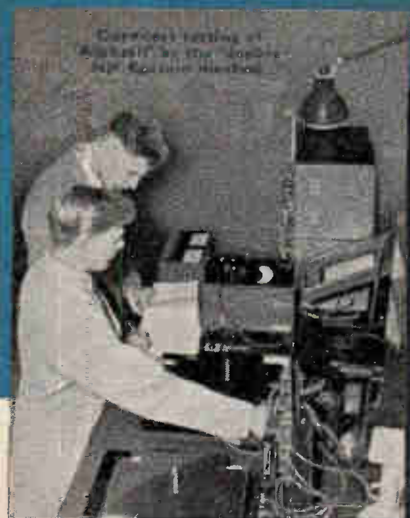

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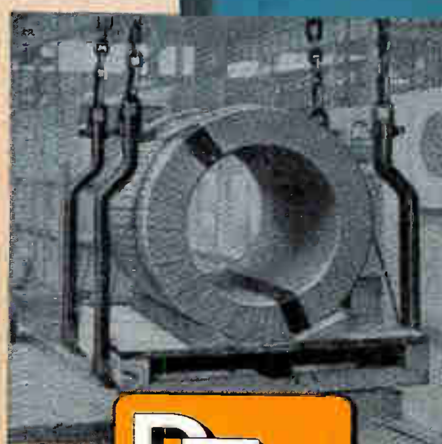
| ALPHASIL ·004HF | 400 | 8·00 watts/lb. |

*Full technical data will be supplied on request.*



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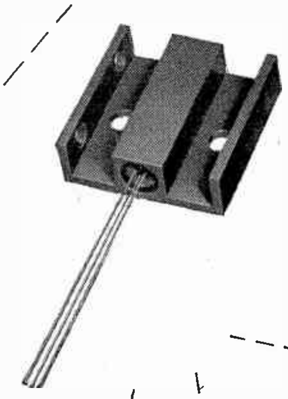

*Full particulars of these devices can be obtained from G.E.C. Valve and Electronics Dept.*

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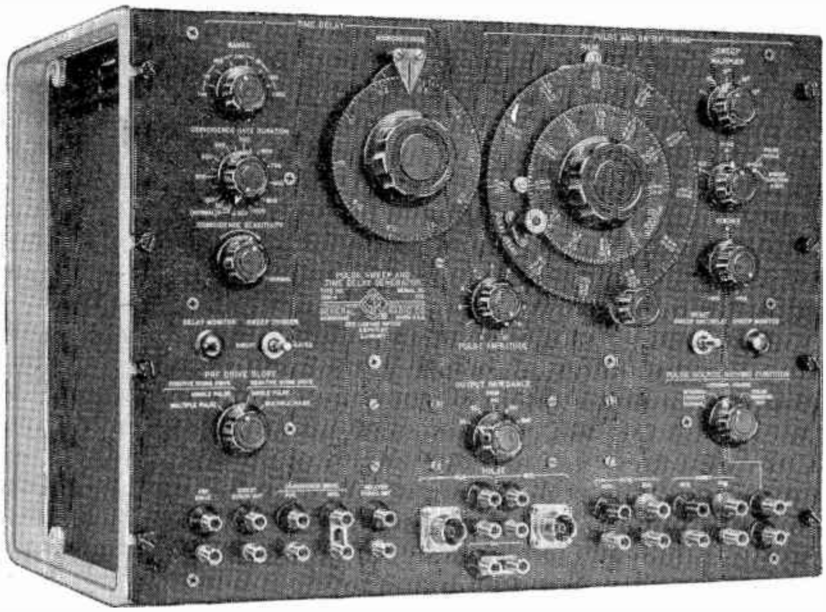

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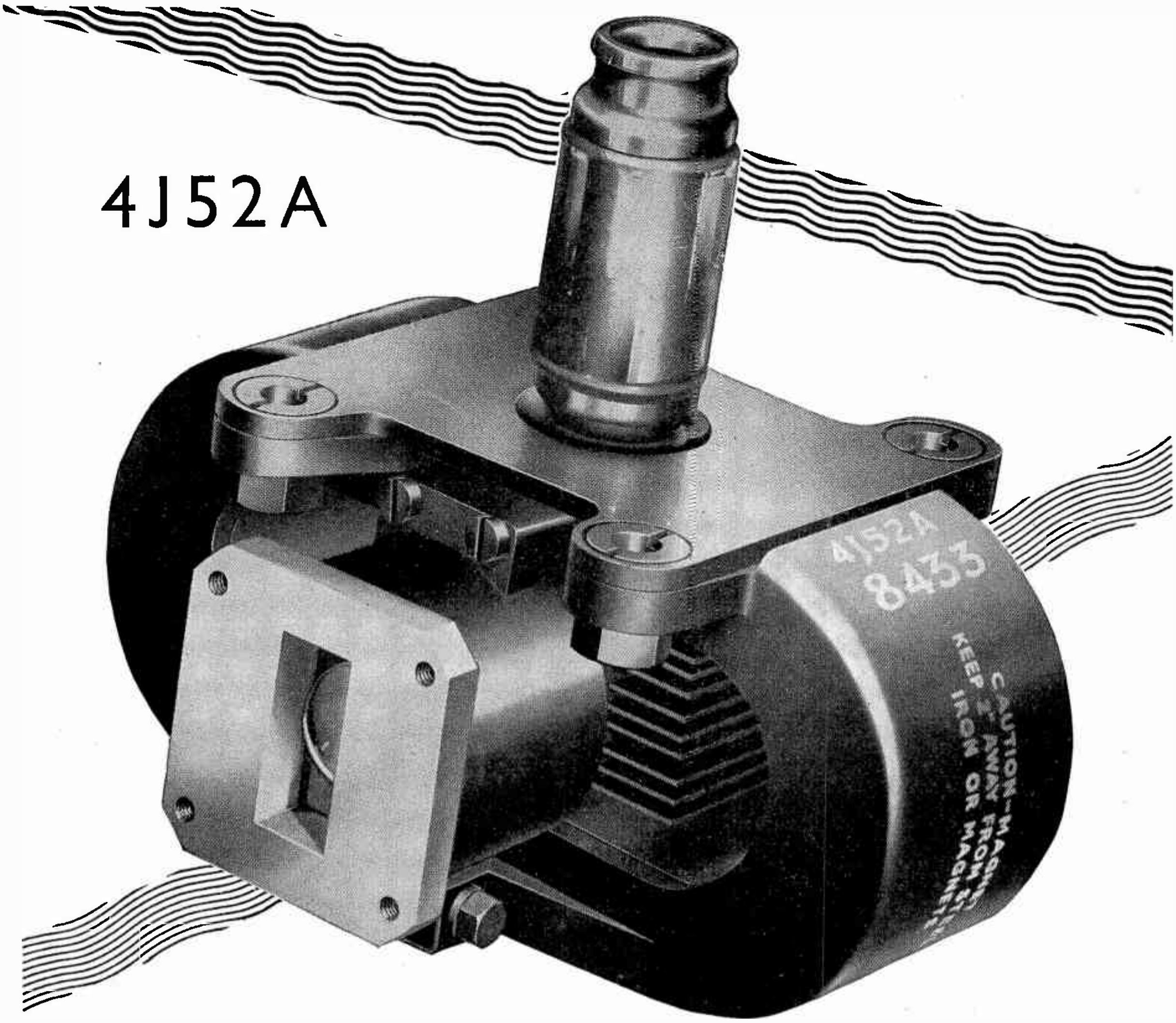


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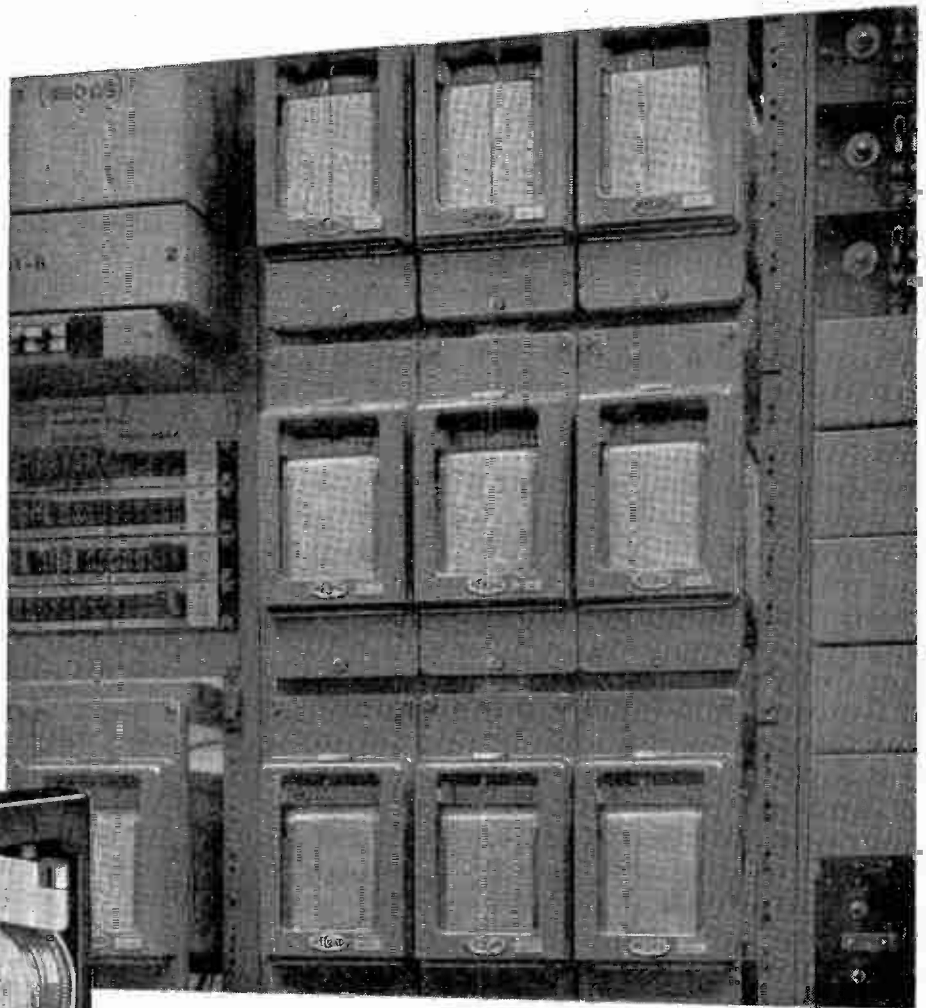

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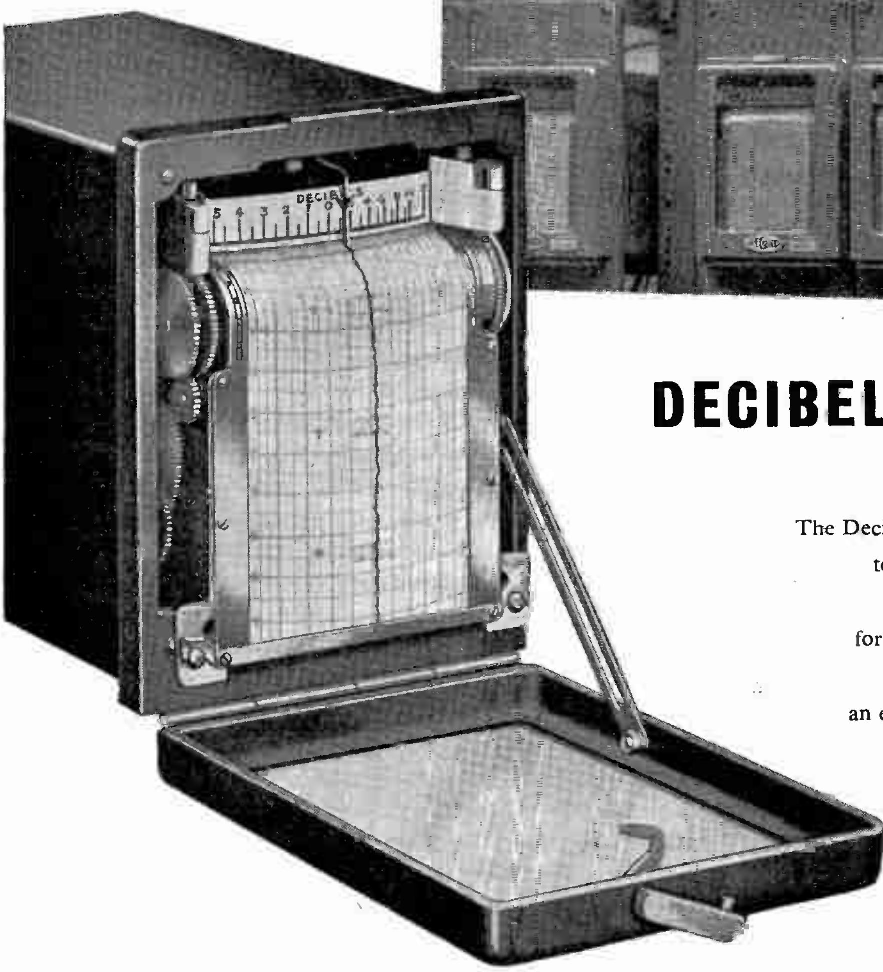

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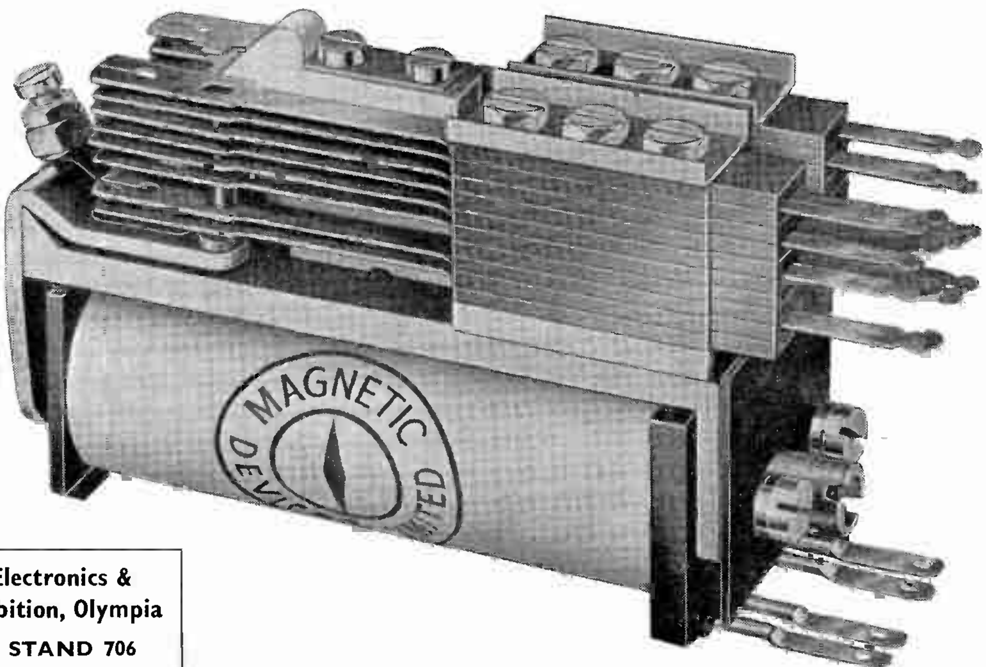


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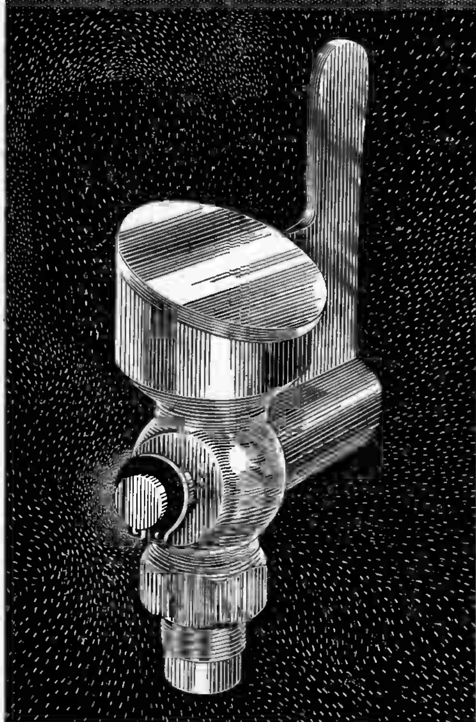

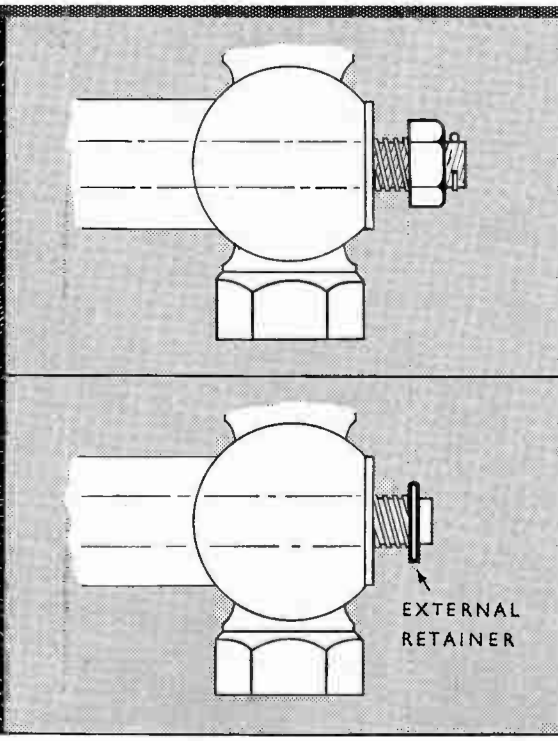


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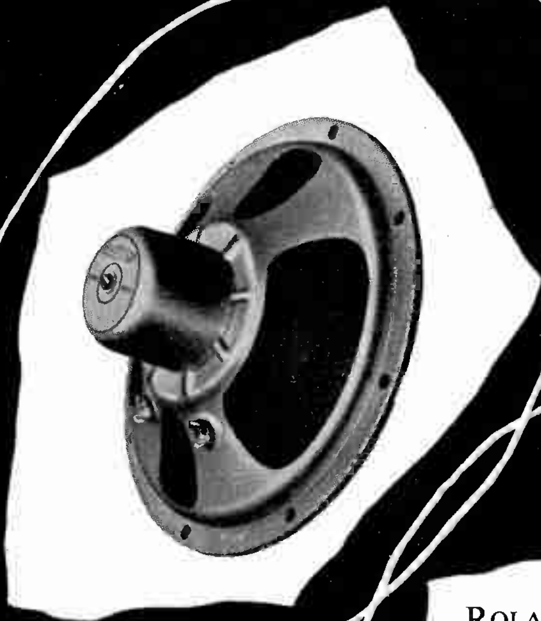

# ELECTRONIC & RADIO ENGINEER

*incorporating* *WIRELESS ENGINEER*



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VOLUME 34 NUMBER 5 **ELECTRONIC & RADIO ENGINEER**

MAY 1957 *incorporating WIRELESS ENGINEER*

# Exhibition Comment

ELSEWHERE in this issue we give an account of some of the apparatus shown at four recent exhibitions and next month we shall deal with the Instruments, Electronics and Automation Show. This is a new venture in exhibitions, which we shall watch with interest.

Of the ones dealt with here, the Physical Society's retained its usual character and covered research items, instruments and test gear. The R.E.C.M.F. exhibition seemed to us to have changed slightly and to be now primarily a components show, with test apparatus taking very much a second place. We found much less overlap between the two exhibitions than in previous years.

The Third International Show was a relatively small exhibition devoted mainly to foreign test and measuring equipment, while the Electrical Engineers' Exhibition was, in the main, outside our field, but did contain a few items of electronic interest.

There is no doubt at all about the popularity of exhibitions in our field. The principal ones were at times most uncomfortably crowded and visitors needed to be extremely fit, both mentally and physically, if they were to derive much benefit from them.

Our review indicates the main exhibits with perhaps some stress on the research items, as being indicative of future development. If we were asked to summarize in a few words the main trend of development, we should say miniaturization and transistorization, if we may be excused these rather horrible, but expressive, words. The two are compatible and, indeed, the extremes of the first cannot be obtained without the aid of the second. A third trend, at present somewhat incompatible with the others, is high-temperature operation, but, as the temperature limits of semiconductors are continually increasing, he would be a bold man who would dare to say that this incompatibility will persist for long.

# The Myriatron

IMAGE DISSECTOR FOR HIGH-SPEED CINEMATOGRAPHY

**By G. H. Lunn* and R. A. Chippendale, B.Sc.†**

Many techniques involving the use of image tubes as optical shutters for high-speed photography have been described [1–5]. The operating principle of the image converter is outlined in Fig. 1.

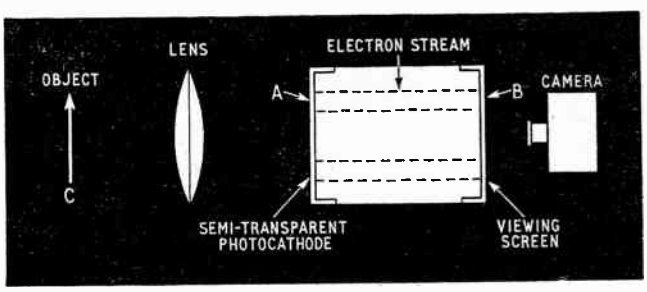
Any object C is imaged on to the photocathode A. The resulting photo-electrons are accelerated by a voltage of up to about 25 kV to form a visible image on the aluminium-backed fluorescent screen B. Since the aluminium layer on the phosphor can be opaque to light, the camera, with lens open, will not record unless the accelerating potential is applied to the image converter. It can be seen that the efficient shuttering action of the device depends on the application of square voltage-pulses to the tube. For single-shot recording in the microsecond region many techniques have proved quite satisfactory, and Saxe[6,7] has been able to operate with 20-kV pulses of a few millimicroseconds duration but, when attempts are made to operate repetitively with a series of pulses (e.g., $10^{-7}$ sec pulses, $10^{-6}$ sec apart), it is found that the afterglow of the fluorescent screen (down to $1/e$ in 15 $\mu$sec) makes recording of discrete pictures impossible.

The problem of multiple-frame recording at the high speeds indicated above has, in the main, been tackled in two ways. Walker[8] has used another type of electron-optical shutter, the Kerr cell, combined with a high-speed rotating mirror, whereas Sultanoff[9] and Courtney-Pratt[10] have developed new cameras using image-dissection methods. It is the combination of this latter principle of image dissection with the image converter shutter which has given rise to the myriascope.

The tube is similar to the image converter of Fig. 1 except that the myriatron's photocathode is active only in small areas 0·001 in. square, 0·01 in. apart (centre to centre). The picture of an object seen on the fluorescent screen is therefore equivalent to what would be seen if the object were viewed by eye through an opaque screen pierced with a corresponding regular array of small square holes. In fact, one would then be looking at a 1% sample of the object, since the total clear area is 1/100 of the opaque area.

* *A.W.R.E., Aldermaston.*
† *Siemens-Ediswan Research Laboratories, lately with Mullard Research Laboratories.*

Fig. 1. *The image-converter principle*



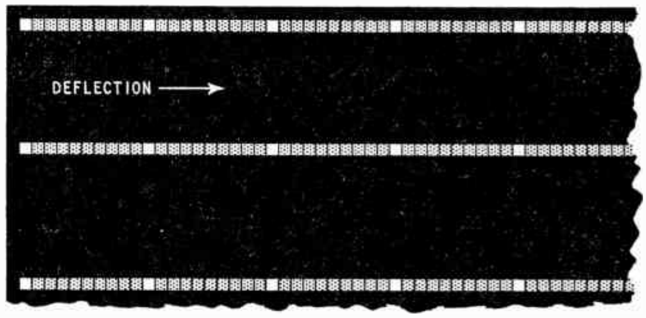
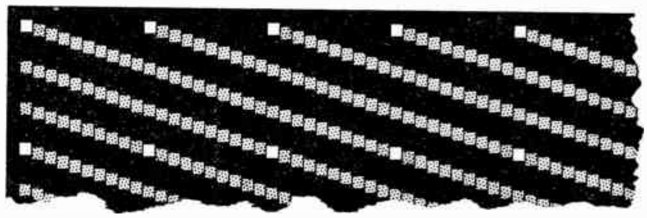




Fig. 2. *Forms of dot pattern on the fluorescent screen*

Fig. 3. *Scanning pattern whereby the cathode pattern is moved over the screen*



The image produced upon the viewing screen is a similar tenuous mosaic and, consequently, only 1/100 of the area of the fluorescent screen is energized. The decay characteristics of the screen after the excitation ceases are thus operative only for this small area of the whole. The rest of the screen is thus available for other 'pictures'.

The photo-electrons from the cathode form parallel beams, one for each active area, and the whole set of beams can be moved over the fluorescent screen by deflecting fields. At the beginning of a transient light signal, these beams may strike the screen at the positions shown white in Fig. 2. If the electrons are steadily deflected horizontally and to the viewer's right, they will

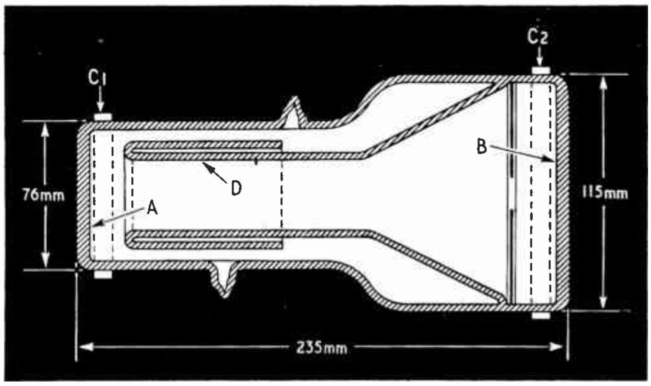



Fig. 4. *Outline diagram of the construction of the myriatron*

strike the screen successively at the points shaded grey, giving rise to a continuous series of sampled pictures. With the system of deflection shown, movement through nine spot widths is possible before the luminous squares reach positions which were occupied by adjacent squares at the start of the scan. Thus, ten sample pictures can be obtained. In practice, a camera would be focused on the screen and would record all ten on the same negative. The most obvious way of sorting out individual pictures (though it is not used in practice) is to view a print of the photograph so obtained through an optical screen similar to that described above. Sample pictures corresponding to successive instants of time could then be obtained by moving the screen about.

The system of scanning shown in Fig. 2 is not the best possible, since only 10% of the screen area is utilized. A better method is to deflect obliquely as in Fig. 3. This enables more individual pictures to be obtained. The limit to which this technique can be carried without serious overlapping of adjacent lines is 60 pictures per scan[14]. The relationship between line spacing and number of pictures is shown in Table 1.

The spacing is expressed as a decimal of the side of each square showing that overlapping occurs with a 100-picture scan.

## The Myriatron

The tube is a diode constructed of hard borosilicate glass as shown in Fig. 4. The photocathode A and aluminium-backed fluorescent screen B (ZnSAg.) are deposited on polished flat end-plates, connection being made by tungsten seals through the envelope to external contacts $C_1$, $C_2$ for cathode and anode respectively. The aluminium layer on the fluorescent screen is extended as a metallic coating on the surface of the glass re-entrant D which terminates 12 mm from the cathode. In the preparation of the photocathode, an opaque reflecting layer of aluminium is deposited on the internal glass surface in the patterned form described earlier. On top of this is laid a conventional semi-transparent Sb-Cs photocathode[11,12] giving as an operative area a one-inch circle with 100 small squares

TABLE 1

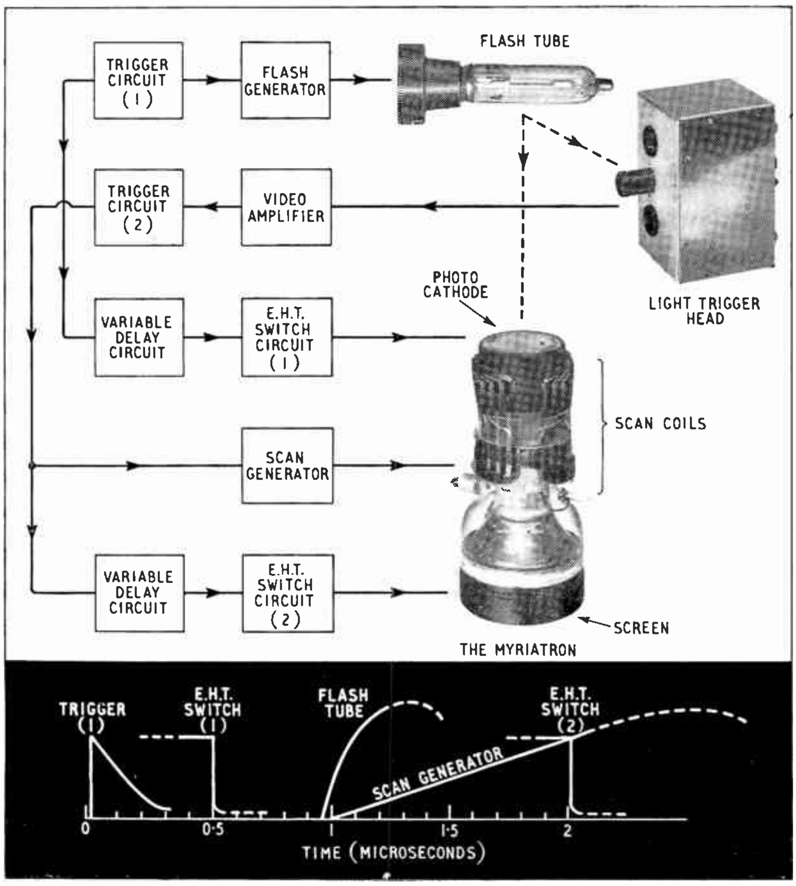
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number of pictures .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 |
| Line spacing .. | −0·2 | 0 | +0·15 | +0·2 | +0·36 | +0·7 | +1·0 |

per diameter. Electron-optical focusing and an image magnification of four times are achieved by means of a short coil around the photo-cathode end of the tube. In this respect the device is identical to the Mullard ME1201 image converter[13].

## Magnetic Deflection Method

The passage of a current through two suitably designed saddle coils placed around the image tube will result in a displacement of the image on the screen. Much work has been done on magnetic deflection for image converter streak cameras[15]. Usually, the event is imaged on to a slit and the slit image focused on to the photocathode. The line image so produced at the screen is then deflected at right angles to itself to give a streak picture. From the record obtained, the changes within the slit during the time of the exposure can be observed. In this technique, it has often been necessary to deflect the

Fig. 5. *Block-schematic diagram of equipment for the observation of 100-joule arditron discharge*



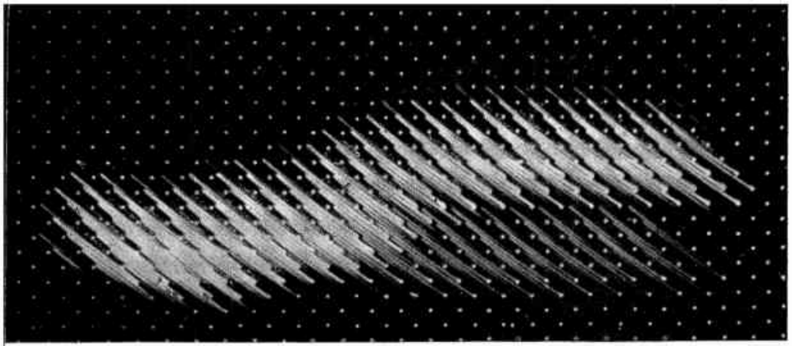


Fig. 6. *Record of arditron flash taken with myriatron*

image as much as $\frac{3}{4}$ of the screen diameter in $10^{-6}$ sec. In the myriascope, a displacement of only 1/20 of the screen diameter in $10^{-6}$ sec is needed to produce an estimated picture rate of $5 \times 10^7$ per second, and this is readily achieved with standard methods.

Coils with distributed windings are used as these have been found to give a minimum of image distortion. The details of a typical coil with five sections in each half (see Fig. 5) are given in Table 2.

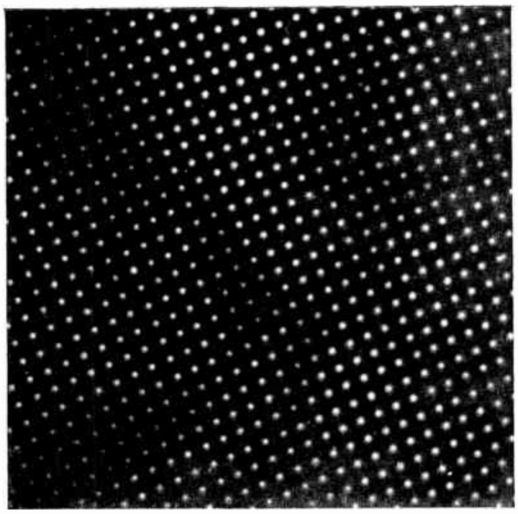
With 185 turns in each half, a coil of this type is suitable for scans of 100 $\mu$sec, a current of 100 mA being sufficient for the type of scan shown in Fig. 6. In general, a 1-in. deflection at the image-tube screen requires between 100–200 ampere-turns, but this is only a guide to design, as the value depends on tube voltage and focus current.

The deflection can be either linear or exponential

TABLE 2

| | | | | | |
|---|---|---|---|---|---|
| Angle included by main sides of section .. .. .. | 40° | 70° | 100° | 130° | 160° |
| Winding ratios (If there are *xn* turns per section, $x$ = the value given) .. .. .. | 30 | 60 | 75 | 90 | 100 |

with respect to time, both forms having advantages in different applications. At first glance, a linear displacement appears more suitable but many events begin with



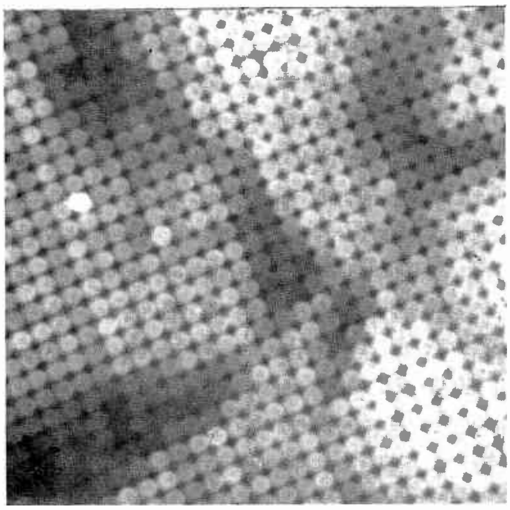
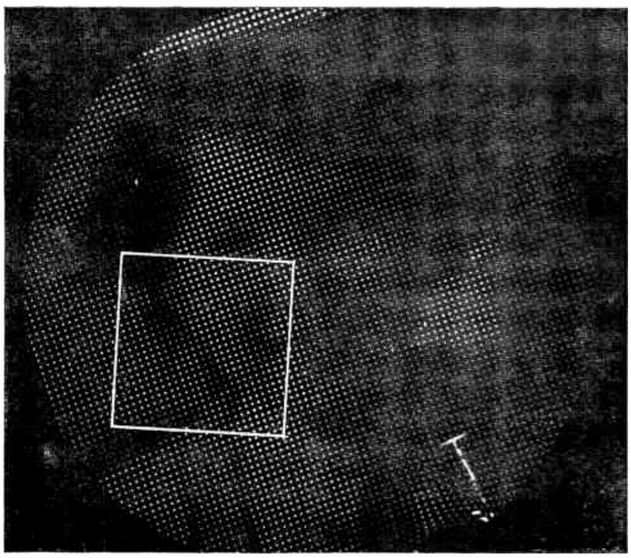
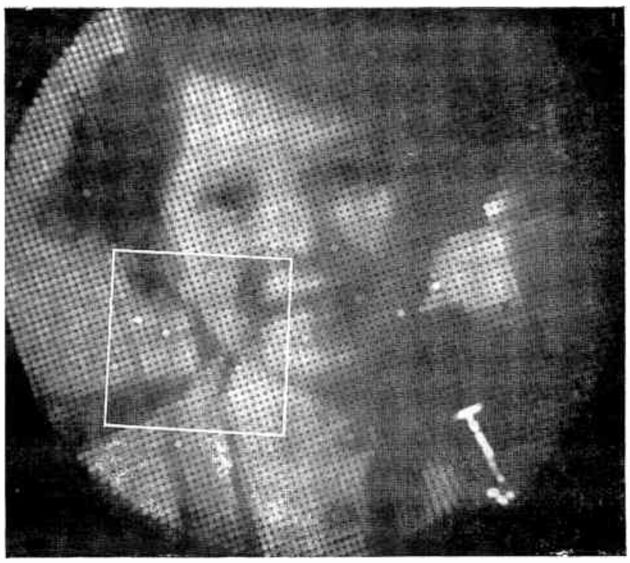


Fig. 9. *Records taken through myriatron; on the left the record is printed in focus showing growth of dot size with over-exposure; on the right the same record is printed out of focus showing apparent increase in picture information. Above are enlargements of the particular areas bounded by the white rectangles*





a rapid change and then slow down. In these cases, an exponential scan could be very useful as it would give maximum time resolution during the period of greatest change and, at the same time, cover a long period of slow movement.

## Study of a Microsecond Spark Discharge

An arditron flash (100 joules, 10 kV in argon) was chosen as the most convenient transient for testing the myriascope camera. A block diagram of the apparatus is given in Fig. 5 together with the time sequence from the initiating pulse (Trigger 1) to the switching-off of the image tube (Switch 2).

The output from trigger 1 is split, first to fire the flash tube, and secondly to apply a voltage across the image tube. This is done when e.h.t. switch 1 operates and earths the image tube cathode. (In the waiting state both cathode and screen are at 7 kV.)

The scan generator and e.h.t. switch 2 (which terminates the exposure by earthing the screen) are operated from trigger circuit 2, which is fired by a pulse from the light trigger head on receipt of the first light from the spark. On the time sequence diagram, the delay between first light from the flash and the start of the scan is shown as very small ; this is, of course, dependent on the overall efficiency of the light trigger system.

### *The Trigger Units*

These consisted of two 2D21 thyratrons coupled by a simple *RC* integrating circuit. If a variable delay was required, *R* was made variable and *C* switched to provide a series of delay ranges.

### *Light Trigger*

An optical system was used to image light from the flash tube on to a CV.337 photomultiplier from which a pulse of 0·5 volt was fed into a video amplifier, so that pulses suitable for triggering a 2D21 were obtained. It is intended to give a detailed treatment of this and other light trigger circuits in a later paper.

### *Scan Generator*

An EL38 (Fig. 7) was used to feed the scan coils. The valve was biased off with approximately 2·5 kV on the anode. A charging resistance of 2·2 MΩ was used and the value of *C* selected for the deflection speed required. When the amplified light trigger-pulse reached A, the pentode was rapidly driven to conduction and *C* discharged through the scan coils. Only the early portion of the waveform was used and this was almost linear.

### *E.H.T. Switches*

These were large hydrogen thyratrons (5C22) tripped by the basic trigger units noted above. To operate satisfactorily, a large current-carrying capacity and a short reproducible firing delay are needed. In practice, the second switch is satisfactory (i.e., the fluorescent-screen voltage rapidly drops to a value at which luminescence is insignificant) but for the first thyratron the requirements are more critical. In this case the action of the switch entails the charging of the tube self-capacitance and strays until the full anode voltage is reached. The accelerating voltage must not change during a recorded scan as this will cause a change of magnification and introduce distortion. For this reason, and because the charging cycle takes approximately $5 \times 10^{8}$ sec to complete, the first thyratron switch is prepulsed so that the full anode voltage can be applied to the myriatron before the arditron flash occurs. Early switching of the camera in this way does not affect the record as the ambient lighting is too weak to record in the short interval until the spark channel becomes luminous.

## Results

Fig. 6 shows a typical composite record of a 100-joule arditron flash. This is an enlargement of the central portion of the negative as the length of the flash occupied

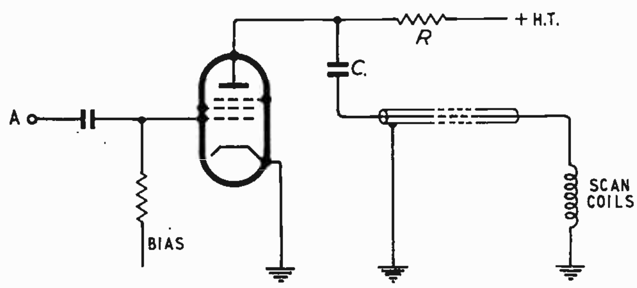



Fig. 7. *Scan generator circuit*

only about one-third of the screen diameter. The timing of this exposure was substantially as indicated in Fig. 5.

The only practical application to date has been this recording of the high-intensity flash-tube discharge, but results of the type shown in Fig. 6 indicate that the recording method operates satisfactorily and that much useful information can be obtained from a visual inspection of the negative. It must be appreciated, however, that the spark record is a special case as it gives what is almost a line image and makes a visual analysis relatively simple. In the case of a transient which may have movement and information over the whole field of view, a special decoding system will be required.

## Record Analysis

Previous cameras based on image dissection techniques (e.g., the Courtney-Pratt camera) have been able to use optical-mechanical methods of analysis. In the case of the myriatron, however, slight distortions introduced by the electron optics make the success of mechanical methods unlikely.

Fig. 8 outlines a promising analytical method which is at present being examined. Compensation for the electron-optical distortions is achieved by 'reading' through the myriatron which made the record. A high-contrast positive is contact-printed from the negative produced by recording through an optical flat (a clean plate stripped of emulsion) as shown in Fig. 8 (a). The positive transparency is now placed [Fig. 8 (b)] with its

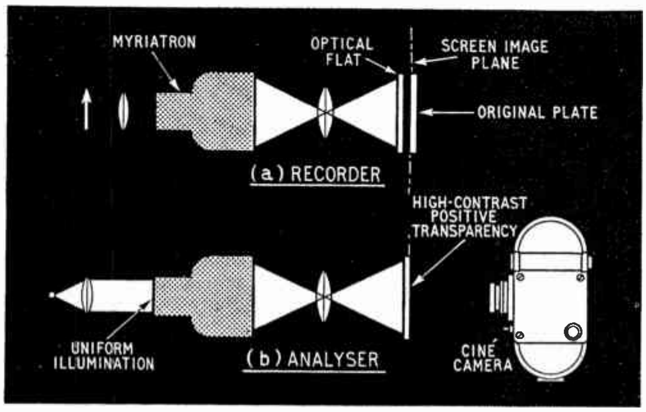



Fig. 8. *Use of myriatron for both recording and analysis; (a) recorder, (b) analyser*

emulsion in the image plane of the lens recording the fluorescent screen and in the exact position occupied by the original negative.

The use of the optical flat for image compensation in Fig. 8 (a) is necessary as the positive transparency is mounted for analysis with its clear glass side towards the image tube. When the photocathode is illuminated uniformly, the 35-mm cine-camera can record individual frames as the luminous dot pattern on the screen is held in different deflected positions by steady direct currents through the scanning coils.

The use of a normal cine-camera would mean that 50 pictures recorded would be projected normally in about two seconds. This could be readily 'slowed down' to 4 seconds by double printing of each picture or 'overlapping' by using half increments in deflector-coil current in the analysis process.

## Conclusion

Although quantitative photographic tests have not been carried out with the myriatron, the tube appears to be much more sensitive than a normal image tube with a continuous semi-transparent cathode. It is thought that a non-luminous object could, given favourable conditions, be recorded at the above picture rate, using flash-tube illumination. As well as an apparent increase in sensitivity, the tube has a marked advantage when recording intensely self-luminous phenomena.

When using a standard image tube of the ME1201 type, some light passes straight through both the photocathode and pinholes in the fluorescent screen, and can spoil the record. In the case of the myriatron, this 'break through' is cut down by at least two orders of magnitude, as 99% of all the light imaged on to the cathode area is reflected back into the optical system by the metallic cathode sub-layer.

At first glance, the picture information contained in the dissected image would appear to be very inadequate but, in many cases, especially where the rapid movement of a sharply-bounded luminous area is being studied, interpolation between dots will be justified and a full spatial distribution deduced for each frame.

Fig. 9, on p. 158, shows a portrait of a child taken through the myriatron. In the print on the left, sharp focus has been maintained and it can be seen that the dot sizes have grown due to overexposure in the highlights.

On the right is a de-focused print from the same negative, giving the effect of much more picture information. There is no doubt that this defocusing technique will be valuable for an appreciation of the records, especially for cine-projection.

One of the limitations of the myriascope lies in the quality of the wide-aperture lens necessary to record the information from the fluorescent screen. The electron-optics of the image tube are such that the 0·001-in. cathode dots are reproduced as sharply-defined squares at the screen but, if we consider the line spacing figures discussed earlier, we find that impracticably high resolution is needed to record more than 50 pictures.

| For number of frames .. | 100 | 90 | 80 | 70 | 60 | 50 | 40 |
|---|---|---|---|---|---|---|---|
| Resolution required .. | | | 6,660 | 5,000 | 2,800 | 1,430 | 1,000 |

(These figures refer to the number of black and white lines per picture width.)

Work is in progress at the Atomic Weapons Research Establishment on the design of an improved wide-aperture reflecting optical system and it is hoped this will lead to the achievement of both increased sensitivity and more pictures per scan.

For further improvement, it is thought that the information per picture could be easily increased by using a larger (2-in. diameter) photocathode to give an equivalent 200-line resolution.

In view of the small scanning displacement required, it is possible that electrostatic deflection could be used without causing prohibitive distortion.

The experimental use of the myriatron in recording the arditron flash has served to show that the method is practicable, and that useful information can be recorded at the rate of 50 pictures in $10^{-6}$ second.

## Acknowledgement

Thanks are due to the Director of the Atomic Weapons Research Establishment, U.K.A.E.A., and to the Directors of Mullard Ltd. for permission to publish this paper. The assistance and advice of Dr. R. F. Saxe, various members of A.W.R.E., in particular E. W. Walker and J. A. Russell, and F. Hall of Mullard Research Laboratories is also gratefully acknowledged.

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# Transistor Bias Stabilization

FEEDBACK CIRCUIT FOR LOW-VOLTAGE OPERATION

By J. Somerset Murray, B.A., A.M.I.E.E.

SUMMARY. *A method of using two transistors in cascade is described which enables the operating conditions of the first to be stabilized to a high degree. As a result, it becomes practicable to operate with a very low collector–base voltage and so to minimize semiconductor noise.*

In valve circuits the operating conditions are commonly stabilized against resistor and valve tolerances by the use of cathode bias. In transistor circuits the same method is impracticable and the basic circuits are, in any case, less stable because of the large effects of temperature.

In the first stage of a transistor amplifier it is usually desirable to keep the collector–base voltage as small as is practicable in order to reduce semiconductor noise. This entails the use of close tolerance resistors, for conventional methods of stabilization are capable of dealing with little more than the effect of temperature changes.

This article introduces a circuit which does for a direct-coupled transistor chain what cathode bias does for a valve. It ensures a usable collector–base voltage however wide the component tolerances. There is also a noteworthy improvement in temperature stability. Indeed, in one case it is possible to obtain nearly complete stability.

Simple ideas applied to transistors can easily be made difficult to grasp if the complete algebra is brought in. The system is explained here, therefore, with the assumption that the transistors are ideal ones; later, some of the imperfections of real transistors will be discussed. The ideal transistor has: $\alpha = 1$, $I_{c0} = 0$, $r_e = r_b = 0$, $r_c = \infty$, $I_b = 0$, $V_{be} = 0$.

## The Problem

An amplifier for low-level signals has been devised and it is now required to supply the d.c. feed arrangements for the first stage. The circuit employs a single battery with about one-third of it used for emitter-current stabilization. So, the first transistor has a voltage pattern as in Fig. 1. The standing current is $I$, so

$$V = I(R_c + R_e) + V_{cb} \quad \ldots \quad (1)$$

(Note: Since $V_{be} = 0$ under the required conditions $V_{ce} = V_{cb}$.)

Again, because $V_{be} = 0$, $V_e = V_b$ and so

$$I = V_b/R_e \quad \ldots \quad (2)$$

Therefore

$$V = \frac{V_b}{R_e} \cdot (R_c + R_e) + V_{cb} \quad \ldots \quad (3)$$

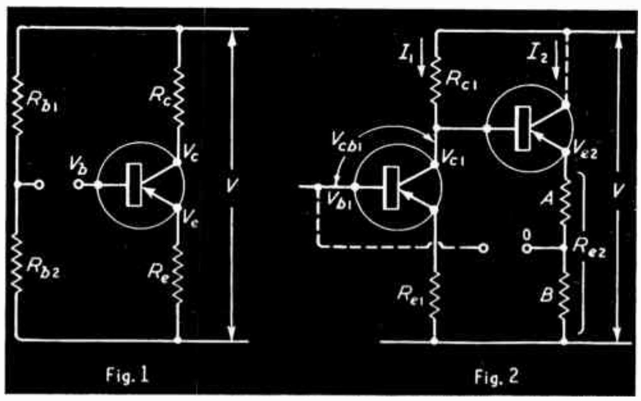
The problem is to design the appropriate value of $V_{cb}$ into the circuit. The classical solution is to determine $V_b$ by means of a potentiometer $R_{b1}$, $R_{b2}$ across the battery. Whereupon

$$V_b = \frac{V \, . \, R_{b2}}{R_{b1} + R_{b2}} \text{ and } V_{cb} = V\left[1 - \frac{R_{b2}(R_c + R_e)}{R_e(R_{b1} + R_{b2})}\right] \quad \ldots \quad (4)$$

The new solution is to make use of the succeeding stage as an emitter-follower to provide a point of potential $V_b$; and, in so doing, make a precise determination of $V_{cb}$ in terms of $V$ the supply voltage, and the product of two voltage dividers (multiplied by a nearly-unity correcting term). This eliminates the variations which can occur with the arrangement of Fig. 1, with which the transistor conditions depend upon the difference between two large quantities, as can be seen from equation (4).

Consider the succeeding stage. This must be either a common-emitter or a common-collector configuration for the system to work (but, as the common-base is rarely wanted after the first stage, this is no real handicap). Whichever of these is chosen, the emitter circuit is the same and unaffected by the collector circuit, because $r_c$ is usually of the same order as the output impedance of a pentode. It, too, will need its base potential fixing by some means. Since $V_{cb}$ and, hence, $V_c$ of the first transistor are going to be determined, we can choose the base potential of the second as equal to the collector

Fig. 1 (*left*). *Conventional stabilizing circuit.* Fig. 2 (*right*). *New circuit in which an emitter-follower $T_2$ provides collector–base voltage stabilization*



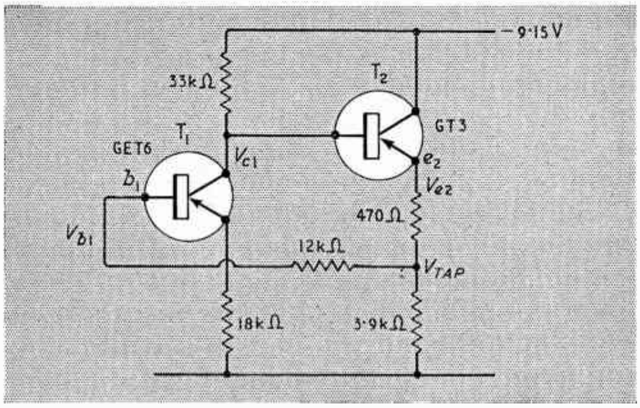



Fig. 3. *Practical circuit with values of components used in the measurements*

potential of the first and then make it so by direct connection. This gives us Fig. 2.

If for $T_2$ we make the same idealizing assumptions as for $T_1$, it follows that $I_2 = V_{c1}/R_{e2}$. Now, $V_{c1}$ will be higher than $V_{b1}$ by the wanted value of $V_{cb1}$. Since $V_{c1} = V_{e2}$, it follows that there must be a point on $R_{e2}$ of potential equal to $V_{b1}$. This point is the point 0 at a potential of $V_{e2} - V_{cb1}$. The final step is to return the base lead of $T_1$ to the point 0.

The first and most important consequence of this type of voltage determination is that we have exchanged the equation for $V_{cb}$ [equation (4)] for a much less critical one. The new equation for $V_{cb1}$ is found as follows:

Consider Fig. 2, assuming ideal transistors,

$$V = I_1(R_{e1} + R_{c1}) + V_{cb1}$$

$$\therefore I_1 = \frac{V - V_{cb}}{R_{e1} + R_{c1}}$$

$I_2$ is determined by $V_{c1}$ and $A + B (= R_{e2})$ and $V_{c1} = V - I_1 R_{c1}$

$$I_2 = \frac{V_{c1}}{A + B} = \frac{V - I_1 R_{c1}}{A + B}$$

therefore,

$$V_{cb1} = AI_2 = \frac{A}{A + B}(V - I_1 R_{c1})$$

Substituting for $I_1$ we get, after a little algebra,

$$V_{cb1} = V \frac{\frac{A}{A + B} \cdot \frac{R_{e1}}{R_{e1} + R_{c1}}}{1 - \frac{A}{A + B} \cdot \frac{R_{c1}}{R_{e1} + R_{c1}}} \quad \ldots \quad (5)$$

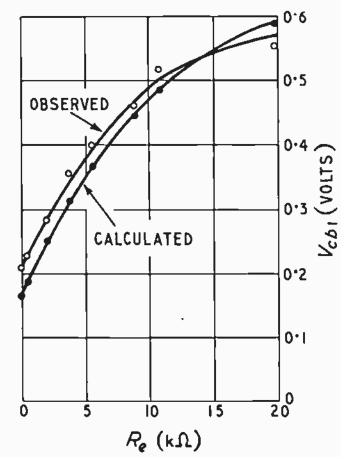
To make use of this equation in practice there must be added two correcting terms, which are both small and can be neglected in comparison with $V$, the supply voltage. The real transistor $T_2$ has a finite $V_{be2}$ and this must be added directly to $V_{cb1}$ in (5). Also, the base current flows through the d.c. resistance joining the base of $T_1$ to the tap on $R_{e2}$. Since $I_{c01}$ also flows through this resistor in the opposite direction, for low values of $I_1$, $I_{b1}$ may be within a few microamps of zero, in either direction. If one assumes that 10 $\mu$A is the maximum base current probable and $R_{b1}$ is limited to 15 kΩ, then the maximum change in $V_{cb1}$ due to this cause is $\pm$ 150 mV. This is of the same order as the base–emitter voltage of $T_2$. It is largely independent of the small changes of current in $T_2$ but is a function of temperature. It is about 150 mV at 20° C and falls to half that value at 45° C due to the increased mobility. It is thus normal practice to add 200 mV to $V_{cb1}$ as found from (5) and expect the result to be correct to $\pm$ 50 mV at 25° C.

To illustrate this, a circuit as in Fig. 3 was set up with the difference that the 18-kΩ emitter resistor in $T_1$ was replaced by a 20-kΩ variable. Taking the collector voltage of $T_1$ as the reference, the values of $V_{be2}$, $V_{c1tap}$, $V_{cb1}$ and $V_{c1}$ were observed as the resistor was varied.

The figures obtained are given in Table 1 and column 6 shows the observed drop across resistor $A$ derived from columns 3, 4 and 5. Column 7 gives the calculated value obtained from equation (5). It is seen that the agreement is satisfactory and inside the limits quoted of $\pm$ 50 mV. Column 8 is the observed 'constant' addition which is very close to 200 mV. If column 8 is added to column 7 we have the calculated $V_{cb}$ which can be compared with column 3. Both these are plotted in Fig. 4.

The effect of a change in a resistor due to age or tolerance can at once be seen. The most important feature is that, in the new circuit, it is impossible for

Fig. 4. *Variation of collector–base voltage of $T_1$ with $R_e$*




$V_{cb1}$ to change its polarity and, hence, for the stage to become inoperative due to bottoming, whatever values occur. This is very different from the classical case of equation (4). In this, if $V = 10$ volts and $V_{cb} = 0{\cdot}5$ volt,

$$\frac{R_{b2}}{R_e} \cdot \frac{(R_c + R_e)}{(R_{b1} + R_{b2})} = 0{\cdot}95$$

Should all the resistors vary by 3 % from the target values in the unlucky directions, it is possible for this fraction to increase by 6% and for $V_{cb}$ to become negative. In the new system the bias would change by 9% of itself instead of by 6% of the total battery voltage. For the case quoted, the improvement in bias stability is over thirteen times against resistor tolerances and, with really low collector–base voltages, e.g. 200 mV, the improvement is more than twice as much again.

## Extension to Real Transistors

Real transistors differ from ideal ones in having $\alpha < 1$ and $I_{c0}$ finite. From the bias point of view, the fact that $\alpha \neq 1$ becomes important on account of the finite value of base current which now flows. This current in $T_2$ flows in the collector load of $T_1$ and

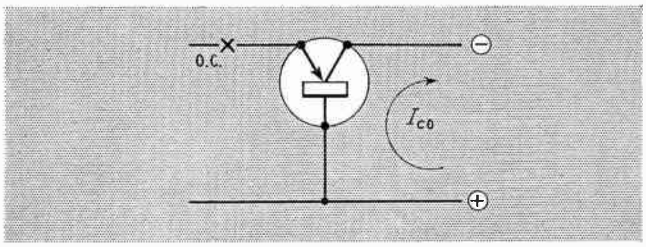



Fig. 5. *Transistor showing $I_{co}$*

should be allowed for in calculating $R_{c1}$. It will, of course, be a function of $I_{e2}$ and this is chosen with regard to the function of $T_2$ in the amplifier proper. The base current of $T_1$ has already been mentioned in its effect on the base potential of $T_1$. This is less the lower value of $R_b$; $R_b$ itself requires consideration on the score of its effect as a feedback path for the signal. It will not now be further discussed.

The current which flows in the base–collector circuit when $I_e = 0$ is called $I_{c0}$. The direction is shown in Fig. 5. The important point is that $I_{c0}$ flows in the opposite direction to $I_b$. It is thus possible for $I_{c0}$, by increasing with temperature, to cancel $I_b$ or even reverse the apparent direction of it. If $I_{c0}$ increases sufficiently as the temperature rises with a finite value of $R_b$, it is still possible for the collector to bottom. However, the danger is slight in comparison with the older system. It is instructive to obtain a ratio for the improvement. The criterion is the stability of $V_{cb1}$ against $I_{c0}$. The value of $dV_{cb1}/dI_{c0}$ for the conditions in the new mesh shown in Fig. 6 is easily seen to be the same as $R_b dI_{b1}/dI_{c01}$ ($I_{e2}$ and $V_{be2}$ constant). $I_{b1} = (1 - \alpha).\ I_{e1} - I_{c0}$, therefore $dI_b/dI_{c0} = -1$; hence, $dV_{cb}/dI_{c0}$ (new) $= -R_b$. When it is possible to eliminate $R_b$ entirely, the thermal stability is complete.

## Comparison of New and Old Circuits

To compare this with the original arrangement, the circuit of Fig. 1 is redrawn in Fig. 7 with a Thevènin transformation of the base-potentiometer circuit. To simplify, we again put $\alpha = 1$ and $I_b = 0$.

Then $I_{c0}$ will flow in $R_c$ and $R'_b$ (the effective paralleled resistance of $R_{b1}$ and $R_{b2}$). The standard result for this circuit is $dI_c/dI_{c0} \approx 1 + R'_b/R_e = S$, the stability factor. To convert this to a change in $V_{cb}$ we have,

$$dV_c/dI_{c0} = -R_c\,.\,S$$

since $V_{bb}$ is fixed, there will also be a change in $V_b$ in the opposite sense and $dV_b/dI_{c0} = R'_b$; the difference between these two is the wanted value. Hence,

$$dV_{cb}/dI_{c0}\ \text{(old)} = dV_c/dI_{c0} - dV_b/dI_{c0} = -(R_c\,.\,S + R'_b).$$

The ratio between these two systems is

$$\text{new/old} = \frac{R_b}{R_c\,.\,S + R'_b} \quad \quad (6)$$

By this time it will be appreciated that with the aid of simple models we have succeeded in explaining the broad principles of this method of bias determination. A complete algebraic analysis is possible but laborious and inevitably omits such effects as the inconstancy of $\alpha$ with current and temperatures and in spite of that inevitable simplification tells very little more.

In view of the novelty of the idea, an experimental determination of the improvement ratio given in equation (6) was undertaken. Equation (5) was checked earlier.

## Experimental Results

To illustrate the conclusion of this argument, some measurements were made on the arrangement shown in Fig. 3, using 10% tolerance resistors. This experiment was to subject the circuit of Fig. 3 to a temperature range from 15°C to 50°C and a comparison with an equivalent four-resistor stabilized transistor was also observed using the same transistor.

The apparatus was inserted in a water bath at 120° F and allowed to cool naturally. Readings were taken every two or three minutes, at integral degrees on the Fahrenheit thermometer. The measurements were made on a d.c. valve voltmeter of 13·3-MΩ input resistance on a 4·5-volt full-scale range. The zero was reset if required before each line of readings, which were obtained on a 5-position switch (Position 1 being for setting the zero). The reference potential was the collector of $T_1$ and the potentials at '$e_2$', the tap, 'b', and earth gave readings of $V_{bc2}$, $V_{1tap}$, $V_{cb1}$ and $V_c$. The battery was a fresh one of 9·2 volts. The first transistor $T_1$ was a GET6 and the second a GT3. These measurements are listed in Table 2 and the variation of $V_{cb1}$ with temperature is plotted in Fig. 8.

Table 3 gives the equivalent set of observations for a circuit like Fig. 1, where $R'_b$ is made approximately equal to $R_b$ in Fig. 3; i.e., 12 kΩ. The circuit could only be adjusted by making $R_e$ variable and setting it for a

Fig. 6 (*left*). *Simplified circuit of Fig. 2 showing only the essential elements.* Fig. 7 (*right*). *Equivalent circuit of Fig. 1*

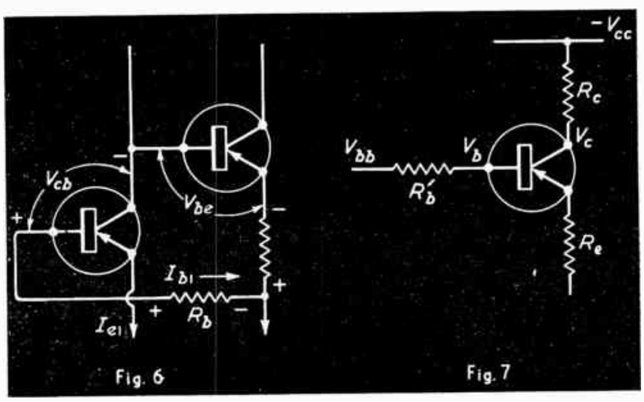



**TABLE I**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| $R_{e1}$ (ohms) | $V_{c1}$ (volts) | $V_{cb1}$ (volts) | $V_{c\,tap}$ (volts) | $V_{be2}$ (volts) | $V_a$ (volts) | $V_a$ (volts) | Correction (volts) |
| 20 | 3·77 | 0·56 | 0·52 | 0·15 | 0·37 | 0·4 | 0·19 |
| 12 | 3 | 0·52 | 0·46 | 0·15 | 0·31 | 0·28 | 0·21 |
| 8·8 | 2·5 | 0·45 | 0·39 | 0·15 | 0·24 | 0·23 | 0·21 |
| 6·1 | 2 | 0·4 | 0·34 | 0·15 | 0·19 | 0·17 | 0·21 |
| 3·9 | 1·5 | 0·35 | 0·28 | 0·14 | 0·14 | 0·11 | 0·21 |
| 2·05 | 1 | 0·29 | 0·2 | 0·1 | 0·1 | 0·06 | 0·19 |
| 0·4 | 0·5 | 0·23 | 0·12 | 0·07 | 0·05 | 0·01 | 0·18 |
| 0·0 | 0·32 | 0·21 | 0·11 | 0·07 | 0·04 | 0·0 | 0·17 |

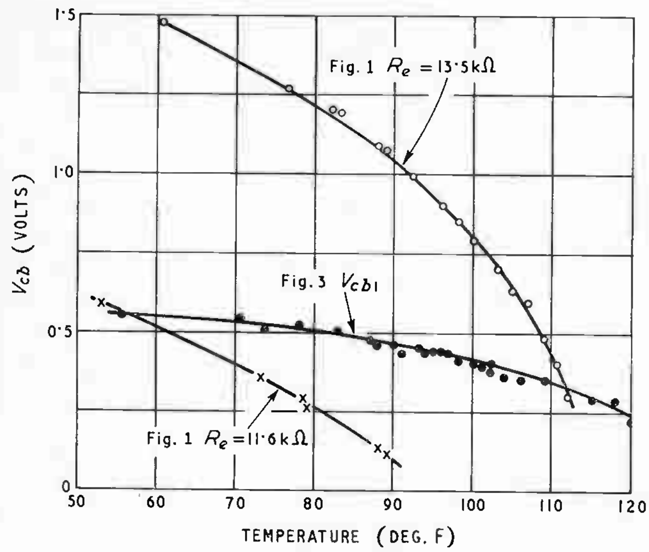



Fig. 8. *Measured results showing the variations of collector–base voltage with temperature for the circuits of Figs.* 1 *and* 3

suitable bias value at the high temperature. The water bath began at 112° F for this run and the bias was set at 0·3 V, and the value of $R_e$ obtained by measurement at the end of the experiment as 13·5 kΩ. The values of $V_{cb}$ are plotted in Fig. 8.

A second set of collector–base values was obtained by setting $R_e$ to a value which gave a collector–base voltage of about 0·5 volt at 60°F. The temperature was then raised to 90°F and a further run was made. The value of $R_e$ turned out to be 11·6 kΩ and the figures are shown in the lower part of Table 3. These lower values of $V_{cb}$ are also plotted in Fig. 8.

It is evident that the slope of the curve for the conventional circuit of Fig. 1 is much greater than that for the new circuit of Fig. 3. Since the same transistor was used, it is probable that the value of $I_{c0}$ in $T_1$ is equal at the same temperature in the two cases. It is certainly true at the same value of $V_{cb}$ but not exactly so when the bias is different. However, if a point at a high temperature is taken where the bias voltages are equal, we have one point at which exact equality may be assumed. This is where the curves cross at 111·7°F. At the cool end, another point at 60°F is chosen where $I_{c0}$ in both cases is very small and any difference due to $V_{cb}$ inequality is also small. Therefore, we can apply equation (6) not to the slope of the curves but to the difference in ordinates at these two chosen points. If this is done, we get

$$dV_{cb}\ (\text{new}) = 0{\cdot}55 - 0{\cdot}32 = 0{\cdot}23 \text{ volt}$$

$$dV_{cb}\ (\text{old}) = 1{\cdot}48 - 0{\cdot}32 = 1{\cdot}16 \text{ volt}$$

and the ratio is $\dfrac{0{\cdot}23}{1{\cdot}16} = 0{\cdot}198$, an improvement factor of 5·05.

For the old circuit, with $R_e = 13{\cdot}5$ kΩ and $R'_b =$ 12 kΩ, we have $S = 1 + \dfrac{12}{13{\cdot}5} = 1{\cdot}89$ and equation (6) gives $\dfrac{12}{1{\cdot}89 \times 37 + 12} = 0{\cdot}162$, a calculated improvement factor of 6·2.

The improvement factor equation omits the change of $V_{be}$ with temperature. This reduces the bias in the new circuit at high temperature by the amount of the change. In the case actually measured, $V_{be}$ falls by approximately 70 mV, and so the value of $dV_{cb}(\text{new})/I_{c0}$ is too large by this amount. The result would be to reduce $dV_{cb}(\text{new})$ to 0·16 volt, which gives an improvement factor of 7·2 due to $I_{c0}$ changes. This is even better than the calculated value. As the measurement of changes in $V_{be}$ is extremely difficult, the agreement between theory and experiment may be considered good. The observed value of five times is the practical one, since it includes changes in $V_{be}$ and the corresponding changes in conditions in the second transistor, which have been neglected in the analysis.

A further point of great importance is the constancy

TABLE 2

| Temp. °F | $V_{be_2}$ | $V_{tap}$ | $V_{cb_1}$ | $V_{c_1}$ |
|---|---|---|---|---|
| 120 | 0·05 | 0·4 | 0·22 | 3·4 |
| 118 | 0·08 | 0·42 | 0·28 | 3·4 |
| 115 | 0·07 | 0·41 | 0·28 | 3·39 |
| 112 | 0·07 | 0·42 | 0·32 | 3·38 |
| 109 | 0·09 | 0·43 | 0·35 | 3·4 |
| 106 | 0·08 | 0·42 | 0·35 | 3·4 |
| 104 | 0·08 | 0·425 | 0·36 | 3·39 |
| 102 | 0·09 | 0·44 | 0·4 | 3·41 |
| 101 | 0·085 | 0·43 | 0·39 | 3·4 |
| 100 | 0·09 | 0·44 | 0·4 | 3·4 |
| 98 | 0·1 | 0·44 | 0·41 | 3·41 |
| 97 | 0·11 | 0·46 | 0·43 | 3·41 |
| 96 | 0·1 | 0·45 | 0·44 | 3·4 |
| 95 | 0·1 | 0·45 | 0·44 | 3·4 |
| 94 | 0·1 | 0·44 | 0·43 | 3·4 |
| 93 | 0·12 | 0·47 | 0·45 | 3·39 |
| 91 | 0·1 | 0·43 | 0·43 | 3·37 |
| 90 | 0·1 | 0·46 | 0·46 | 3·4 |
| 88 | 0·11 | 0·46 | 0·46 | 3·4 |
| 87 | 0·11 | 0·46 | 0·47 | 3·4 |
| 83 | 0·13 | 0·48 | 0·5 | 3·42 |
| 78 | 0·13 | 0·48 | 0·52 | 3·4 |
| 73 | 0·12 | 0·47 | 0·5 | 3·38 |
| 70·5 | 0·145 | 0·49 | 0·54 | 3·43 |
| 54·5 | 0·15 | 0·48 | 0·55 | 3·39 |

TABLE 3

| Temp. °F | $V_{cb}$ | $V_{be}$ | $V_{ce}$ |
|---|---|---|---|
| $R_e = 13{\cdot}5$ kΩ | | | |
| 112 | 0·3 | 0·06 | 3 |
| 110·5 | 0·4 | 0·07 | 3·1 |
| 109 | 0·48 | 0·07 | 3·15 |
| 107 | 0·58 | 0·07 | 3·24 |
| 105 | 0·63 | 0·07 | 3·28 |
| 103 | 0·7 | 0·06 | 3·33 |
| 100 | 0·78 | 0·07 | 3·41 |
| 98 | 0·85 | 0·08 | 3·48 |
| 96 | 0·9 | 0·08 | 3·51 |
| 92·7 | 0·99 | 0·09 | 3·6 |
| 89 | 1·07 | 0·09 | 3·66 |
| 88 | 1·09 | 0·1 | 3·67 |
| 83 | 1·19 | 0·1 | 3·76 |
| 82 | 1·2 | 0·1 | 3·78 |
| 76·5 | 1·27 | 0·11 | 3·83 |
| 60·5 | 1·48 | 0·13 | 3·99 |
| $R_e = 11{\cdot}6$ kΩ | | | |
| 89 | 0·11 | 0·11 | 2·66 |
| 88 | 0·13 | 0·09 | 2·67 |
| 79 | 0·26 | 0·1 | 2·82 |
| 78·5 | 0·28 | 0·1 | 2·84 |
| 73 | 0·36 | 0·12 | 2·89 |
| 53 | 0·58 | 0·14 | 3·1 |

of $V_c$ in this example of the new circuit. This enables a chain of three direct-coupled transistors to be controlled by the first one if the second is used as an earthed collector. The bias connection can then come, as convenient, from the second or third emitter circuit.

**Application**

The value of this safe and easy way of securing a low and constant collector-base voltage for a first transistor is in connection with low-level low-noise amplifiers. As the voltage is decreased, the residual semi-conductor noise diminishes. In conjunction with low currents and high resistances, this low collector voltage permits front-end amplifiers the noise factors of which can compare favourably with those of valve amplifiers. Direct comparison is not valid owing to the different frequency spectra of the noise but, using a 1/3 octave filter at 3·3 kc/s, a noise factor of 12·6 dB in a matched input amplifier has been measured. This needs adjustment for a lossy input transformer (1·5 dB) and for the finite input impedance. This reduction leaves the transistors and circuit responsible for only 8·1 dB of noise factor. A full bandwidth measurement gave a figure 1·2 dB higher (from 50 c/s to 10 kc/s).

The bias circuit described in this article is the subject of British Patent Application No. 32314/56.

# Microwave Model Crystallography

X-RAY DIFFRACTION SIMULATED AT MILLIMETRE WAVELENGTHS

By J. F. Ramsay, M.A., M.I.E.E. and S. C. Snook B.Sc.*

In 1898 a young Indian physicist, Jagadis Chunder Bose, made model 'molecules' of Calcutta jute.[1] The molecules were composed of bundles of parallel fibres of 10 cm in length and 4·5 cm in diameter, subjected to twists. Some of the bundles were twisted in a right-hand direction, some in a left-hand direction. These 'molecules' were found to twist the polarization of microwave radiation of about 5 mm wavelength and, in so doing, were regarded by Bose as furnishing "electro-optic analogues of two varieties of sugar—dextrose and laevulose".

This work of Bose illustrates one of the earliest attempts to make microwave models of the submicroscopic. In passing, it is interesting to note that the 5-mm radiation was generated by sparks in association with a Righi-type dipole oscillator.

About thirty years later an unknown investigator made a microwave model of the asymmetric carbon *atom* which gave rotation of the plane of polarization of waves of about 20 cm length.[2]

Thus, although molecules and atoms had been modelled at microwaves, the interest in the modelling had been to show polarization rotations. By 1930 atomic theory and X-ray crystallography were well established. It is therefore surprising that the diffraction by the microwave models was not looked into.

In 1942 J. A. Stratton pointed out the analogy between X-ray crystallography and short-wave aerial systems.[3] "From the X-ray diffraction pattern," he wrote, "the physicist endeavours to locate the centers of the diffracting atomic dipoles and hence determine the structure of the crystal; the radio engineer must choose the lattice spacing and phases of the current dipoles so as to obtain a prescribed radiation pattern."

Later, writers on 'artificial dielectrics' as used at microwaves have commented on their resemblance to crystal structures, but no experimental investigations appear to have been made.

In 1954 the present writers made atomic models of crystal structure of very simple type and irradiated them with microwaves at a wavelength of 8·7 mm. Reflections at angles corresponding to the Bragg angles of the crystallographic model were obtained.

In 1955 and 1956 Sir Lawrence Bragg demonstrated this microwave model crystallography in lectures to sixth-form school children at the Royal Institution, London. Some account of the problem, the experimental equipment and the phenomena is given in the following.

When a parallel beam of X-rays is incident upon a three-dimensional array of atoms, such as found in a crystal, each atom acts as a scattering centre and causes a very small portion of the incident energy to be deviated. The amount of energy scattered is greater for heavier atoms than for lighter ones, and the distribution of this energy in space depends upon the particular element causing the scattering; each element, having a different electronic structure, has its own 'scattering factor'. As the amount of energy scattered per atom is small no resultant beam will, in general, emerge from the crystal. However, when the incident beam makes a certain angle

* *Marconi's Wireless Telegraph Company, Ltd.*

$\theta$ with a set of lattice planes, the waves from all the atoms in that set add up to produce a diffracted beam. Remembering that, according to Huygens's principle, each atom becomes the source of secondary waves, we see from Fig. 1 that a diffracted beam is formed at an angle $\theta$ given by $2d \sin \theta = n\lambda$ where $d$ is the perpendicular distance between lattice planes, and $\lambda$ is the wavelength of the X-rays. This is the famous Bragg relation.

This relation will hold in any part of the electromagnetic spectrum for an array which has spacings of the order of the wavelength of the incident radiation, and where the scattering centres are small compared with the wavelength. The directions of the diffracted beams are a function of $d$ and $\lambda$ only, and not of the scattering factors of the elements forming the array which will, however, govern the intensity of the beams. Thus it is possible to build an extremely simple model of a crystal at a wavelength of 1 cm, to give diffracted beams in the same directions as the crystal does with X-rays; for example, by using an array of ball bearings supported in expanded polystyrene, although the amplitudes of the beams will not correspond in the two cases. An even simpler model consists of sheets of dielectric equally spaced and parallel with each other.

**The Problem of the Crystal Model**

Modern physics declares that it is impossible to make a model of an atomic structure. As the need for atomic models is a central requirement of microwave crystallography it is possible that this subject will throw light on the epistemological difficulties inherent in established physical theories.

The reader will have seen crystallographic models made of balls connected in systematic arrangements by rods or wires. The balls usually are of noticeably smaller diameter than their spacing; let us say they are 'small balls widely spaced', for convenience of description. Again, the reader will have seen other molecular models consisting relatively of large spheres, or large and small spheres, closely packed. They are held together by practical arrangements not essential to the geometry of the structure, other than holding the spheres in the correct packing. Let us describe this type of model as consisting generally of 'large balls closely packed'.

The balls used in either type of model are usually made of plastic, wood, rubber or the like.

The models are 'thinking tools' where three-dimensional relations can be apprehended by perception.

The two types of scientific model bring out the problem of modelling. Each type is inadequate as a 'true' model of the submicroscopic structure it is intended to represent. In the first type, where small balls are widely spaced, the predominating interest is the geometry of the arrangement of the balls in space, the balls being regarded simply as 'large points' with spherical symmetry. Chemical names can be attached to the points if need be, but that procedure does not make a chemical model with 'quasi-atoms'. The first model is essentially mathematical.

The second model approaches chemistry, is still basically mathematical, and hints at physics. Spherical atoms of different sizes are invoked with diameter as a now significant parameter in consequence of which 'packing' becomes a new geometrical reality not evidenced with small balls widely spaced.

The second type using large touching balls is a better representation since it is known that atoms, if assumed spherical, have diameters of the same order as the spacings; i.e., atoms interpenetrate, or spread into each other. Some molecular models allow this to be featured by providing spheres with flats so that interpenetration appears to exist.

It is desirable to have an idea of the scale of atomic dimensions and spacings in crystals. It is sufficient to describe these as being a few wavelengths of X-radiation. An X-ray wavelength is around $10^{-8}$ cm; i.e., 1 ångström (Å). To assist in visualizing microwave modelling

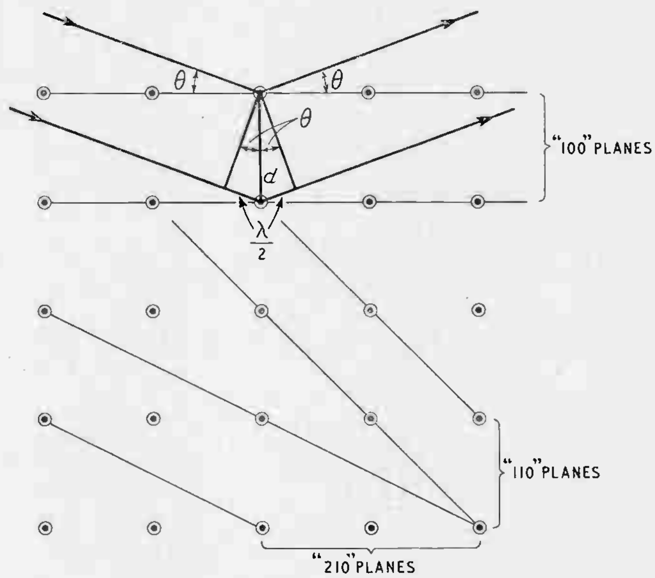


Fig. 1. *Bragg reflection from lattice planes*

a change of scale of $10^8$ will be assumed, 1 cm being the reference microwave wavelength, atoms and spacings being of the order of a few centimetres.

Since the familiar models of crystals are scaled by some factor it is reasonable to suppose that to a given crystallographic model there is a corresponding centimetre wavelength. We may take such a model and consider what would happen if it were irradiated by microwave illumination of the appropriate scaled wavelength.

Taking the first type of model where there are, say, plastic balls connected by wires, we have to remember that the microwave radiation likely to be used would be linearly polarized. The supporting wires would scatter more strongly than the spheres and would have to be replaced by non-reflecting threads; e.g., of nylon. This may be possible. Glass fibres offer another alternative.

Alternatively, the balls can be embedded in an 'expanded' dielectric, of very low dielectric constant (e.g., expanded polystyrene), this mounting being substantially 'invisible' and non-absorbing to microwave radiation.

Thus, to make a microwave model some care has to be taken in remounting the plastic atoms of the conventional model.

These plastic atoms will scatter radiation in a manner simulating atomic scatterers when subjected to a plane microwave. The microwave mechanism of the scattering is, however, very complicated in the general case where the ball diameter is not very small in comparison with the wavelength. "It becomes impossible to predict the pattern of the diffracted radiation on any basis other than the results of a difficult computation" (Stratton). It is, however, possible to indicate qualitatively the phenomena. Following Righi, who made the original investigations in this connection, we may distinguish the incident wave, plane and linearly polarized, as the primary radiation which illuminates the dielectric mass. Forced oscillations of the dielectric ball at the frequency of the incident radiation make it a secondary radiator. The resultant field at any point is the vector sum of the primary and secondary fields; there is, of course, a secondary field both inside and outside the dielectric ball.

The internal field has the characteristic propagating and standing waves of a dielectric cavity determined by the complex permittivity and permeability and the spherical boundary. In general, there are $E$ and $H$ waves. Cavity resonance occurs for particular values of the radius. The ball is 'leaky', in the sense that the secondary field can be detected at infinity; i.e., there is an external component of the secondary field. At sensible distances the external secondary waves are entirely transverse, predominantly spherical.

For the crystallographic requirement it is important to know the angular distribution of the external secondary field in amplitude, phase and polarization, none of which is easily predictable except in simple special cases. If the balls are only a few wavelengths apart as in the model, mutual interaction takes place, as Poincaré pointed out; standing waves of relatively small amplitude then exist in the interaction space.

This discussion has been elaborated since in the second type of conventional molecular model the balls can be large compared with the wavelengths, even interlaced, and the complicated phenomenology is very real. Even with 'atoms' say of expanded loss-free dielectric there will be weak irregular scattering patterns from each with polarization variations.

Of the two traditional models, the small-ball type is the better suited to microwave modelling, in so far as mainly geometrical features of the crystal structure are sought. The small-ball model will dynamically simulate the static arrangement of massive points and the angular properties of the scattering from the arrays will be obtained.

An important proviso has to be made regarding polarization. With microwaves it is easier to obtain linearly-polarized waves than un-polarized waves. Polarization now plays a dominant role in the quasi-crystallography. As has been hinted, inside the structure the linearity of the polarization is upset. Care has to be taken in interpreting measurements if linear polarization is used.

Dielectric atoms have small scattering cross sections. To secure usable reflections many lattice planes are required. The model is difficult to make and expensive in effort. On the other hand, a major feature of the microwave modelling is that models of unit cells only become possible. In order, the basic microwave components are (1) an atom, (2) a lattice plane, (3) a unit cell, (4) the crystal space lattices. Microwave diffraction measurements are practicable with all forms, but it is the unit cell naturally which is the most interesting and productive.

If, however, the unit cell has to be investigated, its low scattering with dielectric atoms makes measurements difficult due to systematic scattering errors in the spectrometer. It is therefore desirable to use conducting spheres (e.g., ball bearings) which have a larger scattering cross section, as used in some conventional artificial dielectrics of radio. The question of whether these are representative atoms is then of first order. On the other hand, they make unit cells possible with intelligible diffracting properties.

Since it is not necessary, for teaching purposes for example, to show crystal reflections in other than one plane, a great convenience thereby arises. 'Cylindrical atoms' can be used, since if they are arranged in parallel gratings standing vertically on the spectrometer table (Fig. 2), crystal reflections of strong amplitude can be obtained in the horizontal plane of a simple spectrometer. The height of the cylinders is made (a) to provide adequately strong reflections in the horizontal plane, (b) to make the illuminated region of the grating array well clear of the table and clear of the top support to

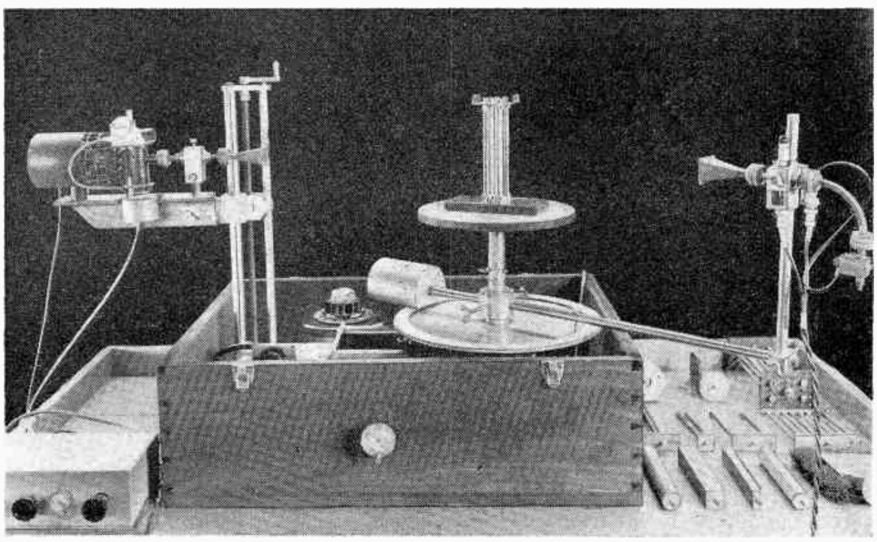


Fig. 2. *Spectrometer for microwave model crystallography*

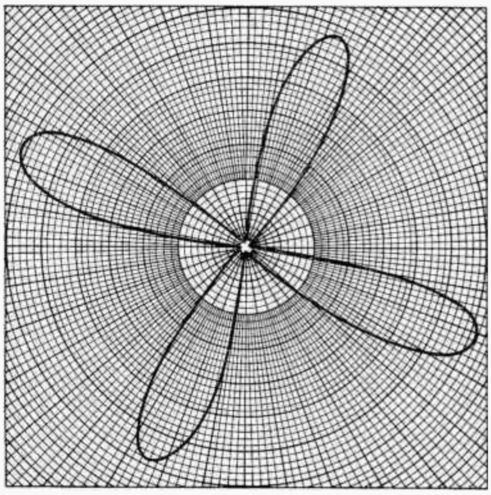


Fig. 3. *Constructive interference (Bragg reflections from '100' planes of crystal model)*

the cylinders. Such models made from metallic rods with top and bottom plates are of exceedingly simple construction and give convincing reflections, as will be described later. As with all the models they have to be accurately constructed and mounted on the spectrometer.

On the other hand, metallic cylinders are poor representations of atoms in themselves. Dielectric cylinders have been used but both are inadequate. It is, of course, out of the question to model electrons on themselves because of scale; they would be too small. A suggestion has been put forward by our colleague R. A. Waldron for modelling a Bohr atom by using a nest of concentric high resistance spherical films possibly vacuum-deposited on expanded dielectric. Each highly-transparent resistive sphere would statically and statistically represent a circular Bohr orbit. For a simpler model concentric resistive cylindrical films would be used, like the rings in a tree, where information in a plane is desired.

The question of the microwave model of an atom is thus a basic practical problem, just as in physics at large the abstract problem of the nature of an atom still persists. In the purely practical technique of microwave model crystallography, physics has indeed to come down to earth. The billiard balls of the Victorians have come back as ball bearings and in scattering microwave radiation simulate the scattering of X-rays by truly atomic crystal structures.

### A Spectrometer for Microwave Model Crystallography

A spectrometer was constructed to demonstrate the Bragg angle phenomenon at a wavelength of 8·7 mm (Fig. 2). A square-wave modulated klystron generator was coupled via an attenuator, to a transmitter horn fixed 1 ft. from the central axis of the spectrometer. The aperture of the horn was 0·9 in. × 1·2 in. so that the illumination over a 2-in. wide model on the spectrometer table was substantially a plane wave of constant amplitude. A similar horn, used as the receiver, was mounted on the spectrometer arm so that it rotated on a radius of 1 ft. A pointer fitted on the arm moved over a circular scale divided into degrees. The height of the two horns from the spectrometer table could be adjusted to suit different models but had to be sufficiently great to prevent stray reflections off the wooden table from being picked up. Both horns could be rotated about their horizontal axis so that any direction of polarization could be used. The models were accurately located on the spectrometer table by means of spigots which fitted into a hole drilled centrally in the shaft on which the table rotated.

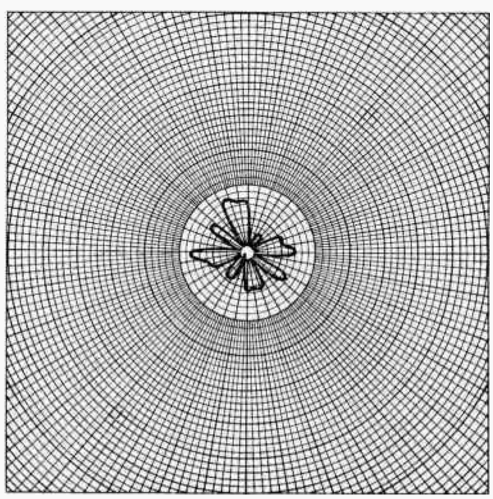
The r.f. power was detected by a crystal diode mounted across a waveguide connected to the receiver horn. The crystal output was fed by means of a flexible coaxial cable into a narrow-band amplifier tuned to the fundamental component of the modulation frequency of the klystron.

In order to facilitate quick location of Bragg angles the spectrometer table was continuously rotated by an electric motor. Geared to the turntable was a magslip which was coupled electrically to a similar magslip rotating the deflector coils of a long-persistence cathode-ray tube. The output of the amplifier was fed through a suitable d.c. amplifier into the deflection coils of the c.r. tube so that, for a circularly-symmetrical scattering object placed on the table, a circle was traced out in synchronism with the rotation of the table, and the radius of the circle was proportional to the r.f. power picked up by the receiver horn. For an object of *n*-fold symmetry *n* 'lobes' were displayed as the table made one revolution and the amplitude and widths of the lobes were related to the effective area of the reflecting plane.

To find the position of Bragg reflections from a model rotating on the spectrometer table the arm was moved round from a position directly facing the transmitter until peaks rose up into a lobate pattern. When the lobes were of the maximum amplitude the value of the Bragg angle was read off the scale, and then rotation of the arm was continued to the next position for constructive interference.

For recording purposes the amplifier output was fed instead into a polar co-ordinate pen recorder, the table of which rotated in synchronism with the model. Some typical records obtained are shown in Figs. 3 and 4. The model used to obtain these figures consisted of nine rods, 0·16 in. diameter, spaced 0·5 in. apart in a 3 × 3 cubic

Fig. 4. *Destructive interference*



lattice. The wavelength used was 0·343 in. Fig. 3 shows the trace obtained with the receiver arm set to receive the reflections from the '100' planes and Fig. 4 with the receiver set near an angle at which no strong resultant beam emerges from the model.

If a cubic structure with 0·5-in. lattice spacing is used at a wavelength of 8·7 mm. (0·343 in.), the Bragg condition

$$n\lambda = 2d \sin \theta$$

gives

$$\sin \theta = \frac{n \times 0{\cdot}343}{2 \times 0{\cdot}5} = 0{\cdot}343n$$

for the '100' plane. For the diagonal plane '110'

$$\sin \theta = 0{\cdot}343n\sqrt{2} = 0{\cdot}485n$$

for '210', '420'

$$\sin \theta = 0{\cdot}343n\frac{\sqrt{5}}{2} = 0{\cdot}382n$$

and so on. These angles are inclinations to the lattice planes shown in Fig. 1.

It will be appreciated that this technique not only allows the usual inspection of lattice planes on the model as is customary in classical crystallographic modelling, but permits an experimental instrumental confirmation. One can literally *see* the planes producing the diffracted beams by stopping the spectrometer, obtaining a Bragg reflection by hand rotation of the crystal, and visually corroborating the geometry of the model in relation to the incident- and reflected-wave normals.

**Possible Applications of the Microwave Analogue**

Microwave analogue crystallography would appear to offer ready application to the teaching of the principles of X-ray crystallography, one of the corner stones of a scientific education. The experimental technique is simple and basic, and can be shown to audiences large or small. Constructive and destructive interference can be demonstrated vividly, and the interaction of radiation with periodic structures brought fully home with all the elegance of calculable prediction.

Students can make their own atomic arrangements if they want to, they can leave atoms out or put atoms in at their pleasure and investigate the consequences. Here is a new heuristic technique of endless variation, pregnant with the promise of new discoveries which whet the scientific curiosity.

Thus, microwave analogue crystallography goes beyond the purely pedagogical. It can be a tool for research. Fundamentally, it is a Fourier transformer, a form of analogue computer. As such, the childish instrument described in this paper may mature into a more adult machine or instrument capable of coping with the real analytical problems of crystallography. In time, amplitudes, phases and spacings may be variable at will inside the model structure and the effects examined. More natural model atoms may appear.

In conclusion, we should like to acknowledge Sir Lawrence Bragg's enthusiastic interest in this radio crystallography, and express our thanks to the Engineer-in-Chief and the Director of Research of Messrs. Marconi's Wireless Telegraph Co., Ltd., for permission to describe this new use for millimetre waves.

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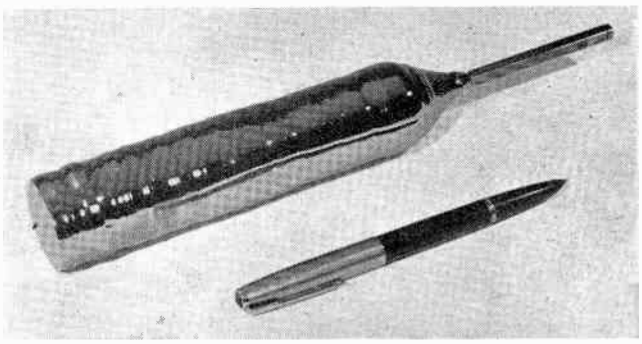
# Large Single-Crystal Germanium Ingot

ONE of the largest single-crystal ingots of germanium in the world was grown recently at the Research Laboratories of The General Electric Co. Ltd., where a research programme on transistors and other crystal valves is in progress.

The ingot, which is about 8 inches long and weighs 1200 grammes, took about 6 hours to grow. Its impurity content is less than 1 part in 20,000,000. It was produced by a process involving the slow withdrawal of a rotating 'seed' crystal from a pool of molten germanium. This technique has been developed to the stage where large crystals can be grown automatically with great consistency and uniformity.

In the manufacture of crystal valves, the production of such large diameter crystals results in considerable savings in cost. When the ingot is sawn into wafers, less material is lost as waste from the trimming of the outside and ends, enabling higher productivity to be obtained from each machine producing the ingots.



*One of the largest single-crystal ingots of germanium in the world grown recently at the Research Laboratories of The General Electric Co. Ltd.*

# Transitron Negative Resistance

By **A. G. Bogle, B.E., D.Phil.***

SUMMARY. *Measurements of the negative resistance of the screen of a transitron-connected pentode (EF50) indicate that the negative resistance is approximately inversely proportional to the cathode current. This is investigated in detail, with the conclusion that the proportionality is nearly constant over a useful range of negative resistance—within ± 10 per cent over the range 3–90 kilohms. The advantages of this in calibrating the negative resistance and using it to measure dynamic resistance are shown.*

Essentially a transitron is a pentode—of such a design that its suppressor grid, when suitably biased, has a controlling effect on its anode current—connected with coupling between the suppressor and screen grids. When suitable electrode voltages are applied, the screen input of such a valve has a negative resistance characteristic: that is to say, the screen current falls with rising screen potential. The requirement for a suitable suppressor characteristic limits the choice of valves that may be used as transitrons. The commonest application of transitrons has been to relaxation oscillators, which of course depend on the existence of the negative resistance to supply their oscillation energy, but do not clearly reveal its presence.

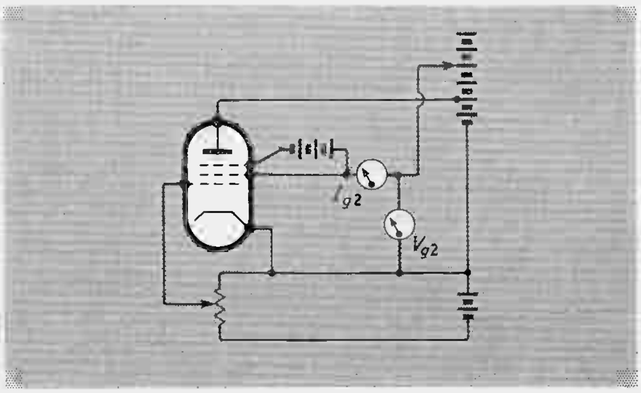



Fig. 1. *Circuit for observing transitron characteristics*

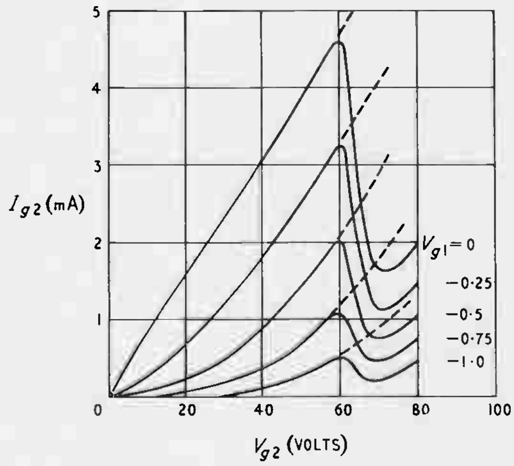



Fig. 2. *Transitron characteristics;* $V_{g3} = V_{g2} - 67$ *V*

The negative resistance of the screen circuit may be clearly shown, and indeed measured, by plotting screen current ($I_{g2}$) against screen potential ($V_{g2}$), while maintaining a constant p.d. between the screen and the suppressor by means of a battery.[1] Fig. 1 shows a suitable circuit, and Fig. 2 a typical set of curves for an EF50 valve when $(V_{g2} - V_{g3}) = 67$ V. The broken lines in this figure indicate the variation of cathode current. Very similar results are obtained with an EF42 valve.

When the transitron curves are plotted in this way, one is struck by their similarity to the dynatron characteristic of a tetrode, a similarity which is the more interesting in view of the difference between the basic phenomena. The transitron action depends on the geometry of the electrodes of the pentode, while the dynatron action depends on the secondary emission properties of the tetrode anode.

It is a useful property of the dynatron, which does not seem to be widely appreciated, that to the first order its negative resistance, at suitable fixed anode and screen potentials and assuming constant secondary emission properties, is inversely proportional to its cathode current. This fact leads to convenient and direct methods of calibrating its negative resistance. The similarity between the transitron and dynatron characteristics raises the question whether a similar inverse relationship between negative resistance and current may be found for the transitron.

### Electrode Current Relationships in the Transitron

The qualitative explanation of the curves shown in Fig. 2 is as follows. For a low screen potential ($V_{g2}$), say 40 V, the suppressor potential ($V_{g3}$) is so low (− 27 V) that it prevents any current from reaching the anode. When $V_{g2}$ is raised to 60 V, $V_{g3}$ rises to − 7 V, and is not sufficiently low to prevent anode current entirely. Thus anode current begins to flow, with the result that not all of the cathode current goes to the screen. Then as $V_{g2}$ is raised further, and the suppressor potential

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becomes less and less negative, an increasingly large proportion of the cathode current is diverted to the anode, causing the screen current to fall sharply. When $V_{g2}$ is 67 V and $V_{g3}$ is zero about three-quarters of the cathode current is taken by the anode, reducing the screen current to about a quarter of the cathode current. For further increases of $V_{g2}$ and $V_{g3}$ the proportionality remains about the same, a small amount of current also being taken by the suppressor.

The relationships between the electrode currents are not very conveniently analysed from the curves of Fig. 2, nor for that matter are they very easily measured with the connections shown in Fig. 1, owing to the interaction between the positive resistance of the screen supply circuit and the negative screen resistance. Both measurement and analysis are more convenient if the effects of variation of $V_{g2}$ and $V_{g3}$ are considered separately. It is found that for constant $V_{g1}$, $V_{g3}$ and $V_a$, variation of $V_{g2}$ affects primarily the magnitude of the cathode current; for constant $V_{g1}$, $V_{g2}$ and $V_a$, variation of $V_{g3}$ affects primarily the partition of the cathode current between the anode and the screen.

## Cathode Current

It is a general characteristic of pentodes, clearly shown by the EF50 valves measured, that $V_a$ and $V_{g3}$ have very much less effect on the cathode current than $V_{g2}$. For the low anode and suppressor potentials employed in the transitron case, the influence of the anode and the suppressor on cathode current is almost negligible, and as far as cathode current is concerned the valve behaves very much as a triode of which the screen represents the anode, and for constant $V_{g1}$, the cathode current $I_k = f(V_{g2})$. Fig. 3 shows the variation obtained with an EF50 valve, plotted in some detail.

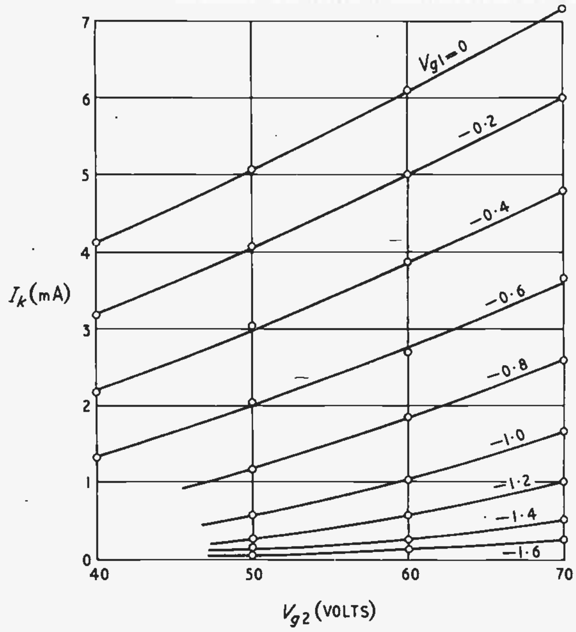



Fig. 3. *Variation of cathode current with screen potential. EF50 valve; $V_a = 25$ V, $V_{g3} = 0$*

## Partition of Current

Electrons leaving the cathode are accelerated by $V_{g2}$, and so have a high radial velocity on reaching the zone of the screen. Those whose flow is directly intercepted by the effective projected area of the screen wires are at once collected by the screen. These form what may be called the primary component of screen current, and may be denoted by $BI_k$, where $B$ is a fractional number depending only on the geometry of the electrodes, and so is a constant for a particular valve. For an EF50 valve, $B$ approximately equals 0·25.

The remainder of the electrons pass through the interstices of the screen and come under the influence of the suppressor. If the suppressor is sufficiently low in potential, the retarding field it sets up is sufficient to turn back all these electrons, which must then all come to rest on the screen, either immediately or after some oscillations through it. If the suppressor could be regarded as an equipotential surface, and if all the electrons reached it with the same radial energy, there would be a critical value of $V_{g3}$, above which all the electrons would pass through to the anode, making $I_{g2} = BI_k$, and below which they would all return to the screen, making $I_{g2} = I_k$.

A sharp cut-off of this sort does not, of course, appear in practice. One reason is that the electrons do not reach the suppressor zone all with the same radial component of kinetic energy. Their energies on leaving the cathode are distributed over a band; and their paths between the cathode and the suppressor vary widely, most of them suffering some axial deflection while passing near one of the grids, causing some of their radial energy to be converted into axial energy. Also the suppressor cannot be regarded as an equipotential cylinder, since its axial potential distribution will be roughly as shown

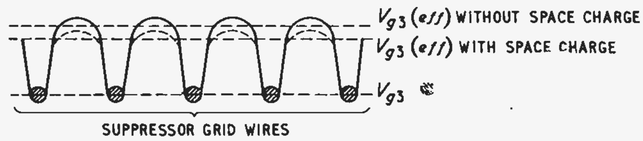



Fig. 4. *Assumed axial variation of potential at suppressor*

in Fig. 4. However, since the electron velocity in this region is low, the electrons are readily diverted to flow in streams between the suppressor-grid wires, in zones where the potential is relatively uniform in distribution and rather higher than $V_{g3}$. An additional effect which cannot be overlooked is that of space charge in the vicinity of the suppressor, which makes the potential in this region lower than it would be in the absence of current. This will be considered in more detail below.

The electrons not directly intercepted by the screen wires constitute a current $I_k(1 - B)$. As outlined above, the effect of the suppressor is to determine what proportion of these passes on to the anode. Thus, if suppressor space-charge effect were negligible, $I_a/I_k(1 - B)$ should be a function of $V_{g3}$ only. Or

$$\frac{I_a}{I_k} = \phi(V_{g3}),$$

since $(1 - B)$ is a constant.

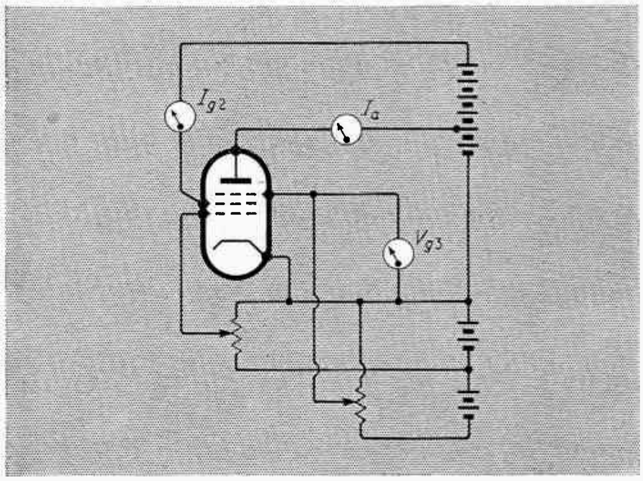


Fig. 5. *Circuit for observing effect of $V_{g3}$ on $I_a/I_k$ ratio*

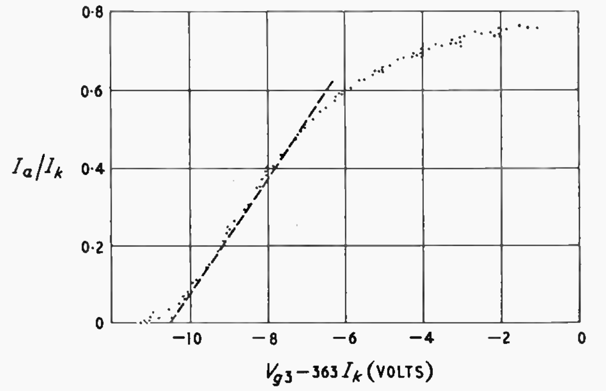



Fig. 7. *Replot of curves of Fig. 6 on modified ordinate scale, showing effect of suppressor space charge*

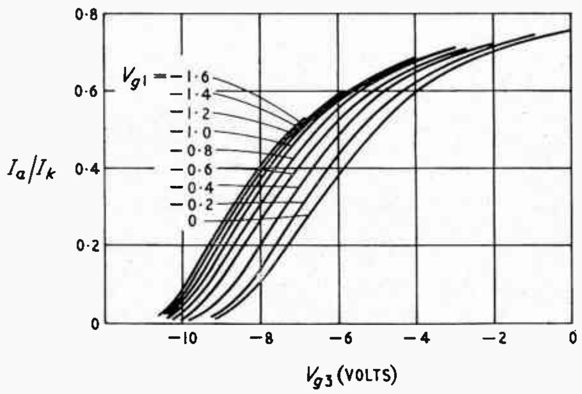



Fig. 6. *Variation of $I_a/I_k$ ratio with $V_{g3}$. EF50 valve; $V_a$ = 25 V, $V_{g2}$ = 60 V*

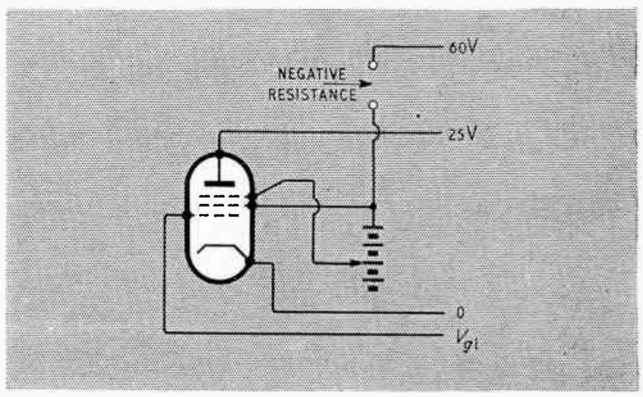



Fig. 8. *Transitron connection*

In order to check this, the valve was connected as in Fig. 5, $V_a$ and $V_{g2}$ being maintained constant while $V_{g3}$ was varied, for various values of $V_{g1}$ between 0 and − 1·6 V. Fig. 6 shows $I_a/I_k$ plotted against $V_{g3}$ under these conditions. The curves are very much the same in shape, indicating that $I_a/I_k$ is mainly dependent on $V_{g3}$, but their lateral displacement for different $V_{g1}$ values (i.e., for different $I_k$ values) indicates that there is also a dependence on $I_k$. This is the sort of effect that space charge would be expected to have, and the curves permit it to be evaluated. The trial assumption that the effective $V_{g3}$ is lower than the actual $V_{g3}$ by an amount proportional to $I_k$, and the plotting of $I_a/I_k$ against $(V_{g3} - CI_k)$, yield Fig. 7, where $C$ = 363 ohms. Here, all the points lie close to a single curve, indicating that $(V_{g3} - 363I_k)$ is indeed a good representation of the effective suppressor potential. The curve has a long straight portion which in this case is adequately represented empirically by

$$\frac{I_a}{I_k} = 0{\cdot}156\ (10{\cdot}55 + V_{g3} - 0{\cdot}363 I_k) \quad .. \quad (1)$$

In addition to the lateral displacement of the curves in Fig. 6 due to space charge, it is also apparent that the curves for lower currents (higher negative $V_{g1}$) have somewhat higher maximum slopes. This effect is analysed by differentiating expression (1):

$$\frac{d}{dV_{g3}}\left(\frac{I_a}{I_k}\right) = 0{\cdot}156 - 0{\cdot}0565\frac{dI_k}{dV_{g3}} \quad .. \quad (2)$$

Hence if the effect of variations in $V_{g3}$ on $I_k$ were truly negligible all the curves of Fig. 6 should have the same slope, $\frac{dI_k}{dV_{g3}}$ being zero. It now appears, however, that the second-order influence of $V_{g3}$ on $I_k$ is not quite negligible, and it is necessary to evaluate it. When this is done, by plotting $I_k$ against $V_{g3}$ for various $V_{g1}$ values, it appears, as might be expected, that $\frac{dI_k}{dV_{g3}}$ is higher for higher values of $I_k$, which explains qualitatively why the curves of Fig. 6 vary as they do in slope.

### The Negative Resistance of the Transitron

The transitron connection represented by Fig. 8 is now considered. $V_a$ and the mean value of $V_{g2}$ are constant and the mean value of $V_{g3}$ can be adjusted by varying the p.d. applied between the screen and the suppressor.

The negative resistance of the screen may be found by considering the effect on $I_{g2}$ of an incremental change of $V_{g2}$. Because of the connection between the screen and the suppressor (here a battery, normally a capacitor) an incremental change of $V_{g2}$ causes an identical change of $V_{g3}$; i.e., $\frac{dV_{g2}}{dV_{g3}} = 1$.

$$I_{g2} = I_k - I_a$$

$$\therefore \frac{dI_{g2}}{dV_{g2}} = \frac{dI_k}{dV_{g2}} - \frac{dI_a}{dV_{g2}}$$

Also

$$\frac{d}{dV_{g2}}\left(\frac{I_a}{I_k}\right) = \frac{1}{I_k}\frac{dI_a}{dV_{g2}} - \frac{I_a}{I_k}\cdot\frac{1}{I_k}\cdot\frac{dI_k}{dV_{g2}}$$

$$\therefore \frac{dI_a}{dV_{g2}} = I_k\frac{d}{dV_{g2}}\left(\frac{I_a}{I_k}\right) + \frac{I_a}{I_k}\cdot\frac{dI_k}{dV_{g2}}$$

Hence

$$\frac{1}{I_k}\cdot\frac{dI_{g2}}{dV_{g2}} = -\frac{d}{dV_{g2}}\left(\frac{I_a}{I_k}\right) + \left(1 - \frac{I_a}{I_k}\right)\cdot\frac{1}{I_k}\cdot\frac{dI_k}{dV_{g2}}$$

Or calling the negative screen conductance $-G$,

$$\frac{-G}{I_k} = \frac{d}{dV_{g3}}\left(\frac{I_a}{I_k}\right) - \left(1 - \frac{I_a}{I_k}\right)\cdot\frac{1}{I_k}\cdot\frac{dI_k}{dV_{g2}} \qquad (3)$$

since $\frac{dV_{g2}}{dV_{g3}} = 1$.

The value of $\frac{d}{dV_{g3}}\left(\frac{I_a}{I_k}\right)$ given by expression (2) is not precise enough for use in the determination of $G$; it is necessary to replot a portion of Fig. 6 on a larger scale, as in Fig. 9, and determine the slopes graphically. The variation of $\frac{dI_k}{dV_{g2}}$ may be determined graphically from Fig. 3. Provided that the excursions of $V_{g2}$ and $V_{g3}$ are small, the curvature of the graphs may be ignored and the variation may be regarded as linear.

Then Fig. 10 shows, plotted against $I_k$, the two components of $-G/I_k$ given in expression (3), and the resultant value as a function of $I_k$ for $V_{g3} = -8{\cdot}5$ V, $-8{\cdot}75$ V and $-9{\cdot}0$ V. From Fig. 10 it appears that for $V_{g3} = -8{\cdot}75$ V, the negative conductance $-G$ is within $\pm$ 10 per cent. of $0{\cdot}108 I_k$, over the $I_k$ range 0·1 mA to 3 mA; the $-G$ range being 0·0108 millimho to 0·324 millimho, with a $-R$ range of 92·5 kilohm to 3·09 kilohm.

## Application of Transitron as Variable Negative Resistance

A variable negative resistance can be a very useful laboratory tool, as H. Pauli, M. G. Scroggie and others have shown.[2, 3] When it is connected to a parallel-resonant circuit, and the circuit is adjusted to the threshold of oscillation (under which conditions, for the transitron, the excursions of $V_{g2}$ are small as required by the assumption of linearity made above), the negative resistance is equal to the dynamic resistance of the external circuit. Hence if the value of the negative resistance is known, the $Q$ of the resonant circuit may be found.

As already mentioned, the approximately linear dependence of $-G$ on $I_k$ leads to simple methods of calibration. For a parallel-resonant circuit consisting of an inductor $L$ and a capacitor $C$, with effective total circuit series resistance $r$, the dynamic resistance $R = \frac{\omega^2 L^2}{r}$ or $\frac{L}{Cr}$. When the circuit is connected to the transitron and the valve is adjusted to the threshold of oscillation, the cathode current has the value $I_1$.

Then the dynamic conductance of the circuit,

$$\frac{1}{R} \text{ or } \frac{rC}{L} \approx kI_1 \qquad (4)$$

Calibration is achieved by the addition of known resistance; either a small resistance in series, or a large

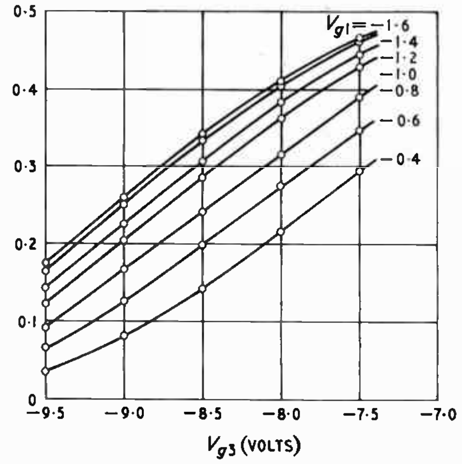
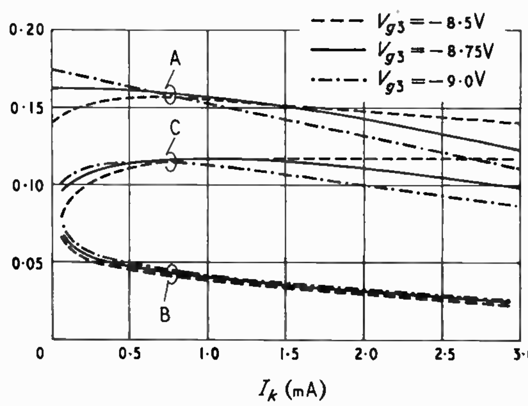



Fig. 9. *Portion of Fig. 6 expanded*

Fig. 10. *Curve* A: $\frac{d}{dV_{g3}}\left(\frac{I_a}{I_k}\right)$, *Curve* B: $\left(1 - \frac{I_a}{I_k}\right)\cdot\frac{1}{I_k}\cdot\frac{dI_k}{dV_{g2}}$, *Curve* C: (A − B) $= -\frac{G}{I_k}$




resistance in parallel, as appropriate to the frequency and the conductance being measured.

If a known series resistance $r'$ is added and the cathode current for threshold oscillation becomes $I_2$,

$$(r + r')\frac{C}{L} \approx kI_2 \qquad (5)$$

If, instead, a known shunt resistance $R'$ is added and the cathode current for threshold oscillation becomes $I_3$,

$$\frac{1}{R} + \frac{1}{R'} = kI_3 \quad \ldots \quad (6)$$

From the simultaneous equations (4) and (5) or (4) and (6) $r$ or $R$ for the circuit under test may be determined. At the same time, the calibration constant $k$ of the transitron has been determined for further measurements of dynamic conductance.

An important disadvantage of the dynatron as a controlled negative resistance is the fact that its action, depending on the surface state of the anode, varies with time in an unpredictable way. With the transitron, the negative resistance depends primarily on the electrode geometry and so is essentially a more stable property of the valve. This fact encourages the belief that the transitron negative resistance may be used for serious measurements of the losses in resonant circuits.

Experimental confirmation of the approximately linear dependence of transitron negative conductance on cathode current, and embodiment of the transitron in a direct-reading 'dynamic conductance meter' have been dealt with by M. R. Barber in an unpublished thesis, and will be described in a later paper.

### REFERENCES


1 Aschen, R., and Chambas, R., "The transitron effect in HF pentode type EF42," *Electronic Applications Bulletin*, 1949, Vol. X, pp. 221–225.

2 Pauli, H., "Measurement of electric effective resistance with the help of negative resistance," *Z. Tech. Phys*, 1929, Vol. X, p. 592.

3 Scroggie, M. G., "Radio Laboratory Handbook." Iliffe, 1950.


# Stereoscopic Industrial Television

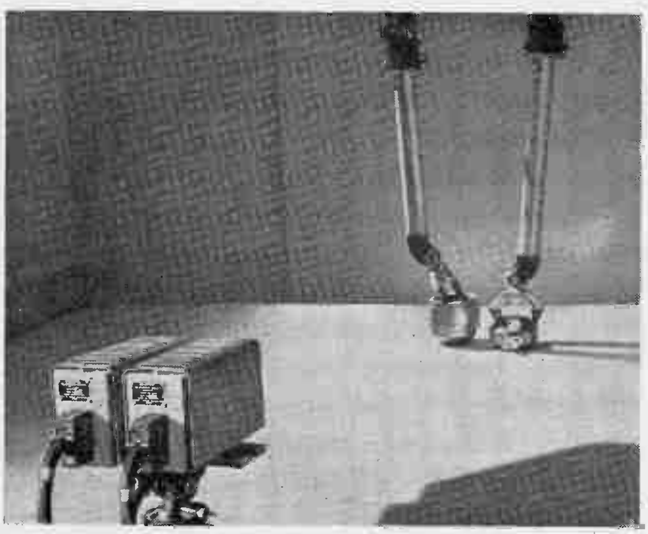
A STEREOSCOPIC television camera has been designed by Marconi's Wireless Telegraph Company for use in conjunction with remote-handling equipment at the Atomic Energy Authority's research station. The advantage of stereoscopic vision is that the operator finds it easy to judge the distance of the manipulator's 'hands' from the objects to be handled.

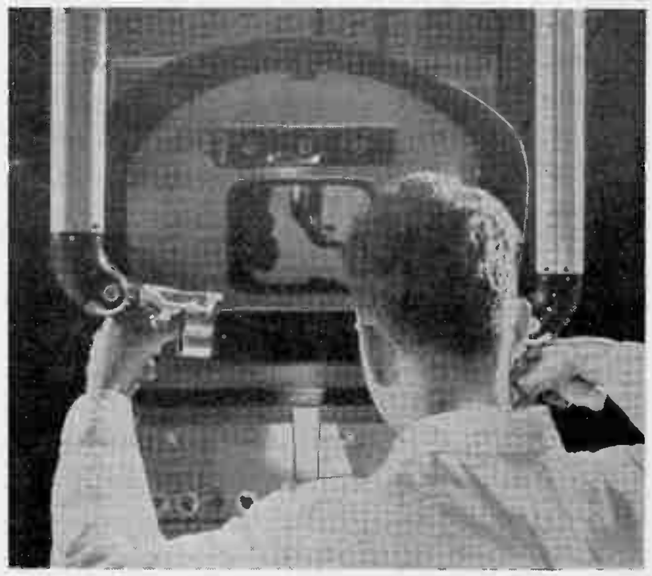
The camera channel consists of two Vidicon cameras mounted side by side with their lines of sight inclined so that they intercept at the point of interest. Two corresponding monitors are provided. In front of each monitor screen is a polarized light filter, the planes of polarization of the two filters being at right angles to one another. After passing through the polarizers, the pictures are combined by means of a half-silvered mirror and are viewed with the aid of suitable spectacles.

Although relatively simple, this type of stereoscopic television makes stringent demands on the overall linearity of each camera and associated monitor. Small errors of picture height and width, for example, which would have no appreciable effect on the picture quality of a single channel are sufficient to ruin a stereoscopic picture by causing mis-registration of the two pictures. The deflection systems must likewise be very linear or, at least, have identical non-linearities.

The accompanying pictures illustrate the remote-handling system in use in conjunction with a manipulator made by Savage & Parsons Ltd.

*Two Vidicon cameras view the remote end of the handling device, which is normally inside a biological shield*





*Operation of remote-handling device with the aid of stereoscopic television*

# Saving Labour in Numerical Computations

From the point of view of the practical engineer, numerical computation is often at best a bore and, at worst, a severe hindrance. Unfortunately, effective progress in practical work is usually impossible for long without it. We may need it in order to apply a well-understood general formula to a particular case, or to obtain a general understanding of the behaviour of certain quantities in relation to each other. Labour-saving tricks of computation can be applied widely; they do not depend for their effectiveness on the nature of the particular problem in question.

If we wish to evaluate an expression of the form

$$y = x_1 x_2^2 x_3 / x_4^3$$

a slide rule is quite adequate if accuracy to two or three significant figures is required, but a slide rule is of less use in computations where additions or subtractions are combined with multiplications or divisions; if the result required is a difference between two nearly-equal quantities, special care is required. Suppose, for example, we need to evaluate

$$y = (1000 + x)^{1/3} - (1000 - x)^{1/3}$$

for $x$ of the order 10. A slide rule will give $(1000+x)^{1/3}$ to 3 significant figures so, as this number is slightly over 10, the first decimal place will be doubtful. Similarly, $(1000 - x)^{1/3}$ will be a number just under 10 for which the first decimal place will be doubtful. The difference will be a decimal which may well be less than 0·1 so that we shall, in effect, have no reliable information at all about its value. In this particular case, the obvious way out is to use the binomial theorem.

This theorem states that if $x$ is numerically less than $a$ then, whether $x$ is positive or negative,

$$(a + x)^n = a^n(1 + x/a)^n$$

$$= a^n\left\{1 + n.\frac{x}{a} + \frac{n(n-1)}{2!}\left(\frac{x}{a}\right)^2 + \frac{n(n-1)(n-2)}{3!}\left(\frac{x}{a}\right)^3 + \ldots\right\}$$

the series being infinite unless $n$ is a positive integer. Applying this to the determination of $y$, we have

$$y = 10\left(1 + \frac{x}{1000}\right)^{1/3} - 10\left(1 - \frac{x}{1000}\right)^{1/3}$$

$$= \frac{x}{150} + \frac{x^3}{81 \times 10^7} + \cdots$$

so that $x/150$ is a very good approximation to $y$ when $x$ is small compared to 1000. A less obvious way out is to use the fact that

$$\alpha - \beta = (\alpha^3 - \beta^3)/(\alpha^2 + \alpha\beta + \beta^2)$$

which gives, when $\alpha = (1000 + x)^{1/3}$, $\beta = (1000 - x)^{1/3}$,

$$y = \frac{(1000 + x) - (1000 - x)}{(1000+x)^{2/3} + (1000+x)^{1/3}(1000-x)^{1/3} + (1000-x)^{2/3}}$$

The numerator now simplifies to $2x$ and, in the denominator, the terms are added instead of subtracted so that, roughly speaking, the whole denominator will be obtained to three-figure accuracy if each individual term is obtained to that accuracy. The last equation for $y$ could be used, whatever the value of $x$ might be, whereas the binomial series would converge slowly if $x$ were, say, 973; if $x$ were numerically greater than 1000, $y$ would have to be rearranged to give a series of descending instead of ascending powers of $x$.

It is commonly necessary to evaluate a polynomial, or the sum of the first few terms of a series. If, for example,

$$y = 153 - 82x + 14x^2 - 7x^3 + x^4$$

direct substitution is straightforward if $x$ is any integer between 1 and 10 multiplied by a positive or negative power of 10, such as 2 or 30 or 400 or 0·07. If $x$ has a value like 1·2347, such substitution is still a possible method, but may be laborious if the polynomial has high degree or if high accuracy is required. Alternatively, we can evaluate $y$ by means of algebraic division by $x - 1{\cdot}2347$. The 'remainder theorem' states that if a polynomial $f(x)$ is divided by $x - a$, the remainder is $f(a)$; that is, the value of the polynomial when $x$ is replaced by $a$. Thus, in doing the division, we are not interested in the quotient, but only in the remainder. Even when the value of $y$ is required for a complex value of $x$, it can be found in a similar manner. Thus, if we require $y$ when $x = 2 + 3j$, we note first that

$$(x - 2 - 3j)(x - 2 + 3j) = x^2 - 4x + 13$$

and divide $y$ by $x^2 - 4x + 13$. Again, we are not concerned with the quotient, but only with the remainder, which is

$$y_R = -87x + 296$$

$y_R$ will have the same value as $y$ when $x = 2 + 3j$, since $y - y_R$ is necessarily a multiple of $(x^2 - 4x + 13)$ and, therefore, zero when $x = 2 + 3j$. We therefore substitute $(2 + 3j)$ for $x$ in $y_R$ instead of in $y$, and obtain

$$y = 122 - 261j \text{ when } x = 2 + 3j.$$

Sometimes we are concerned with the inverse problem: What is the value of $x$ when $y$ is given? In the case we have just been considering, we can find this out by solving an algebraic equation; this has been the subject of earlier articles and need not be considered further here. In the case where $y$ is a tabulated function of $x$, such as sin $x$ or $e^x$, we can find $x$ given $y$ by 'inverse interpolation', or using the tables 'backwards'. If, however, $y$ is a function of $x$, which is not a polynomial, and is either not tabulated or only sparsely tabulated, we can often obtain $y$ satisfactorily by Newton's method, which uses the fact that in general, if $a$ is an approximation to a root of the equation

$$f(x) = 0$$

then $a - f(a)/f'(a)$ is a better approximation, $f'(x)$ being the derivative of $f(x)$ (which can be any function which possesses a derivative for values of $x$ near $a$). Consider, for example, the real positive root of the equation

$$f(x) = \sin x - \tfrac{1}{2}x^2 = 0$$

($x$ being in radians). A rough graph makes it clear that $x$ is somewhat less than $\frac{1}{2}\pi$. We also know that $\sin x$ changes very slowly when $x$ is near $\frac{1}{2}\pi$, and is nearly 1 ; this suggests that $x \approx \sqrt{2}$. We therefore start with $x = 1{\cdot}4$. Then $f(1{\cdot}4) = 0{\cdot}00545$ ; $f'(1{\cdot}4) = \cos 1{\cdot}4 - 1{\cdot}4 = -1{\cdot}23003$, so the next approximation is

$$1{\cdot}4 + \frac{0{\cdot}00545}{1{\cdot}23003} = 1{\cdot}4044$$

and we find $f(1{\cdot}4044) = 0{\cdot}00002$. Newton's method is unsatisfactory if $f'(x)$ is small in the neighbourhood considered ; in such a case, the best procedure is to put $x = a + x'$ and expand $f(x)$ in ascending powers of $x'$. A straightforward approximate equation for $x'$ of the form

$$(x')^n \approx A$$

will usually then be obtained.

Another computation which is frequently required is one in which we wish to tabulate and plot a function. If, for example,

$$y = \frac{(x^4 - 2x^2 + 3)^{\frac{1}{2}}}{x^2 + 7} + \frac{1}{100}x^2$$

and we are interested in values of $x$ from 0 to 10, the first point to notice is that only even powers of $x$ occur. It therefore saves labour to choose values of $x^2$, not $x$, as round numbers ; there is no need for the values of $x$ tabulated to be equally spaced, though it is usually desirable that they should be approximately so. We shall therefore take $x^2$ as 1, 5, 10, 20, 30, 40, 60, 80 and 100. The details of the calculation are given in Table 1.

Here, the most important step is the initial one of deciding what quantities shall be computed in order to obtain $y$ with as little thought during the process of computation as possible. For, where hard thinking is required during the process of computation, one is likely to make a systematic error. An isolated error, such as an error of addition, is likely to show because one of the values computed will give rise to a point which obviously does not lie on a smooth curve with the remainder, but a systematic error may mean that we have the wrong curve. We first complete Column B with the chosen values of $x^2$ ; Column A, the corresponding values of $x$, can be left till last because it is only required to enable us to plot $y$ against $x$, not in order to help with the calculation. Column C is simply Column B × 0·01, but it is worth putting in unless one is completely confident of being able to manage without it. Column D is obtained by squaring Column B and adding 3 ; we then subtract twice Column B to obtain Column E, the square root of this being Column F. The quantity in this column has to be divided by the quantity in Column G (seven more than that in Column B) to obtain the first term of $y$, recorded in Column H, and then Column C has to be added to obtain $y$ itself.

It saves a surprising amount of effort to work vertically, not horizontally. When working out Column C, we concentrate entirely on dividing by 100 ; we can forget why we have to do so, and the required values are then soon written down. In Column D, all we need to think of is squaring Column B and adding 3 ; this can be recorded as $B^2 + 3$ before we start if necessary. In Column E, we only have to think of subtracting twice Column B, which is easy because we chose the entries in Column B to be round numbers. Similar remarks apply to the remaining columns. The point is that while doing any one column we only have to think of one simple process—squaring, addition, subtraction, or looking up square roots (with tables or slide rule), etc. Should we find we need extra points, it may be necessary to work horizontally, but then we have the easily-calculated points already in Table 1 as a guide.

Thus, we see that the process of computation is not so difficult as it seems initially to those unaccustomed to it. It pays to break it up into a number of steps each of which is elementary and easy, and the process required at each step is worth recording. It is better to have too many steps than too few, because the time wasted in chasing mistakes when there are too few steps is usually large compared with the time required to do the extra steps. Time spent in preliminary algebraic manipulation of an expression to get it into the form most suitable for numerical computation is seldom wasted.

**TABLE 1**
Values of $y$

| A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|
| $x$ | $x^2$ | $0{\cdot}01x^2$ | $x^4+3$ | $D-2B$ | $E^{1/2}$ | $x^2+7$ | $F/G$ | $C+H=y$ |
| 0 | 0 | 0 | 3 | 3 | 1·7321 | 7 | 0·2474 | 0·2474 |
| 1 | 1 | 0·01 | 4 | 2 | 1·4142 | 8 | 0·1768 | 0·1868 |
| 2·2361 | 5 | 0·05 | 28 | 18 | 4·2426 | 12 | 0·3536 | 0·4036 |
| 3·1623 | 10 | 0·1 | 103 | 83 | 9·1104 | 17 | 0·5359 | 0·6359 |
| 4·4721 | 20 | 0·2 | 403 | 363 | 19·053 | 27 | 0·7057 | 0·9057 |
| 5·4772 | 30 | 0·3 | 903 | 843 | 29·034 | 37 | 0·7847 | 1·0847 |
| 6·3246 | 40 | 0·4 | 1603 | 1523 | 39·025 | 47 | 0·8303 | 1·2303 |
| 7·7460 | 60 | 0·6 | 3603 | 3483 | 59·017 | 67 | 0·8809 | 1·4809 |
| 8·9443 | 80 | 0·8 | 6403 | 6243 | 79·013 | 87 | 0·9082 | 1·7082 |
| 10 | 100 | 1 | 10003 | 9803 | 99·01 | 107 | 0·9253 | 1·9253 |

# Phase-Lock A.F.C. Loop

(*Concluded from p.* 146 *of the April issue*)

TRACKING SIGNALS OF VARYING FREQUENCY

**By R. Leek, A.C.G.I., B.Sc.(Eng.), Graduate I.E.E.***

When constructing a phase-lock type circuit to track changes in the input signal, it is necessary to minimize the resulting steady-state phase error to obtain optimum loop performance. Some general statements may be made regarding the cases considered in the preceding sections.

Thus, the error $\phi_{ss(2)}$ may be reduced by making the d.c. loop gain $Ak_3$ as large as possible, from equation (29). Increasing $A$ also reduces the time-varying part of $\phi_{ss(3)}$, which is the integrated form of $\phi_{ss(2)}$, or $\phi_{ss(3a)}$ in equation (11). Over a given frequency range for which the input signal frequency is to be tracked, $\delta f_s$, say, the maximum error due to $\phi_{ss(3a)}$ would be $\frac{\delta f_s}{k_3 A}$ when $f_{s0} = f_{g0}$ at one end of the range $\delta f_s$. Optimum conditions for operation in the range $\delta f_s$, would be obtained by adjusting the zero-lean frequency of the controlled oscillator such that $f_{g0}$ has the value of $f_s$ at the centre of the range $\delta f_s$. The maximum error $\phi_{ss(3a)}$ would then be half the previous error, viz. $\frac{F_s}{2k_3 A}$, and would occur at each limit of the range $\delta f_s$. The error $\phi_{ss(3a)}$ causes the controlled oscillator frequency to follow the input frequency ramp with the same rate of change of frequency but with a frequency or "velocity" lag. The lag is such that the frequency input to the detector is $\left( f_i + \frac{\Delta F_s}{k_3 A} \right)$.

The residual part of the error $\phi_{ss(3)}$, $\phi_{ss(3b)}$, may be minimized by reducing $\tau T_2$, i.e. $\frac{C_2 R_1}{k_3}$, from equations (13) and (30). This infers a high a.c. loop gain and a wide-bandwidth shaping network. By increasing these factors the error could be made as small as desired and perfect tracking of the input signal would result. However, when the input signal is in the presence of noise, perfect following of the input involves perfect following of the noise also. Thus, a compromise must be made between faithfully following the input signal and ignoring the noise. This is the basis of the Wiener theory in which optimum tracking of a signal in noise is obtained by deriving a shaping network which minimizes the sum of the mean square errors due to the noise and the signal. Derivation of the optimum shaping network is beyond the scope of this article but a treatment is given in Appendix 2 for the elementary type of shaper considered in the present application; i.e., the single time-constant type. The nature of the compromise between tracking the signal and the noise may be seen from the theory of Appendix 2 and the results of Fig. 8.

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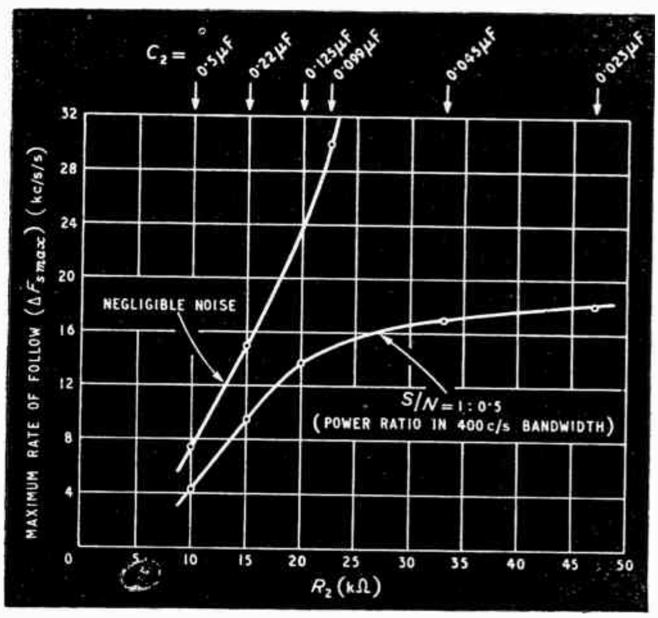
Fig. 7. *Maximum rates of follow and pick-up. All measurements were taken at* $f_{g0} = 35$ *kc/s (i.e.,* $\phi_{ss(3a)} = 0$*) with the bandwidth of amplifier A* (Fig. 1) *at* 2·8 *kc/s and* $f_i = 100$ *kc/s. The constant loop parameters were:* $R_1 = 1{\cdot}2\ M\Omega$, $k_1 = 3$ *V/radian* ($\phi_3$ *small*), $k_2 = 1{\cdot}23$ *kc/s/V*, $A = 85$. *The arbitrarily-chosen controlling factor was* $\tau = T_2$, *or* $R_2 = \sqrt{(R_1/C_2 k_3)}$




| $C_2$ (µF) | $R_2$ (kΩ) | $f_{pu\,max}$ (kc/s/s) | $\Delta F_{s\,max}$ (kc/s/s) | $f_{pu\,max}:\Delta F_{s\,max}$ |
|---|---|---|---|---|
| 0·500 | 10·0 | 4·8 | 7·3 | 1 : 1·52 |
| 0·220 | 15·0 | 8·6 | 15·0 | 1 : 1·75 |
| 0·125 | 20·0 | 13·9 | 30·0 | 1 : 2·16 |
| 0·080 | 25·5 | 21·0 | — | — |
| Negligible Noise | | | Average | 1 : 1·81 |
| | | | | |
| 0·500 | 10·0 | 1·2 | 4·3 | 1 : 3·58 |
| 0·220 | 15·0 | 3·1 | 9·5 | 1 : 3·06 |
| 0·125 | 20·0 | 4·6 | 13·7 | 1 : 2·98 |
| 0·023 | 47·0 | 9·6 | 18·2 | 1 : 1·90 |
| S/N Ratio = 2·0 | | | Average | 1 : 2·88 |

## 4. Phase-Lock Loop Incorporating Appreciable Delay Time

In the particular application of the loop, for which most of the results below are quoted, a narrow-band filter was added to the loop between M and A, Fig. 1. The filter provided frequency discrimination by making the loop sensitive to a narrow band of the total frequency spectrum at the input to M. The filter also confined the bandwidth of noise presented to D to that of the filter bandwidth.

### THE LOOP PHASE EQUATION

The importance of shaping and delay time rather than gain between the mixer and the detector was mentioned in Section 3. In the absence of noise or in low noise conditions, the shaping between mixer and detector is of little consequence once lock is secured, since the frequency or "velocity" lag is made much less than half the filter bandwidth by increasing the d.c. gain in the shaper (see Section 3). When the noise level is high, the deviation of the oscillator frequency due to the signal $v_4$ containing noise may be comparable with the half bandwidth of the filter (see Section 5). Also, the shaping introduced by F is of importance during the lock-on stage (see Section 5). The delay introduced by a narrow filter is important since it may be comparable to the shaper time constant.

Considering an ideal filter having a rectangular amplitude/frequency characteristic and a phase slope which is linear in the passband, the delay time will be given by the phase slope (in radians per radian/sec), $T_1$, say. Such a perfect filter may not be realized in practice but this conception allows a simple modification to the loop phase equation to be made ; otherwise, the transfer function of the filter in question would be added to the loop equation. Considering the filter in this way is equivalent to assuming that the filter acts as a Heaviside distortionless line and has the effect of adding a distributed constant network to a loop consisting of lumped networks. For such a line, a change in any of the input parameters, amplitude or phase, appears unmodified at the output after a certain delay time. In the loop, one can consider a change $\Delta f_g$ from the controlled oscillator to provide a phase step $\frac{\Delta f_g}{p}$ to the filter which appears $T_1$ seconds later at the detector. Using the shift theorem of Laplace transforms, this delay will make the loop gain function go from $\frac{\phi_1(p)}{\phi_3(p)}$ to $\frac{\phi_1(p)}{\phi_3(p)} \cdot e^{-pT_1}$. Thus, the loop equation (12) becomes,

$$\phi_1 = e^{-pT_1} \cdot \frac{1}{p} \cdot k_3 \cdot Y_s(p) \cdot \sin \phi_3 \quad \ldots \quad \ldots \quad (31)$$

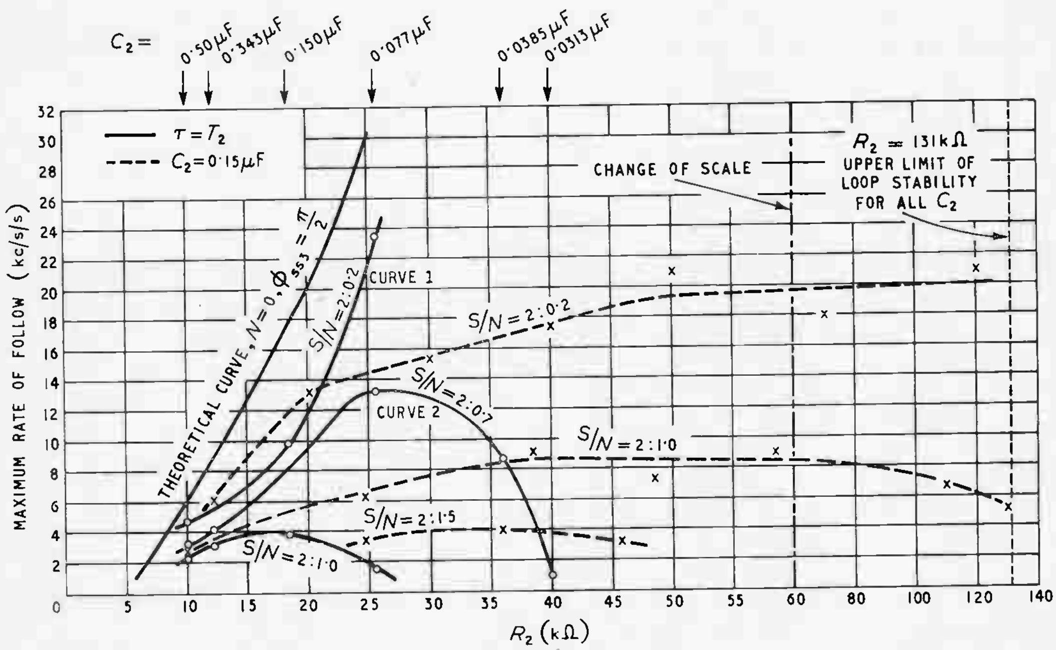



Fig. 8. *Some values of maximum rate of follow for the loop using the filter of* Figs. 9 *and* 10

### THE STEADY-STATE PHASE ERROR

Consider the loop locked to the input signal frequency, $f_s$. If $T_1$ is negligibly small and a sweep of $f_s$ commences, a static phase error is produced as described in 3.1. It is apparent that if the delay in the filter were so large that $(f_s - f_g)$ became greater than half the filter bandwidth before an error signal reached the oscillator control, no follow-on would be possible. If $F_{s\,max}$ is the maximum expected rate of change of input signal frequency and $B_F/2$ half the filter bandwidth, the filter delay $T_1$ must not be greater than,

$$T_1 \ngtr \frac{B_F}{2F_{s\,max}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (32)$$

This assumes that the switching signal to the phase-sensitive detector is tuned to the centre of the filter pass-band, Such a value of $T_1$ is large and is unlikely to cause a restriction in loop operation in practice. Thus, for the present application, $F_{s\,max}$ was 25 kc/s/s and $B_F$ about 800 c/s, so that the largest allowable delay was 16 msec. The longest delay used was 2 msec so it could be assumed that, without noise, the phase error was independent of filter delay time and the results obtained substantiate this assumption.

When noise performance is considered, the effect of $T_1$ will be significant and a full treatment is beyond the scope of this article, but the integral corresponding to equation (A18) of Appendix 2 is given at the end of that Appendix.

OPERATION ON THE EDGE OF THE FILTER PASS-BAND

The rapidly changing edges of the filter amplitude/frequency characteristic have been found to give rise to modes of operation described below.

## 5. Practical Results

MAXIMUM RATES OF FOLLOW OF FREQUENCY RAMP

The maximum rate at which the loop was capable of tracking ramps of input signal frequency starting in the locked-on condition was of interest, and was called the maximum rate of follow.

Figs. 7 and 8 show some results, which are by no means exhaustive, for various signal-to-noise ratios at the detector input, $v_1$. The maximum rate of change of frequency was attained over a spectrum 60 kc/s wide, starting in the locked condition at one end of this spectrum, and increasing the rate of change of frequency at a linear rate. Fig. 7 applies to a loop with a relatively wide-band amplifier A. With $R_1$, $k_1$, $k_2$ and $A$ fixed and $R_1 \gg R_2$, the loop gain was proportional to $R_2$ which is plotted as abscissa. Comparison of the maximum rates of follow with the values expected from the equation for a noise-free signal indicates that unlocking occurs when the steady-state phase error has built up to about 65°. The curves of Fig. 8 for the loop using the filter of Figs. 9 and 10 show the nature of the compromise required between the phase error due to the signal and that due to noise phase jitter. When there is little noise, $C_2$ can be made small and the loop gain made high, so reducing $\phi_{ss}$ at high sweep rates while the associated increase in noise bandwidth is unimportant ; e.g., curve 1, Fig. 8. With noise, the same procedure results in deterioration of performance at the high-gain end due to large noise phase jitter ; e.g., curve 2, Fig. 8. An optimum noise bandwidth thus exists for each signal-to-noise ratio.

The maximum rates of follow were independent of the bandwidth between mixer and detector, in the absence of noise, down to the minimum bandwidth used ; viz. 400 c/s, as expected from the consideration of this point in Section 4.

Noise in the system produces jitter on the controlled oscillator frequency which causes corresponding amplitude modulation at the detector input $v_1$, according to the amplitude/frequency characteristic of the filter or amplifier between mixer and detector. At high noise levels and using a narrow-band filter, the deviation due to jitter becomes comparable to the filter half-bandwidth. The signal-plus-noise power measured at $v_1$ is then found to be little more than the signal power without noise. The procedure when making signal-to-noise ratio measurements was therefore to measure the signal power when negligible noise was present and the noise power when the loop was unlocked.

By adding a d.c. (i.e., lean) voltage to the output of the phase-sensitive detector by external means, the controlled oscillator frequency was made to change at rates prescribed by this lean voltage. The maximum rate of follow could then be increased or decreased and the range of operation of the detector moved bodily according to the sense of the lean. Thus, the two inputs to the detector were 90° out of phase for the loop locked to a signal changing at the same rate as that prescribed by the lean voltage for the controlled oscillator frequency–neglecting the small frequency or 'velocity' lag since the d.c. gain was high. Increasing the lean in a sense opposite to that caused by the input frequency ramp, a stage was reached where unlock occurred when $f_s$ was fixed. Measurements of the rate of change of controlled oscillator frequency and phase error corresponding to this critical lean voltage indicate that this is an alternative method of measuring the maximum rate of follow. This method is more satisfactory than that involving a finite width of spectrum, since the lean voltage may be increased up to the critical value in steps, or at as small a rate as desired to obtain any required accuracy.

When both $f_g$ and $f_s$ were changing, the maximum rate of change of frequency remained constant when the

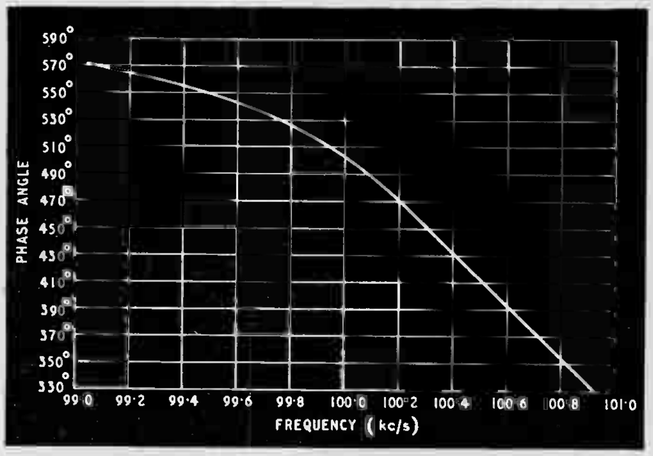
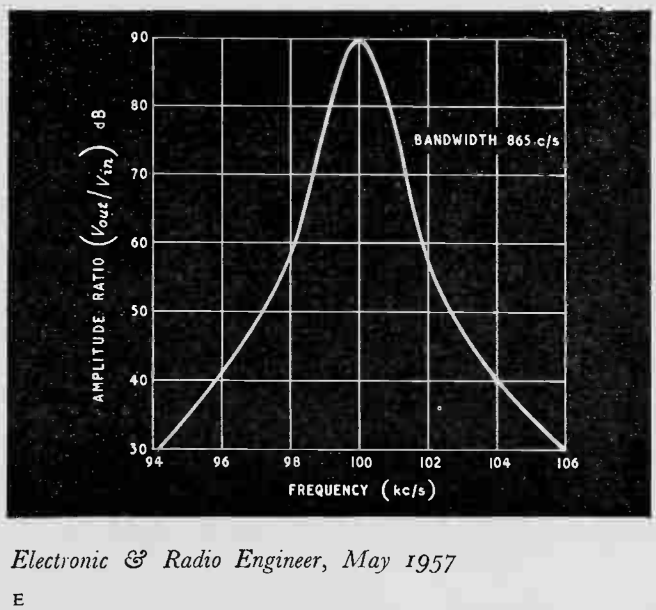



Fig. 10. *Phase response of filter XEL 5356*

Fig. 9. *Amplitude versus frequency response of XEL 5356 filter*



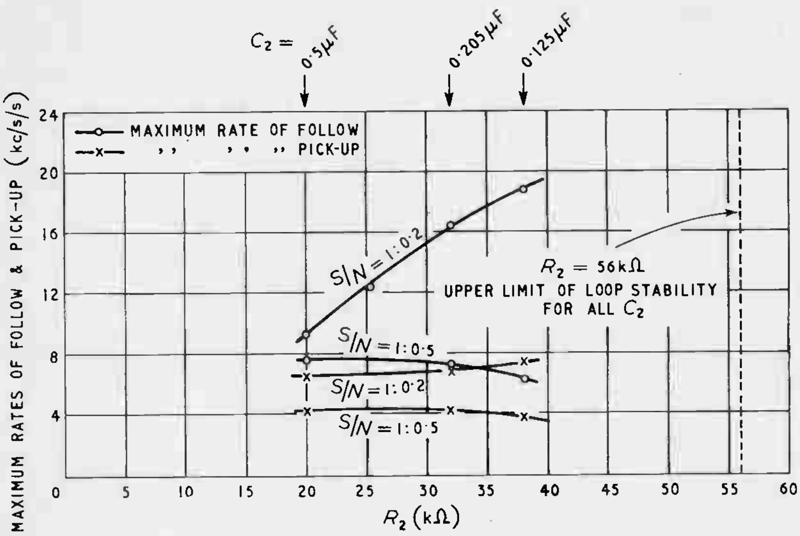



Fig. 11. *Some values of maximum rates of follow and pick-up for the filter of* Fig. 12

latter was considered as the algebraic sum of the rates of change of $f_g$ and $f_s$ as in equation (15) et seq.

### MAXIMUM RATES OF PICK-UP AND PULL-UP

The maximum rate of follow is determined by commencing with the loop in the locked condition. In practice, it is also of interest to determine the maximum rate at which the input signal may change such that the loop may pull-in and follow-on. The limiting rate of change of input for which the loop is incapable of locking and following was termed the maximum pick-up rate. The pick-up process involves a forced speeding-up of the pull-in process followed by the formation of the steady error required to provide the rate of change of frequency. Some values of maximum pick-up rate are quoted in Fig. 7 and some further values given in Fig. 11 for a loop using the narrow-band filter whose characteristics are shown in Fig. 12.

Next, the input-signal frequency was fixed and the controlled-oscillator frequency changed at a rate determined by an external lean voltage. A well-defined maximum rate of change of controlled-oscillator frequency was found for which lock could be secured, and this was termed the maximum pull-up rate, or maximum search rate, since the loop effectively searched the input spectrum for a signal. For rates of sweep higher than this maximum, the loop response was insufficient to prevent the signal being swept through. From the measurements taken, it appeared that the maximum pull-up rate and pick-up rate were identical when similar loop constants were used in each case.

Further, the relative rates of pick-up and pull-up remained constant when both $f_g$ and $f_s$ were changing, similar to the case for relative maximum rates of follow.

### GENERAL REMARKS

All the above measurements were made by a method of repetitive trials and any particular result represents the mean of several such trials. The estimated experimental error; $\pm 0{\cdot}2$ kc/s/s for 10 kc/s/s, was of the same order as the observed spread due to taking repetitive measurements. It may therefore be said that any true zone of uncertainty, when using signals of changing frequency, was masked, or did not exist, to the extent of the limits stated.

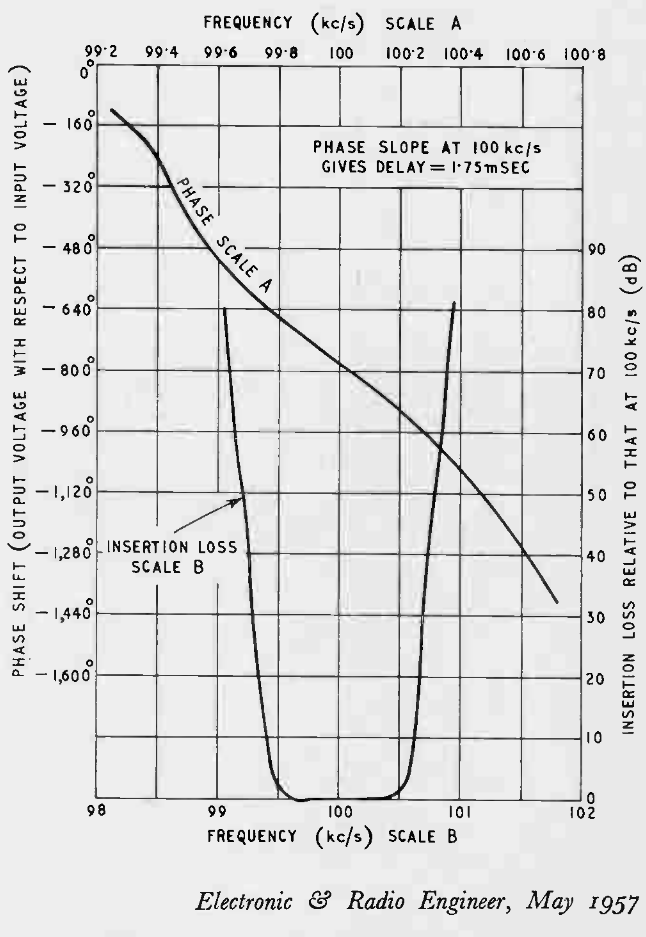
The limiting rate at which the signal frequency may be swept is ultimately determined by the filter inserted between the mixer and the detector. When the frequency of the input signal to a narrow-band filter is changed, the output signal shows ringing effects if the frequency of the input changes at about a rate $B^2_F$ or more, where $B_F$ is the filter bandwidth[6]. This rate of change of frequency is many times more than the maximum rates of follow and pick-up so that ringing effects may be ignored in the present application.

### THE PUSHING EFFECT

The phase-lock loop is a non-linear type system which may have more than one stable state; e.g., following a frequency step, the loop may pull in to the new frequency or, if the frequency step is larger than the pull-in range, the controlled oscillator will revert to its free-running frequency $(f_i + f_{g0})$. However, when a narrow-band filter of the type indicated in Figs. 9, 10 and 12 is used, a further mode is found to exist, as indicated below.

When the bandwidth between mixer and detector is

Fig. 12. *Amplitude and phase characteristics of filter.* (*Marconi filter, Edition B, No.* 541,319)



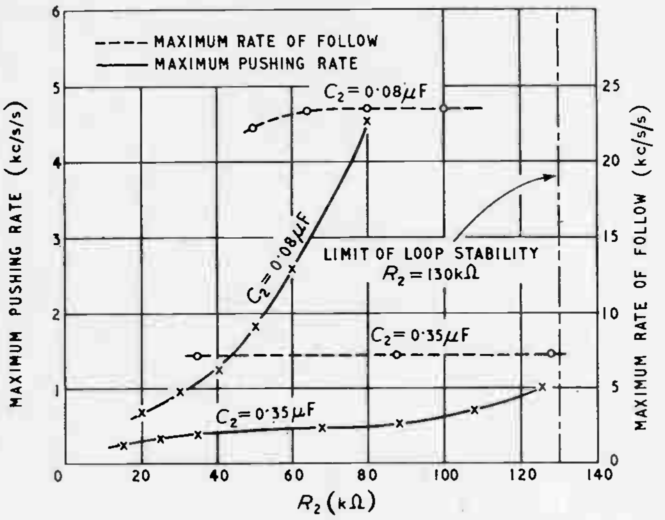



Fig. 13. *Maximum pushing rates for various loop parameters, with the filter characteristics of Fig. 9 and* $R_1 = 1{\cdot}2\ M\Omega$. *The gain constant for the phase-sensitive detector D is* $2{\cdot}5\ V/radian$ $(\phi_1 - \phi_2$ *small) and for the controlled oscillator* $1{\cdot}23\ kc/s$ *per volt* $v_4$

**TABLE**

*Variation of Critical Beat Frequency with* $R_2$, *other parameters being fixed as shown.*

| $R_2$ (kΩ) | Critical Beat Frequency, (c/s) |
|---|---|
| 5 | Negligible Pushing |
| 15 | 640 Weak Pushing |
| 25 | 750 |
| 45 | 950 |
| 105 | 1,100 |
| $R_1 = 1{\cdot}2M\Omega$ $C_2 = 0{\cdot}5\ \mu F$ | $k_1 = 2{\cdot}5$ Volt/radian ($\phi_3$ small) $k_2 = 1{\cdot}23$ kc/s/Volt |

very wide, the loop has a pull-in range consistent with previous results[4]. In these conditions, the pull-in range is determined by the variation of loop gain with beat frequency $(f_g - f_s)$ (see Section 3). When a filter of narrow bandwidth is inserted, the loop gain involves the falling edge of the filter amplitude/frequency characteristic for comparatively low beat frequencies. An attempt was made to lock on, starting with $(f_{g0} - f_s)$ much larger than half the filter bandwidth and zero lean voltage at the shaper input, and sweeping $f_s$ in the appropriate sense. The beat frequency fell until at a critical beat frequency equal to approximately half the filter bandwidth, the controlled-oscillator frequency was 'pushed ahead' at a rate prescribed by $f_s$. The critical beat frequency persisted during the pushing process, and if the direction of $f_s$ were reversed, the controlled-oscillator frequency returned to its free-running value at a drift rate not greater than that prescribed by loop constants. Thus, true lock on the edge of the filter pass-band did not exist. An instance was observed where three 'locked' conditions existed; viz., the normal one at the centre and one near each edge of the filter pass-band, using the extremely sharp cut-off filter of Fig. 12. On an edge, the beat frequency corresponded to operation at a position between the main lobe and a side lobe of the amplitude/frequency characteristic of the filter. In such a position, pushing could occur for both directions of sweep so that the controlled-oscillator frequency was pushed for one direction and 'dragged' for the other direction of sweep; i.e., a crude form of lock.

The critical beat frequency at which pushing commenced was found to depend on the shaper constants, and some values are given in the Table. The pushing effect was found to persist up to a well-defined limiting rate of change of input-signal frequency, which was called the maximum pushing rate. Some observed values are given in Fig. 13, together with the corresponding maximum rates of follow. A circuit diagram of the phase-sensitive detector is given in Fig. 14. For input-frequency ramps of magnitude greater than the maximum pushing rate, normal lock was obtained up to the further limiting value determined by the maximum pick-up rate. Thus, the maximum pick-up rate and the maximum pushing rate define the limits of a range of input frequency ramps for which normal lock-on and follow is possible.

The pushing effect was examined for loops using filter bandwidths up to 10 kc/s and in each case the beat frequency at which pushing occurred was about half the filter bandwidth. The effect was more marked for filters having steep-sided amplitude/frequency characteristics. In the case of a wide filter for which the maximum pushing rate was much less than the rate of pull-in to lock, it was observed that normal pull-in occurred once the signal was well within the filter pass-band. The time taken to pull in over 5 kc/s was 0·3 sec.

Conversely, when $f_s$ was fixed and the controlled oscillator frequency swept by applying an external lean voltage, a minimum rate of sweep was observed below which the oscillator was unable to overcome pushing and enter normal lock, which was called the minimum search rate. If the controlled oscillator frequency was swept at a search rate less than this minimum, the sweep was arrested short of the signal frequency by an amount approximately equal to half the filter bandwidth.

The values of maximum pushing rate and minimum search rate were found to be numerically equal, within experimental error, and when both $f_g$ and $f_s$ were sweeping, the pushing effect occurred as in Fig. 13 when rates of sweep were considered relative and added algebraically.

### AMPLITUDE MODULATION OF THE INPUT SIGNAL

The effect of amplitude modulation of the input signal on the pulling effect of a simple locked oscillator is to reduce this pulling effect to zero for 100% modula-

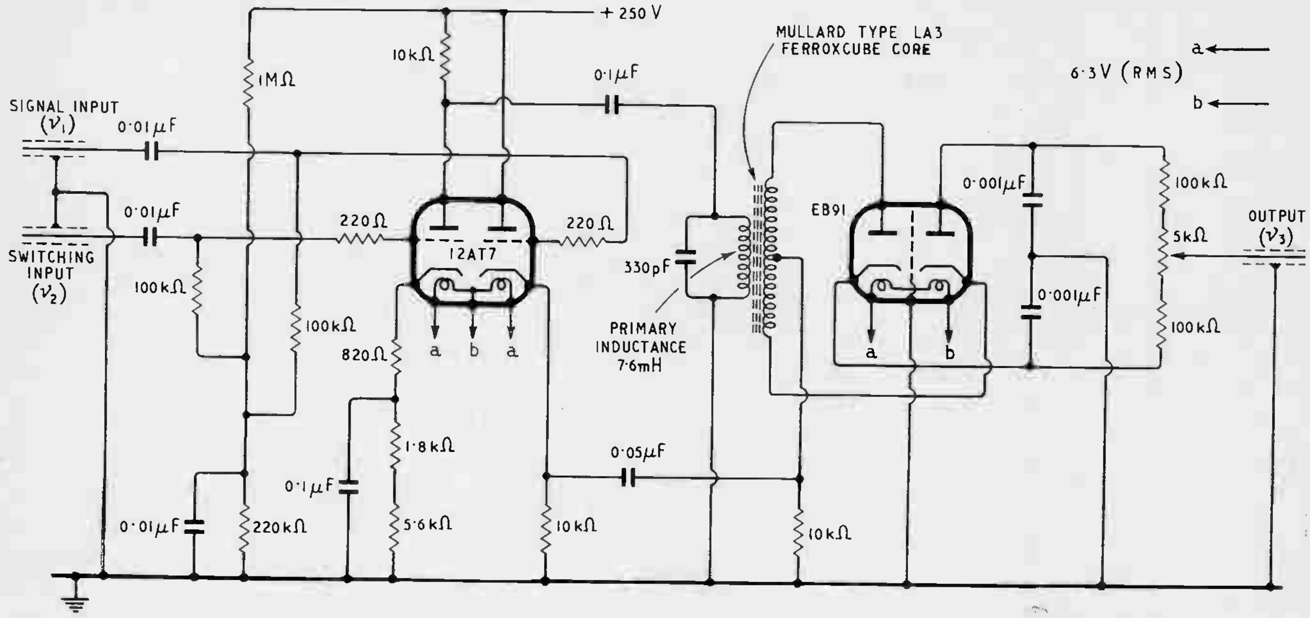



Fig. 14. *The phase-sensitive detector circuit*

tion[7]. Such a system may lock to either of the sidebands or to the frequency of the modulated input signal.

When the input signal is amplitude-modulated, the phase-lock loop will lock both to the sidebands of the input signal and to the frequency of the modulated carrier signal. Although extensive measurements have not yet been carried out, a loop has been used with an input signal of frequency 10 kc/s which was amplitude-modulated to a depth of 50% at a frequency of 100 c/s. When the loop was locked to a sideband of this signal, this lock was not greatly impaired by the presence at the detector output of beats due to the carrier signal, 100 c/s away and the other sideband, 200 c/s away. The phase-lock loop would, therefore, appear to be capable of considerable frequency discrimination.

The author wishes to thank Mr. S. C. Dunn, English Electric Co. Ltd., Luton, for some helpful criticisms, and his acknowledgements are due to the Chief Engineer, English Electric Co. Ltd., for permission to submit this article for publication.

## APPENDIX 2

*Noise Performance of the Phase-Lock Loop*

As outlined in Section 3, the performance of the loop when the signal contains noise is dependent on the contributions of the signal and the noise to the formation of the total phase error at the output of the phase-sensitive detector. The error due to various types of input signal has been derived in Section 3 and it is the purpose of the following argument to derive the phase error due to the noise.

The loop phase equation is

$$\phi_3 = \sin^{-1}\left[\frac{p\left(\frac{1}{k_3 A} + p\,\tau T_2\right)\cdot\phi_1}{1 + p\,T_2}\right], \text{ from equation (22).}$$

When the d.c. gain $A$ is large, as in practice, the shaping network has a transfer function given by equation (A.9). Equation (22) may be modified accordingly, and the approximation $\sin\phi_3 \approx \phi_3$ will also be made, thus,

$$p\,\phi_1 = \frac{1}{\tau}\left(1 + \frac{1}{p\,T_2}\right)\phi_3 \quad \ldots \quad \text{(A11)}$$

$\phi_3$ is the error phase output, $(\phi_2 - \phi_1)$. When noise is present in the input signal, it is assumed that the noise signal may pass through the detector as a random function added to $\phi_3$. Thus, the total error at the detector output would be $(\phi_3 + \phi_N)$, where $\phi_N$ is a noise function. The phase error $\phi_3$ will then be composed of a part due to the signal, $\phi_{3S}$, say, and a part due to the noise, $\phi_{3N}$, say. The equation (A11) becomes,

$$p\,\phi_1 = \frac{1}{\tau}\left(1 + \frac{1}{p\,T_2}\right)(\phi_3 + \phi_N) \quad \ldots \quad \text{(A12)}$$

Using $\phi_3 = \phi_2 - \phi_1$,

$$p^2 \cdot \phi_3 + p \cdot \frac{1}{\tau}\phi_3 + \frac{1}{\tau T_2}\cdot\phi_3 = p^2\,\phi_2 - \left(\frac{p}{\tau} + \frac{1}{\tau T_2}\right)\phi_N \quad \text{(A13)}$$

When the noise is purely random, its spectral density is constant over a much wider frequency range than the loop bandwidth, which is determined by the narrow band filter or amplifier between the mixer and detector and by the shaping network. Also, correlation between the input signal and the noise may be taken as zero, so that the cross-spectral densities of the second derivative of $\phi_2$ and the noise $\phi_N$ in the right-hand side of equation (A13) may be taken as zero. If $G_\epsilon(f)$ is the error spectral density, then,

$$G_\epsilon(f) = |y_1(p)|^2\,G_I(f) + |y_2(p)|^2 \cdot N \quad \ldots \quad \text{(A14)}$$

where $N$ is the constant spectral density of the noise, and

$$y_1(p) = \frac{1}{p_2 + \frac{1}{\tau}\cdot p + \frac{1}{\tau T_2}} \quad \ldots \quad \text{(A15)}$$

i.e., the transfer function associated with the second derivative of $\phi_2$,

$$\text{and}\quad y_2(p) = \frac{-\left(\frac{1}{\tau}\cdot p + \frac{1}{\tau T_2}\right)}{p^2 + \frac{1}{\tau}\cdot p + \frac{1}{\tau T_2}} \quad \ldots \quad \text{(A16)}$$

$p = 2\pi jf$,

and $G_I(f)$ is the spectral density of the input signal.

Now, the total mean square error is,

$$\phi^2_3\,|_{mean} = \tfrac{1}{2}\int_{-\infty}^{+\infty} G_\epsilon(f)\,df \quad \ldots \quad \text{(A17)}$$

where $G_\epsilon(f)$ is the spectral density of the total error, as above.

Equation (A14) represents the contributions to the total error of the input signal and the noise, such that

$$\phi^2_{3N}\,|_{mean} = \frac{N}{2}\int_{-\infty}^{+\infty}\left|\frac{\frac{1}{\tau}\cdot p + \frac{1}{\tau T_2}}{p^2 + \frac{1}{\tau}\cdot p + \frac{1}{\tau T_2}}\right| dp \quad \ldots \quad \text{(A18)}$$

$\sqrt{\phi^2_{3I}|_{mean}}$ was calculated previously for various types of input in Section 3 and is the phase error which results when noise is absent.

Equation (A18) gives the mean square phase noise error: and the integral involved is of the form,

$$I_n = \frac{1}{2\pi j} \int_{-\infty}^{+\infty} \frac{g_n(x)}{h_n(x) \cdot h_n(-x)} \, dx \qquad \text{for}$$

which there are tables.

The solution in this case is,

$$\phi^2_{3N} \mid_{mean} = \frac{N}{4}\left(\frac{1}{\tau} + \frac{1}{T_2}\right) \quad \ldots \quad (A19)$$

$$\text{or } \phi^2_{3N} \mid_{mean} = \frac{N}{4}\left(\frac{k_3 R_2}{R_1} + \frac{1}{R_2 C_2}\right) \quad \ldots \quad (A20)$$

The phase error due to the signal alone, say, for a ramp of frequency at the input, from equation (30), is,

$$\phi_{ss(3)} = \sqrt{\phi^2_{3I} \mid_{mean}} = \left(\frac{t}{k_3 A} + \tau T_2\right)\Delta F_s \quad \ldots \quad (A21)$$

(when $\sin \phi_{ss(3)} \approx \phi_{ss(3)}$), or, when $A \gg 1$,

$$\sqrt{\phi^2_{3I} \mid_{mean}} = \tau T_2 \, \Delta F_s \quad \ldots \quad (A22)$$

$$= \frac{R_1 C_2}{k_3} \Delta F_s \quad \ldots \quad (A23)$$

The compromise between the minimization of the phase error due to noise and that due to the signal, in order to form the minimum total mean square error, may now be appreciated. From equations (A19) or (A20) minimization of the phase noise error demands high values of $\tau$ and $T_2$, i.e., a low a.-c. loop gain and a low bandwidth in the shaping network. From equation (A21), the residual error $\tau T_2 \Delta F_s$ may be reduced by diminishing $\tau T_2$. In practice, $k_3$ and $R_1$ were fixed, so that given values of $C_2$ fixed $\phi^2_{3I} \mid_{mean}$ according to equation (A23). Optimum loop performance could then be obtained by choice of the optimum value of $R_2$ for each input-to-noise ratio, according to (A20). The associated results are shown in Fig. 8.

Considering equation (A18), it is observed that the mean square phase noise error is determined by the product of the input noise level and an integral in terms of loop parameters. This integral has the dimension of bandwidth and a 'loop noise bandwidth', $B_N$, say, may be defined as

$$B_N = \int_{-\infty}^{+\infty} \left| \frac{\frac{1}{\tau} \cdot p + \frac{1}{\tau T_2}}{p^2 + \frac{1}{\tau} \cdot p + \frac{1}{\tau T_2}} \right|^2 dp \quad \ldots \quad (A24)$$

$$= \phi^2_{3N} \mid_{mean} \cdot \frac{4\pi}{N}, \text{ from (A18)}$$

$$\text{or } B_N = \pi\left(\frac{1}{\tau} + \frac{1}{T_2}\right) \text{ rad/sec,} \quad \ldots \quad (A25)$$

from (A19),

$$\text{or } B_N = \pi\left(\frac{k_3 R_2}{R_1} + \frac{1}{R_2 C_2}\right) \text{ rad/sec} \quad \ldots \quad (A26)$$

from (A20).

For a given input signal-to-noise ratio, the mean square phase-noise jitter is directly proportional to $B_N$ which may be determined from loop constants using equation (A26).

When the input signal-to-noise ratios are very low, the phase-noise error will be considerably larger than the phase error due to an input frequency ramp which the loop is capable of tracking. The optimum loop conditions may then be approximated to by minimizing $B_N$ alone. By inspection, from equation (A26), the minimum noise bandwidth occurs when,

$$\frac{k_3 R_2}{R_1} = \frac{1}{R_2 C_2}$$

$$\text{or } R_2 = \sqrt{\frac{R_1}{C_2 k_3}} \quad \ldots \quad (A27)$$

$$\text{or } \tau = T_2 \quad \ldots \quad (A28)$$

from (A25).

$$\text{i.e., } B_N = \frac{2\pi}{T_2} = \frac{2\pi}{\tau} = 2\pi\omega_n \text{ rad/sec} \quad \ldots \quad (A29)$$

from (23) and (A25), $\omega_n$ being in rad/sec.

Using the above method, the mean square phase noise error derived from the loop equation (31) becomes,

$$\phi^2_{3N} \mid_{mean} = \frac{N}{2} \int_{-\infty}^{+\infty} \left| \frac{\frac{1}{\tau} \cdot p + \frac{1}{\tau T_2}}{e^{pT_1} \cdot p^2 + \frac{1}{\tau} \cdot p + \frac{1}{\tau T_2}} \right| dp \quad \ldots \quad (A30)$$

which need be integrated over the filter bandwidth only.

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# New Distributed-Constant Components

SOME interesting distributed-constant components were announced last year in the U.S. They are *RC* networks, particularly easy and cheap to manufacture by printed-circuit techniques[1], and a new design of distributed *LC* delay line with improved performance compared with conventional types.

### RC Networks

The *RC* networks employ sheets of ceramic material of suitable dielectric constant as a base. Resistors are printed on the surface of such sheets or, alternatively, on one surface only, the other being coated with a layer of highly-conducting material. The basic circuit elements so produced are as in Fig. 1 (a) and (b). These can be connected up in a variety of ways to provide low-pass filter networks, open- or short-circuited *RC* transmission lines, and other useful configurations.

The simplest device, which is obtained by connecting the network of Fig. 1 (a) in circuit by terminals 1 and 4, leaving the rest unconnected, is a series *RC* network. The device behaves almost exactly like a lumped-constant network with *R* and *C* equal to the total distributed values.

Low-pass filters, obtained by applying an input to 1 and 2 and taking the output from 3 and 4 are somewhat superior in frequency response to three lumped *RC* sections with the same total *R* and *C*.

The distributed network can be used with advantage to replace single-section *RC* decoupling networks of large attenuation. Another useful property is that the phase change for a given attenuation is greater than that of a three-section network; in phase-shift oscillators, the valve need only provide a gain of 12 times against 29 times for a 3-section network.

Open- and short-circuited transmission lines, obtained by connecting to 1 and 2, with 3 and 4 either floating or short-circuited, have the unique property that, beyond a certain frequency the phase angle of impedance is constant at 45°. The impedance beyond this frequency falls off at 10 dB per decade. (The values for single

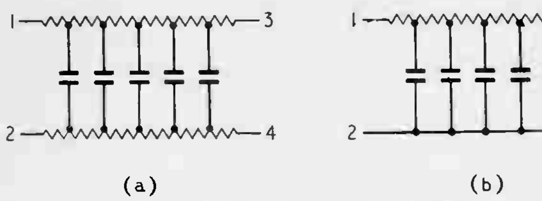


Fig. 1. *Basic distributed-constant RC networks*

lumped $RC$ networks are 90° and 20 dB.) A suggested application is the phase-compensation of feedback amplifiers.

**Delay Lines**

The distributed $LC$ delay line of the type shown in Fig. 2 is well known. It usually takes the form of a coil wound on a conducting mandrel, the capacitance between turns on the coil and the mandrel forming the necessary shunt capacitance. If a sliding contact is provided as indicated in Fig. 2, the delay is continuously-variable. When such a delay line is used in pulse circuits, overshoot is encountered. This has been found to result from a variation in delay with frequency, and from end effects, and the object of a new design of delay line[2] is to avoid these defects. It has been shown that, with normal coils, the effective inductance decreases with frequency, so that the time delay $T_d = \sqrt{LC}$ is frequency dependent. By adopting a system of skewed turns (Fig. 3), the effect can be compensated, and $L$ kept constant over a wide frequency range. An additional advantage is that higher $Q$ values are obtained. End effects have been reduced by the use of tapered capacitance strips instead of a simple conducting mandrel. The impedance can, by this means, be kept constant at all points along the line, thus eliminating reflections.

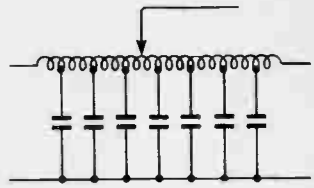

Fig. 2. *Distributed-constant delay line*

Fig. 3. *Diagram of skewed turns on form of rectangular cross section*

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# High-Quality Loudspeaker System

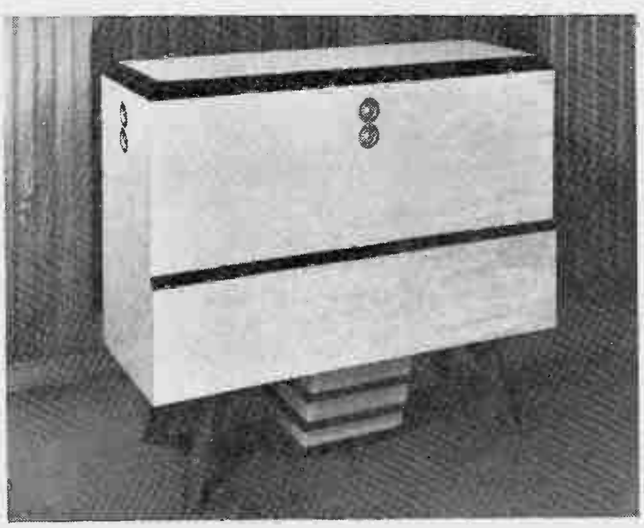
THE G.E.C. 'Periphonic' loudspeaker system was recently demonstrated. The main feature of it is the use of two metal-cone loudspeakers operating in push-pull. It is claimed that, like the push-pull operation of valves, this greatly increases the linearity of the system.

The ordinary cone tends to decrease in diameter when moving in the direction of its apex and to increase when moving the other way, thus giving asymmetrical operation. By using two speakers mounted head to tail, and placed so that the cones move in opposition, the effect is cancelled out. Whenever one cone is so moving that its diameter is tending to increase, the other is so moving that its diameter is tending to decrease.

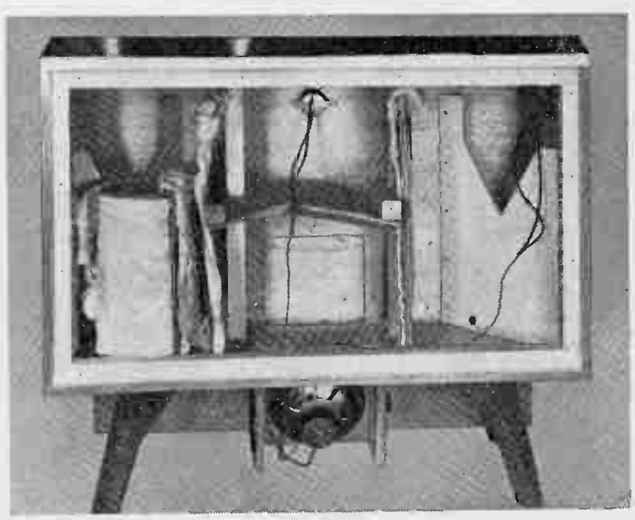
The two loudspeakers are set at a slight angle and they are mounted outside (and below) the 'speaker cabinet'. This is actually an acoustic chamber which is fed from the gap between the speakers. It is specially stiffened to minimize resonances and contains absorbing diaphragms.

The metal-cone speakers cover up to about 2,000 c/s. Higher frequencies are looked after by six 'presence' loudspeakers (tweeters) mounted in three pairs. The body of the cabinet measures 42 in. by 24½ in. high by 15 in. deep and the l.f. response is good down to 30 c/s.

*The push-pull loudspeakers are mounted beneath the 'cabinet'. Four of the six high-frequency units can be seen mounted in pairs on the front and side*



*In this view of the interior some of the acoustic baffles can be seen and also the back of one of the loudspeakers*



# Exhibition Review

**The Physical Society's, The B. & K., The R.E.C.M.F and The Electrical Engineers'**

As usual, the general impression left by the Physical Society's Exhibition has been one of superb instrumentation and an almost exuberant virtuosity in the use of new materials and techniques. This year, the emphasis seemed rather more on the application of recent developments to further the progress of physical research, or to improve methods of measurement. Even such elementary processes as the plotting of a linear graph, and the determination of the density of mercury, can be carried out nowadays with a previously unimaginable accuracy, and both of these were explained in the exhibit of the National Physical Laboratory.

Accurate time-keeping, as understood in the seventeenth and twentieth centuries, was illustrated by the Science Museum's exhibit of the cycloidal-cheek pendulum support of Huygens, and by the Royal Aircraft Establishment's demonstration of a small version of the 'caesium clock' which was developed in 1954 at the Massachusett's Institute of Technology. The latter is a frequency standard based on a resonance line of $^{133}$Cs which is known to an accuracy of 1 part in $10^9$, is given as "approximately" 9192.63185 Mc/s, and is stable at this frequency independently of any applied magnetic field. The transition from one state to the other is accompanied by a reversal of the magnetic moment of the caesium atom; and the molecular-beam technique of Rabi and his collaborators, using inhomogeneous magnetic fields as filters and a hot-wire detector, enables the frequency of the applied r.f. field at resonance to be determined. The theory of the method is given in D. J. E. Ingram's "Spectroscopy at Radio and Microwave Frequencies" (Butterworth). Caesium is vaporized in the oven shown in Fig. 1, and goes as a slow stream of atoms through the first filter field, which passes only atoms in one of the two quantum-states concerned. These proceed through the transverse magnetic field from a variable microwave oscillator to the second filter field, which passes only those which have changed state by absorbing energy from the oscillator; the amplified output from the detector would normally indicate a resonance peak. In the demonstration, the output operated a servomechanism which locked the frequency of an external oscillator at the resonance frequency.

The Acoustics Group of the Physical Society staged some impressive exhibits centred on speech. In the Standard Telecommunications Laboratories' recording and play-back unit, the visitor heard himself as others hear him, and it was explained that the shrill small voice that goes to the outer world is reinforced by the filtered lower frequencies passing to the ear by bone-conduction, this side-tone building up the manly baritone one hears oneself. Thus, conscious of being a rather squeaky bone-headed type, one passed to the Post Office Research Station, who showed that the side-tone is really one's means of regulating rather than pitching the voice; for an artificial side-tone fed to the speaker by earphones and delayed by about $\frac{1}{5}$ sec makes normal utterance impossible and induces stuttering. Other Post Office exhibits showed that intelligibility is conveyed by the frequencies above 600 c/s, and gave recognizable synthetic speech from what can best be described as an electronic version of the late Sir Richard Paget's work. In the synthesizer, two co-ordinate dials each dealt with two of the four parameters pitch, hiss or breath noise, and the frequencies of the two chief acoustic resonances (the 'formants'). By manipulating the two controls (Fig. 2) together, the operator produced a mechanical but nevertheless very civil "How are you ?".

The Building Research Station showed the directive use of diffraction from a vertical column of small loudspeakers to spread sound laterally towards an audience and away from reverberant roofs. Mr. D. M. A. Mercer, of Southampton University, showed the use of a variable acoustic delay line in studies on cross-correlation. And a number of teaching demonstrations arranged by Dr. G. G. Parfitt, of Imperial College, included apparatus to explore the acoustic field within a closed room with and without absorbent walls, optical observation of the path of ultrasonic waves, and a neat mechanical illustration of negative resistance exploiting Bernouilli's theorem for a constricted water jet passing one face of a flexible membrane.

Signals Research and Development Establishment exhibited a sound spectrograph for the frequency-time analysis of short fragments of speech and other sounds. This is fed with a tape-recording fitted as a continuous tyre on a rotating drum; this recording is played back repeatedly, through a gradually varying filter, the frequency-time spectra being recorded by stylus on Teledeltos paper. Admiralty Signal and Radar Establishment had two ingenious applications of fundamental

Fig. 1. *Constant-frequency oscillator using caesium tubes (R.A.E.)*

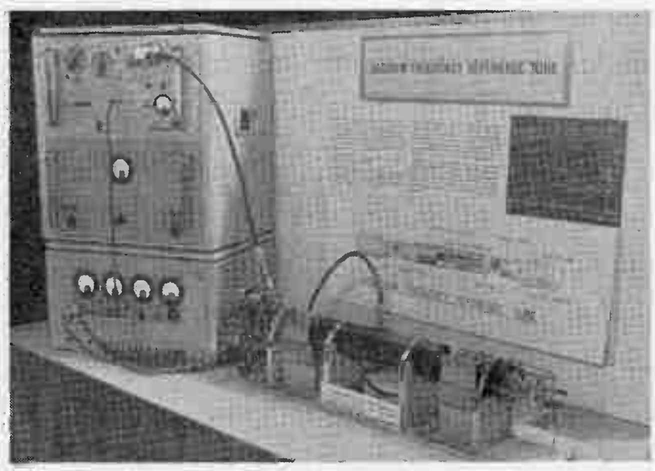
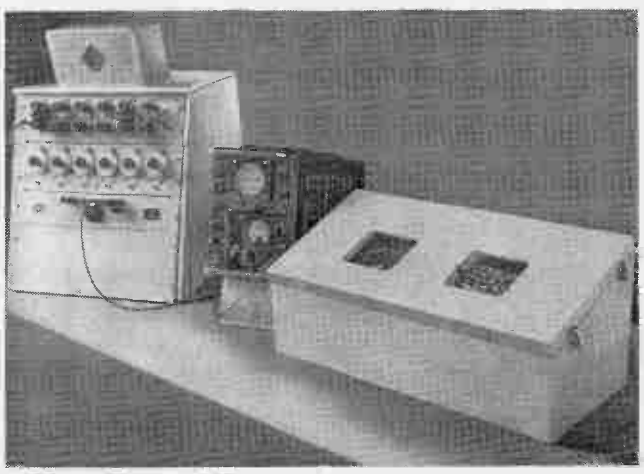
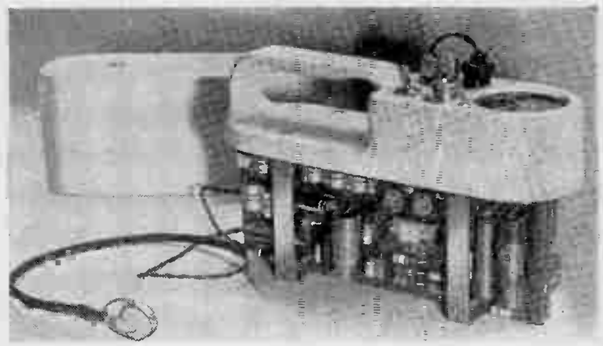


Fig. 2. *Synthetic speech equipment (P.O. Research Station)*



physics. The first was an artificial dielectric made (just like the text-book diagrams of dielectrics) of layers of polystyrene printed with a pattern of conducting discs and separated by expanded polystyrene from which a light-weight microwave lens is built up in layers. The second was a focused version of the Michelson interferometer in which the diffraction effects accompanying ordinary optical techniques in the microwave region are avoided. They also showed a portable nuclear resonance fluxmeter, employing the proton resonance in a small water-filled probe for the measurement of strong magnetic fields, and for stabilizing an electromagnet.

Three other exhibits were of outstanding interest. The liquid-helium demonstration by the Society's Low-Temperature Group, showing the superconducting behaviour of lead in the neighbourhood of absolute zero (or rather, the accompanying absence of permeability if you look at it that way), had a small permanent magnet poised in equilibrium above a lead dish. Messrs. Edwards exhibited models of D. H. Parkinson's helium liquefier, an amazing piece of heat-transfer work which was only about the size of an ordinary vacuum flask. And the same firm's many beautiful and scintillating examples of multilayer interference films were outshone by an electroluminescent panel in which the field was applied across a phosphor (or electrolucifer ?) sandwiched between a layer of transparent cadmium oxide and an aluminium sheet; details of frequency, voltage and power consumption were available, but not the contents of the sandwich.



*Battery-operated Geiger counter employing a full-size tube. The e.h.t. is generated by a transistor d.c. converter and stabilized by a corona discharge tube.* (*Burndept*)

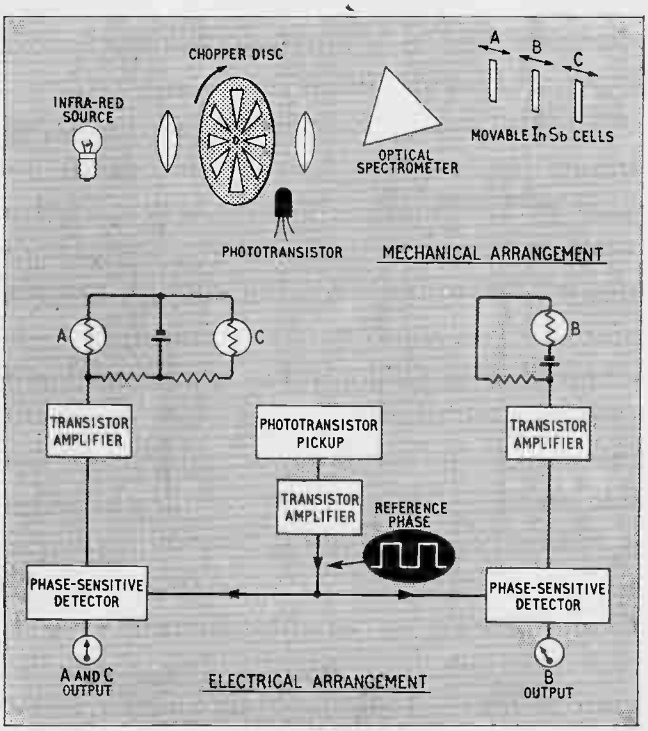



Fig. 3. *Infra-red spectrometer using indium antimonide cells* (*R.R.E.*)

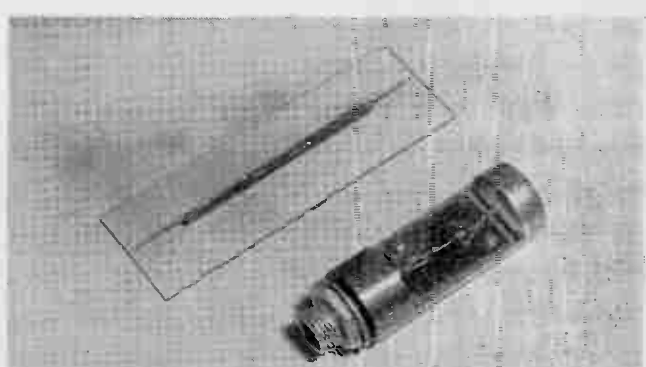
Spectroscopy, which in recent years has invaded the radio-frequency and microwave range, seems to be coming a little nearer home with the general exploitation of infra-red analysis, and several infra-red spectrographs or spectrophotometers were shown. Among new materials for infra-red work is Messrs. Barr & Stroud's arsenic trisulphide, highly transmitting to 15 $\mu$, from which large windows and optical components can be made. Another is indium antimonide in which the photo-electromagnetic effect is utilized in an infra-red photocell (The Plessey Co. Ltd.), and which is being developed as a photoconductive detector and also as a p-n junction detector operating at liquid-air temperature (Radar Research Establishment). Cells made from single crystals of indium antimonide have a response to radiation which extends to wavelengths of about 7·8 microns—well into the infra-red. Techniques for the manufacture of cells have been worked out. Typical cells have a resistance of 100 ohms at room temperature, falling on receipt of incident illumination. The cell resistance is thus several orders of magnitude less than that of lead-sulphide cells, and is of the right order for matching to the input impedance of transistors. The response time of indium antimonide is very short ($10^{-7}$ sec).

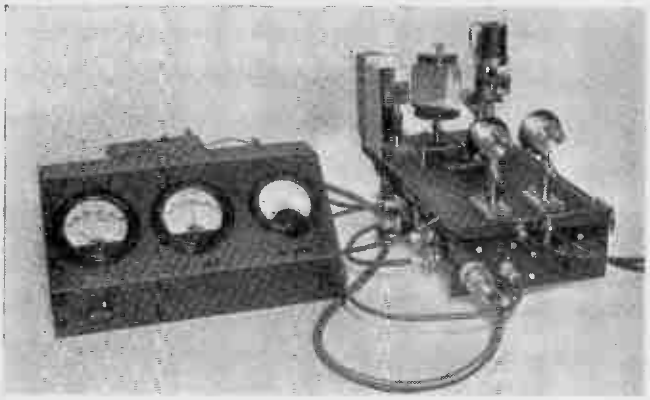
A spectrometer operated entirely from dry batteries was demonstrated (see Fig. 3). The output of the optical part of the system was directed towards three InSb cells as indicated in the upper part of the diagram. The cells, which are long and thin, are placed with their long axes in the same direction as the spectral lines, to give good resolution. The output voltages of cells A and C are connected in opposition, the difference voltage (a series of pulses at the chopping frequency) is amplified, detected, and displayed on a meter. The relative positions of the cells can be adjusted so that this voltage is zero. This gives two points on the spectral-response curve at which the illumination is equal. Cell B can now be used to locate the peak of the curve so that, if the general shape is known, the complete curve can be defined. Cell B can also be used to locate troughs in the spectral response caused by absorption; e.g., by gases.

The indium antimonide p-n junction photocell shown was operated at 90°K, the speed of response and sensitivity being very great.

Another photoconductive compound, cadmium sulphide, is the basis of some new G.E.C. photocells. Both single-crystal and powder-layer cells were shown. These have response peaks at 0·5 $\mu$ and 0·7 $\mu$, and sensitivities of as much as 1 A/lumen. Relays can be operated directly by such cells. Units, consisting of a photoconductive cell operated by an electro-luminescent device so as to form a bi-stable pair, were also on view. A lead-sulphide photovoltaic cell was shown by the Services Electronics Research Laboratory. The spectral response of these cells is similar to that of conventional lead-sulphide photoconductive cells, but the sensitivity is less and the response much faster (less than 1 $\mu$sec).

*R.R.E. Indium antimonide photoconductive cells*





*Transistor infra-red spectrometer using indium antimonide photocells (R.R.E.)*

*This photo-electric integrating flashmeter (left) gives full-scale deflection for an illumination of* 0·0005 *foot-candle-second. The disc in the battery compartment is a variable-density filter. (Ministry of Supply Chemical Defence Experimental Establishment)*

In addition to the research items, a great number of instruments in production were shown, and some of these also appeared at one or more of the other exhibitions. In this review, therefore, no attempt is made to distinguish between one exhibition and another. It may be remarked, however, that components were shown mainly at the Radio & Electronic Component Manufacturers' Exhibition and foreign apparatus at the 3rd International Instrument Show organized by B. & K. Laboratories Ltd.

The general trend of intrumentation is towards the measurement of quantities outside the limits of previous techniques. The photoelectric integrating flashmeter illustrated here exemplifies this, and also the tendency towards compactness and ease of operation visible in many instruments. This device, which is sensitive to very faint illumination such as may occur outdoors at night, is based on the accumulation of charge on a low-leakage capacitor which receives the current from a photocell. A second photocell compensates for dark-current drift and background illumination.

The same tendencies were visible in more conventional measuring instruments. A 50-c/s transformer ratio-arm bridge by Wayne Kerr has a ratio of $10^{12}$ to 1, the resistance range, for example, covering 1 milli-ohm to 1,000 megohms. A general-purpose Avo bridge has an easily-read slide-rule type of dial.

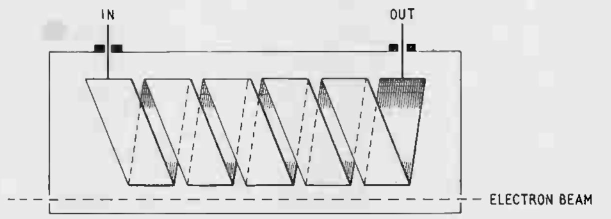
The frequency range of oscilloscopes is now being extended to the kilomegacycle region; the Atomic Weapons Research Establishment showed a 0–1,500-Mc/s instrument using a G.E.C. cathode-ray tube with a travelling-wave deflection system (Fig. 4). The latter is a slow-wave system in which the velocity of propagation of the signals along a helix is made equal to the velocity of the electrons in the writing beam. Millivoltmeters, for use up to 10 Mc/s, were shown by Burndept and British Physical Laboratories.

The Y amplifier response of general-purpose oscilloscopes is steadily being extended into the tens of Mc/s range and many instruments also respond to d.c. Nagard showed a two-channel oscilloscope, using a two-gun tube, with an amplifier response of 0–10 Mc/s (rise-time 0·035 μsec), and a single-channel instrument with a d.c. amplifier responding up to 25 Mc/s. In the Easy-Six oscilloscope of the Heath Co., the problem of Y amplification is tackled differently. A response from d.c. to 10 Mc/s is obtained from two amplifiers, one d.c.-coupled and the other a.c., operating in parallel with a cross-over network.

At the other end of the scale, a Sanders oscilloscope designed for low-frequency working had sweep times as long as 10 seconds. Accuracy of time and voltage measurement is catered for nowadays. For example, the Solartron CD643 enables measurements to be made better than 2%. Among the more specialized units were a 12-channel instrument in which the tubes were grouped together to facilitate photographing the traces simultaneously (Southern Instruments) and a radial deflection spiral oscillograph (U.K.A.E.A.) for time-interval measurements (trace duration 250 μsec, time resolution 0·05 μsec).

Among instruments in which a cathode-ray tube was a vital element, the Post Office demonstrated the application of a v.h.f. spectrum analyser (25–140 Mc/s) with a logarithmic Y amplifier to measurements of the output of a 70-Mc/s frequency modulator. The frequency sweep is obtained by varying the polarization of a ferrite-cored coil. A Decca instrument for testing wide-band receivers has a c.w. tuning range of 10–200 Mc/s in one band, obtained by beating the outputs of two X-band klystrons. The Polarad spectrum analyser is virtually the combination of a moderately simple oscilloscope with a microwave receiver. Five different 'receivers' are available, covering in all 10 Mc/s to 44,000 Mc/s and the sweep is adjustable from 400 kc/s to 25 Mc/s.

Fig. 4. *Deflection system for travelling-wave oscilloscope.* (G.E.C.)




The use of binary stages as frequency-dividers is now well established, and frequency-measuring equipment employing them was shown by Racal and Cintel, while Mullard had a similar device using transistors. In general, a gate, controlled ultimately by a standard-frequency crystal, is opened for a

*A typical modern valve millivoltmeter (Burndept), with a range of 1 mV f.s.d. up to 10 Mc/s*

known time interval (say, 1 second) and the number of cycles of the input waveform counted and the result displayed. The maximum frequency that can be measured in this way depends on the speed of the binary stages. The Cintel equipment can measure up to 11·2 Mc/s directly, frequencies in the range 11·2–20 Mc/s being converted to something less than this by heterodyning with a crystal harmonic.

An ingenious system is used in the Racal SA.28 equipment to extend the range of the basic 1-Mc/s counter to 30 Mc/s. A double superheterodyne is employed. The first frequency change is effected by heterodyning the input signal with a high-frequency variable oscillator. The second frequency change, which reduces the signal frequency to something under 1 Mc/s, is effected by means of a heterodyne signal derived by beating the variable oscillator against a harmonic of a 1-Mc/s crystal oscillator. If the variable oscillator drifts, both heterodyne frequencies change equally, and the ultimate output frequency is unaffected. The latter is counted by a 1-Mc/s counter.

Instrumentation for nuclear physics naturally occupied a position of some importance. Particle detection and counting apparatus ranged from compact hand-held instruments to

*Racal digital frequency meter*

elaborate equipments such as the Labgear printing counter, which provides a record of about 6,000 counts. Several pulse-height analysers were shown, including a large 100-channel Philips equipment.

The Radar Research Establishment showed a digital millivoltmeter capable of measuring direct voltages up to about 10 V with an accuracy of 10 $\mu$V. Determination of an unknown voltage is made by comparing it with a number of known voltages obtained from a standard source and potentiometer networks, and progressively increasing the known voltage until it is equal to the unknown voltage. This process is carried out automatically, each step being initiated by a pulse from a pulse generator. The result is displayed as a 10-digit binary number, each unit representing 10 $\mu$V. On initiating the comparison process, the unknown voltage is compared with one of $2^9 \times 10\ \mu$V, and the difference is amplified in a transistor amplifier. If the unknown exceeds the known voltage, the $2^9 \times 10$-$\mu$V reference is retained during the next comparison step, in which the known voltage is $2^9 \times 10\ \mu$V $+ 2^8 \times 10\ \mu$V. If not, it is rejected, and the next comparison reference voltage is merely $2^8 \times 10\ \mu$V. The process is continued, significant digits being retained and displayed, until balance is reached.

N.P.L. showed a precision temperature controller designed for use with a liquid bath. The accuracy over 50-hours' operation is ±0·002°C. An audio-frequency bridge containing a temperature-sensitive element produces an error-signal, the

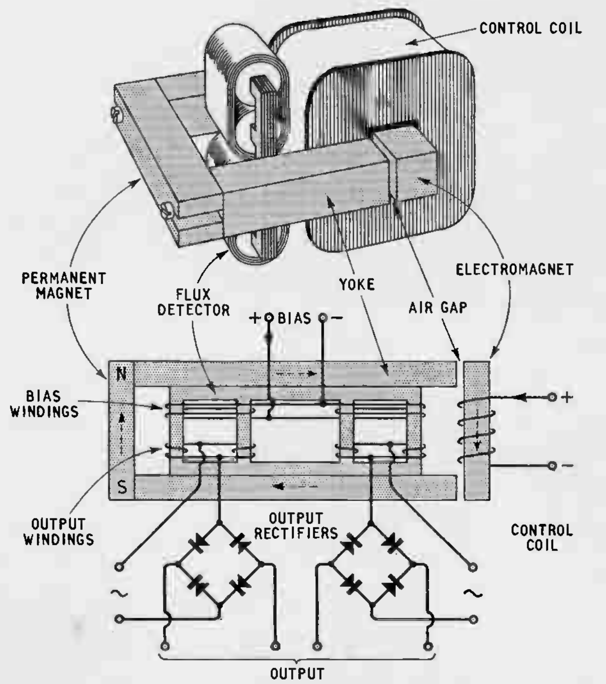



Fig. 5. *Magnetic discriminator for constant-current supply.* (*Westinghouse*)

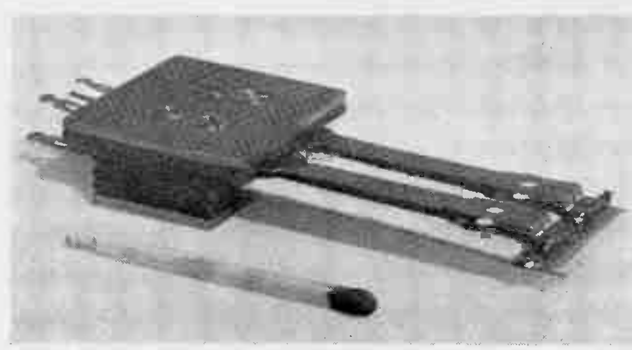
sense of which is detected and caused to operate a relay controlling the heating supply. Suitable phase-sensitive detectors using 6BN6 and EQ80 f.m. detector valves were demonstrated. Conventional thermostats have also been improved and examples adjustable over a 500°F range, with a sensitivity of ±0·1°F, were shown by Electro-Methods.

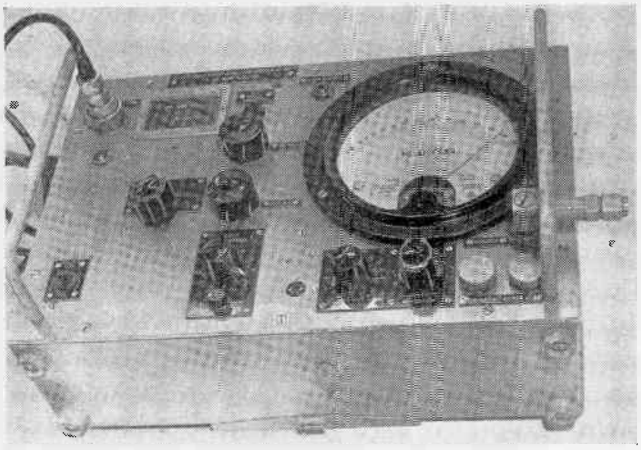
Interest in colour television was not very apparent, but Waveforms Ltd. showed a colour-bar-dot generator which they are developing to provide a complete video signal conforming to the B.B.C.'s 405-line experimental system.

Several constant-current d.c. supplies were shown. These are of use, for example, in particle velocity analysis. A Westinghouse supply is stabilized in an unusual manner. The output current energizes an electromagnet placed in the field of a stable permanent magnet. The difference between the two fluxes acts as an input signal to a pair of balanced magnetic amplifiers (as shown in Fig. 5), the output of which controls a saturable reactor. The temperature coefficient of the system (caused by changes in the permanent magnet) is basically negative and is corrected by a suitable positive temperature-coefficient resistor, the overall zero stability being ±0·25 per cent.

Much greater precision is claimed for an electromagnet power supply shown by Newport Instruments. In this, the magnet current is passed through a low-value resistor, the resulting potential drop being compared with the potential of a

*Electrostrictive relay, based on a barium titanate–metal element. Very little holding power is required.* (*G.E.C.*)





*Precision calibrator, providing a 1-Mc/s output at 28–180 mV ± 0·25% (10° to 30° C) with a harmonic content of less than 0·1%. (Aeronautical Inspection Directorate)*

Mallory cell with an estimated stability of 2 parts in $10^6$ in 10 hours. The error is amplified and used to control the magnet current. Where greater accuracy is required, a nuclear resonance head is used to generate a potential proportional to the field-strength of the magnet.

In the fluxmeters shown by the Admiralty Signal & Radar Establishment, use was made of the fact that the frequency of resonance of protons in hydrogen depends on the strength of the magnetic field in which the hydrogen atoms are situated, field-strength and resonant frequency being in simple proportion. The field of an electromagnet was made to vary about its mean value by superimposing a 50-c/s ripple on the energizing current. The proton resonant frequency was thus swept across a small band. Resonance was detected by a probe consisting of a small coil, supplied with r.f. current, with a core containing a hydrogen compound (water plus additives). The change in circuit damping as the resonance frequency coincided with the applied frequency was detected and displayed on an oscilloscope, the X-deflection of which was controlled by the 50-c/s ripple.

The system was adapted to the stabilization of an electromagnet by controlling the current supplied. The magnet strength is varied by a 50-c/s ripple and, if the frequency supplied to the probe is suitably adjusted, an output pulse is obtained from the detector at a particular phase of the 50-c/s supply. These pulses can be employed to control the firing time of thyratrons in the magnet power-supply unit so that, if the field-strength decreases, the firing angle is increased, and vice versa. An improvement of 60 times in stability is readily obtained.

Two interesting mechanical devices were shown by N.P.L. One was an instrument for measuring thin sheets with an accuracy of ±0·25 micron. The other was a system of springs which could be adjusted to have zero stiffness. Among the applications demonstrated for the latter were a spring balance giving very sensitive indications of slight deviations from a large weight, and an anti-vibration mounting with infinite damping.

Auto-tuners (mechanical devices for pre-setting shaft positions) were shown by Ekco. These are made in both single-turn and multiple-turn types, and were originally developed for remotely-controlled tuning of radio transmitters and receivers. The single-turn types provide 12 pre-set positions with an accuracy of 15 minutes of arc.

A novel linear-measurement device was shown by Plessey. This is, in effect, an opened-out version of a multi-pole resolver, the rotor and stator taking the form of a flat scale and slider. Setting repeatability is given as 25 micro-inches. Known as the Inductosyn, the device is intended for machine tool control and similar applications.

Another measuring device, this time for comparing the sizes of components with an accuracy of $10^{-5}$ in., employed an electromechanical displacement transducer as the sensing element. The deviation in dimension of an object from the standard is displayed on a meter.

R.R.E. demonstrated a device for measuring the flux stored in a rectangular hysteresis-loop ferrite ring of the type used in magnetic memory matrices. A single turn passes through the core, and alternating current is applied, so that the core switches from one state of saturation to the other. An output pulse is generated every time the flux reverses. A current proportional to the voltage-time integral of the trains of pulses is displayed on a meter calibrated in lines of flux.

Ultrasonic cleaning equipment was shown by several companies. Radio Heaters, for example, had a generator with an output of 1 kW at either 50 kc/s or 1 Mc/s, so that it can be used for both low- and high-frequency cleaning. The same firm is recommending transducers made from zirconate materials rather than titanates. It is claimed that zirconate transducers are not damaged by overheating to 400°C and can, in any case, be operated up to 250°C, whereas barium titanate can only be used below 70°C. Dawe Instruments showed a small cleaning plant in action.

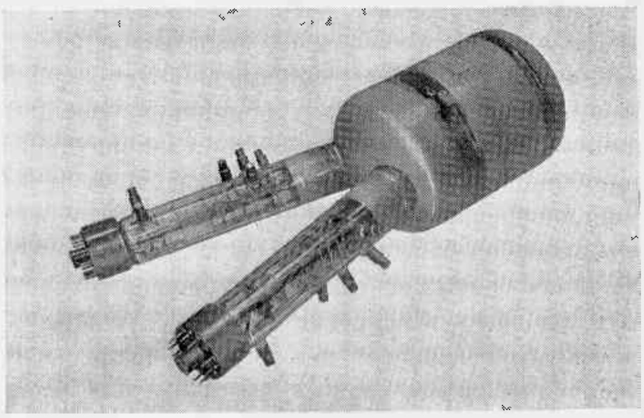
Equipment for testing high-power magnetostriction transducers was shown by Mullard. A new design of electrodynamic driver is employed, the vibrating element being mounted in a compressed-air bearing.

Transducers of the ceramic type were shown by Technical Ceramics.

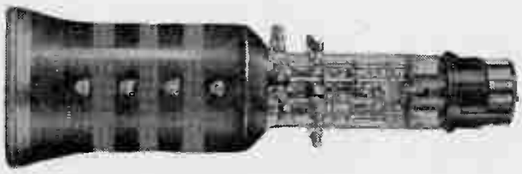
Valves and allied devices were, as usual, well represented.

*Magna-Gage electronic comparator stand*

*Double-gun gold-island storage tube for use in time-expansion equipment. (U.K.A.E.A.)*



Many new microwave valves have been developed; several firms showed travelling-wave tubes, some with noise factors as low as 8 dB, and backward-wave oscillators. The upper frequency limit of triodes has been raised. G.E.C. had a disc-seal triode usable to 6,000 Mc/s, and Mullard showed two new disc-seal triodes for use as signal amplifiers or low power stages at 4,000 Mc/s. Ferranti showed ceramic valves and high-power amplifier klystrons for X-band operation. A five-cavity klystron amplifier with permanent-magnet focusing was shown by Mullard. This has a power gain of 60 dB and a power output of over 1 watt at 9 kMc/s, and is suitable for amplifying the harmonics of a crystal-controlled v.h.f. source. Another klystron, the KT9–150W, tunable over a wide range of frequencies in the X-band, provides a C.W. power output



*Double-gun high-sensitivity cathode-ray tube.* (*20th Century Electronics*)

in excess of 150 W. A new magnetron has been developed for inexpensive radar equipments.

Among the smaller valves, S.T.C. showed a triode for wide-band amplifiers with a mutual conductance of 47 mA/V, a cold-cathode decade-counting valve with an anode current of 3·7 mA, and voltage stabilizers in the range 55–304 volts. An electrometer valve with a linear grid-current anode-current relationship was shown by Mullard. It is intended for use in ratemeters. Special-quality valves produced by this company now have published specifications which include mechanical tolerances and electrical characteristic 'spreads'.

Cathode-ray tubes with helical post-deflection accelerators are now becoming common. Deflection sensitivities are of the order of 1 mm/volt. Special purpose c.r.t.s. include data storage and frequency-multiplier types (G.E.C.), a gold island secondary-emission storage tube for fast writing and slow subsequent reading (U.K.A.E.A.), and an eight-gun tube (20th Century). Among the more conventional c.r.ts were a 3-in. instrument type requiring only 400 V e.h.t., and a rectangular-screen television camera viewfinder tube with low-voltage electrostatic focus (Mullard). A television tube with a mesh grid was shown by G.E.C.; this requires less video drive than conventional types, but has a different 'gamma'.

Apart from the indium antimonide devices already mentioned, there were no striking developments in semiconductors, but rather a steady progress in the expected directions—increased power-handling capacities, voltages, operating temperatures and frequency limits.

Power rectifiers in both silicon and germanium are now becoming common, and silicon zener reference-voltage diodes are beginning to make their appearance. Development is continuing in the older rectifier materials, selenium and copper oxide. Westinghouse, for example, showed selenium rectifiers capable of operating at full load at 100°C, copper-oxide rectifiers with reduced 'creep' (increase of reverse current with time) and with the permissible a.c. input increased from 8 V to 25 V, and a miniature selenium diode with a reverse resistance of 300 MΩ at 60 V at room temperature. The same firm demonstrated the importance of studying rectifier characteristics under dynamic conditions. The forward current of a germanium rectifier, for instance, has an effect on the reverse characteristic.

Some very small germanium junction photodiodes were shown by S.T.C. These were 0·08 in. diameter, with a sensitivity of 30 mA/lumen. S.T.C. also showed development silicon power diodes for currents up to 5 A. G.E.C. had 6-V zener reference voltage diodes with resistance of 25 ohms at 5–15 mA, and a 30-V diode for voltage limiting. Germanium diodes for 100-V working were shown by Mullard.

Transistors are employed very extensively in all kinds of low-power equipment, such as portable Geiger counters, and applications in computing equipment were demonstrated by Standard Telephones & Cables, Mullard, and Siemens-Ediswan research laboratories. B.T.H. showed a transistor self-balancing radiation pyrometer. A lead-sulphide photocell is used as a detector. The unknown radiation and the output of a tungsten filament lamp are made to illuminate the cell alternately, the difference being amplified, detected, and used to control the current supplied to the lamp filament so as to obtain a balance between the two radiation sources. The lamp current is then proportional to the unknown radiation. The instrument reads down to 150°C.

Photo-transistors are now being applied commercially to the counting of packages. Metropolitan-Vickers demonstrated such

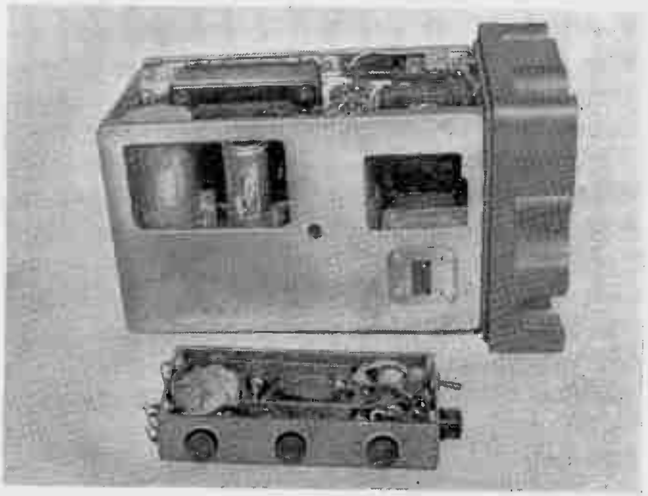
*Mullard rectangular television camera viewfinder tube with electrostatic focus*

a counter, built in two compact units, one housing the light source and the other the photo-transistor and relay. The interruption of the light by the passage of an object on the conveyor belt causes the relay to operate and gives a count of one.

Two neat applications of transistors to power supplies were demonstrated by S.R.D.E. One of these was a constant-voltage battery charger for sealed accumulators, which are liable to damage if gassing occurs. This is the transistor equivalent of a series-parallel valve stabilizer and has a semiconductor diode as the voltage reference. The other was a very compact 100-watt power pack designed to perform the same task as a vibrator power pack. Eight power transistors are employed in a push-pull square-wave oscillator which replaces the vibrator.

The need for components capable of operation at much higher temperatures than are encountered in ordinary radio

*100-watt transistor power pack alongside vibrator power pack of similar power ratings*



equipment was reflected in many exhibits. S.R.D.E., for example, showed boron nitride for use in insulators. This material is stable in air up to about 800°C and has excellent insulating and dielectric properties. They also showed an octal valve base moulded in glass-bonded mica for use at over 300°C. Particularly interesting are capacitors employing aluminium oxide as the dielectric, but capable of working at 200 V peak a.c. at 100°C. The dielectric is only about 1 micron thick, and is anodically formed on aluminium foil, the other electrode being a thin evaporated layer of aluminium with self-healing properties. The capacitors are about the same size as plain-foil electrolytics but have an insulation resistance of 1,500 ohm-farads at 100°C. The shelf life is expected to be indefinite.

Plessey showed C-core transformers for operation at 250°C, and S.T.C. a new type of thermistor, with cold resistances of 100 ohms to 2 megohms, for operation at 50–100°C. Dubilier and G.E.C. had terylene-dielectric capacitors. These have high insulation resistances and can operate up to about 125°C.

Among the more conventional components, there was a marked trend both to miniature size, to suit transistor devices, and to the design of components so as to fit them for use in printed circuits. Some firms had components mounted on 'bandoliers' for automatic circuit assembly.

Moulded-track variable resistors were shown by Plessey. The application of these to liquid level indication was demonstrated, a 20-kΩ unit being operated by a float in an oil bath. It is claimed that millions of operations are possible before a resistor of this type becomes unfit for service. A number of shapes and sizes are available, a feature of some of the twin-gang potentiometers being that it is possible to 'line up' the two resistors so that their values are the same at all angles of rotation of the common shaft.

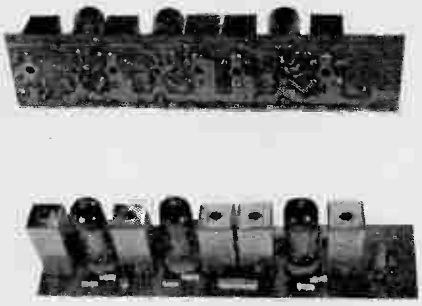
The same firm showed some humidity-sensitive resistors developed for use in radar sondes. These consist of a plastic material (hydroxy ethyl cellulose) which changes dimensions when it absorbs or loses water, and carbon, which is either used to load the plastic or sprayed on the surface. The sprayed humidity elements are more sensitive, but the loaded elements are more stable. Work done so far indicates that both types are potentially useful for industrial applications. The resistance of the elements increases with humidity, the increase over the range R.H. = 0 to 100% being about seven times for the loaded type and a hundred times for the sprayed-layer type. Resistance values at R.H. = 0% are in the tens of kilohms range in the case of elements produced so far, but may easily be varied.

Subminiature overtone quartz crystals for soldering directly into circuit were shown by Cathodeon, who also had very high stability crystals which, when used in a special drive unit, give frequency errors of 5 parts in $10^8$ (long term) and 1 part in $10^8$ (short term).

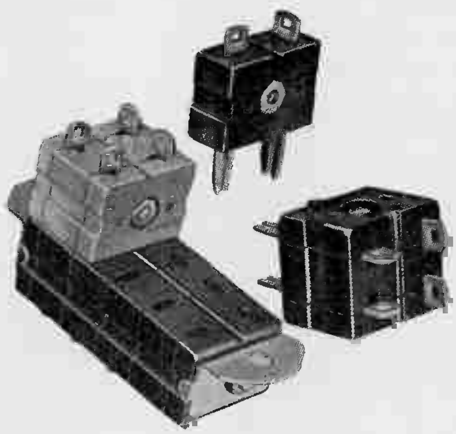
Among the magnetic materials, T.M.C. had 'Supermumetal' tape, with very high permeability, and zero temperature coefficient of permeability in the range 0–40°C. Several firms showed very thin tapes of magnetic material, for example, George L. Scott had tape composed of a nickel-molybdenum alloy which was only 0·003 in. thick. The principal application of such thin tapes is high-speed logical elements in computers, toroidal tape cores of material with a rectangular hysteresis loop being used in memory matrixes, etc. The switching characteristics of typical tape-wound cores were demonstrated by S.R.D.E Tape cores have the advantage over ferrites of lower coercivity, but require careful heat treatment before use and are liable to damage if mechnically strained.

Coil-winding wires designed for easy soldering and bonding were shown by Fine Wires Ltd. These are covered with two insulating layers, one of nylon and an outer cover of acetate. In coil assembly, the insulated wires are wrapped round a terminal. Application of heat from a soldering iron removes the insulants and a soldered joint can then be made. The coil is then sprayed with acetone, temporarily softening the outer acetate insulation, which coalesces to form a bond between turns on drying out.

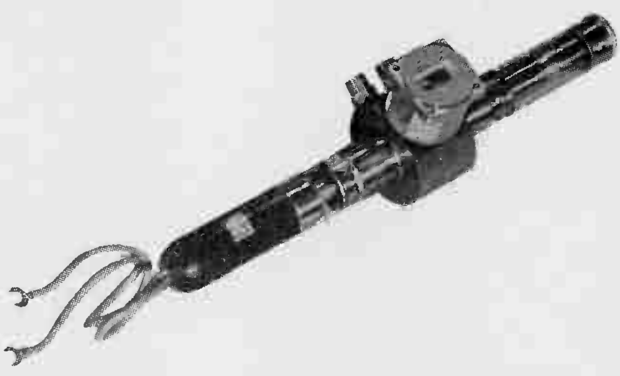
At present, quartz crystals are almost the only devices for use at frequencies above the audio range as standard frequency sources. A promising new arrival in this field is the ferrite magnetostrictor. An oscillator based on this device was demonstrated by Mullard. A small tube of nickel-zinc ferrite was employed, vibrating longitudinally. The frequency of oscillation was 136 kc/s, and the temperature coefficient of frequency was about 50 parts in $10^6$/°C. A similar device was used in a passive filter with a sharp band-pass characteristic centred on about 85·5 kc/s. A 'rejection notch' in the frequency characteristic occurs just above resonance. The filter shown was used between 100-Ω terminations, and had an insertion loss of 10 dB in the pass-band and about 45 dB in the stop-bands, rising to 90 dB at the rejection frequency, which was about 86·3 kc/s.



35-*Mc/s i.f. strip on printed circuit.* (*T.C.C.*)



*N.S.F. Varicon connectors*



*The cathode of this 1-MW Ferranti magnetron is heated by electron bombardment*

Plessey showed a 'magnetic reactor' in which a ferrite-cored inductor is subject to the field of an electromagnet. Varying the current through the latter varies the effective permeability of the ferrite and, hence, the inductance of the coil. The inductance change in a 0·2-$\mu$H coil is 0·04 $\mu$H per mA.

Electroluminescent passenger instruction signs for use in aircraft were shown by Thorn. These are compact, consume only 4 or 5 watts, and can operate efficiently from the aircraft's 400-c/s mains via a step-up transformer. The overall weight, including the transformer, is said to be half to one-third of that of a conventional sign.

Two interesting techniques with possible microwave applications were demonstrated by Mullard. Fig. 6 shows the essentials of a regenerative signal-integrating system. The system is for use with pulsed signals of constant repetition frequency, and depends on the fact that when regeneration is applied, signals increase linearly in amplitude but noise, being uncorrelated, increases as the square root of the sum of the squares of input and feedback noise amplitudes. In practice, a carrier-operated quartz-crystal delay line is employed; the necessary modulators and demodulators are not shown in the diagram. With a loop gain of about 0·8, a substantial improvement in signal detectibility is obtained.

The other technique is a system for obtaining a stable output from a klystron by injecting a locking signal derived from a stable low-power source (Fig. 7). The output of the balanced modulator consists of two frequencies separated by about 60 Mc/s. As the output klystron is tuned so that its frequency approaches one of these, locking occurs, the output klystron's frequency being controlled by the reference frequency over a limited tuning range. If the frequency of the 30-Mc/s oscillator is varied, the klystron frequency varies in sympathy until 'pull-out' occurs. The amount of variation permissible s a function of the ratio of output power to locking power and, when this is 20 dB, a variation of ±5 Mc/s can be obtained, the output remaining substantially constant over this range. The system can be used for amplifying low powers, for frequency modulation, or for tuning receivers.

Interesting cavity wavemeters were shown by De Mornay Bonardi; eleven models cover 2·6–90 kMc/s. They are nitrogen-filled and designed for a temperature range of −30 to +70°C.

At the extreme other end of the frequency spectrum, a very wide range of apparatus for acoustical research was displayed by Brüel & Kjaer including an a.f. spectrometer having 27 fixed, one-third octave, band-pass filters with centre frequencies from 40 c/s to 16 kc/s.

The use of radioactive material for measuring the efficiency of washing machines is embodied in the Soil-o-Cator of Nuclear Instrument & Chemical Corp. Standard swatches, which are 3 in. by 5 in. pieces of fabric carrying a spot of radioactive 'dirt', are used. The dirt is a mixture of fat, protein and carbon black and three types of swatch are available with any one of the three components of the dirt radioactively labelled.

The radioactivity is measured with a Geiger tube connected to a timer and scaler. The swatch is initially measured and then a second time after being washed. The ratio of the initial and final counts per minute is an indication of the efficiency of the washing process. The equipment has been simplified so that it can be used by people with little training and the amount of radioactive material in the swatches is stated to be low enough for them to be handled without special safety precautions.

S.R.D.E. showed an ingenious device for detecting the presence of moisture in cables during tests of the repeaters for the trans-Atlantic submarine cable. Each repeater contains a variable-inductance tuned circuit, the tuning being effected by means of an aneroid barometer-type of capsule which moves the ferrite core of the coil. A small quantity of a chemical mixture which evolves hydrogen on exposure to a moist atmosphere is inserted in the repeater when it is sealed into the cable. If moisture enters, the pressure of the hydrogen evolved operates the aneroid capsule and so causes the tuned circuit to be detuned. The circuit is arranged to modify the frequency response of the repeater.

A different frequency is allocated to each repeater so that a faulty one can be detected by noting the change of frequency of its tuned circuit by transmission measurements.

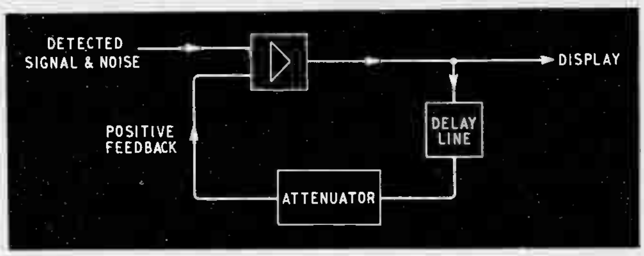
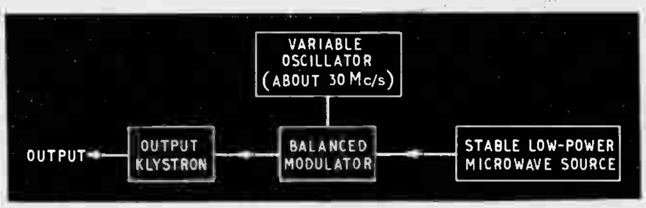
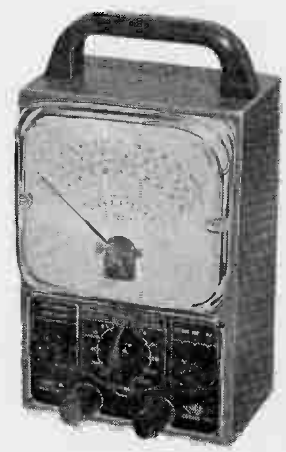



Fig. 6. *Regenerative signal integrating system.* (*Mullard*)

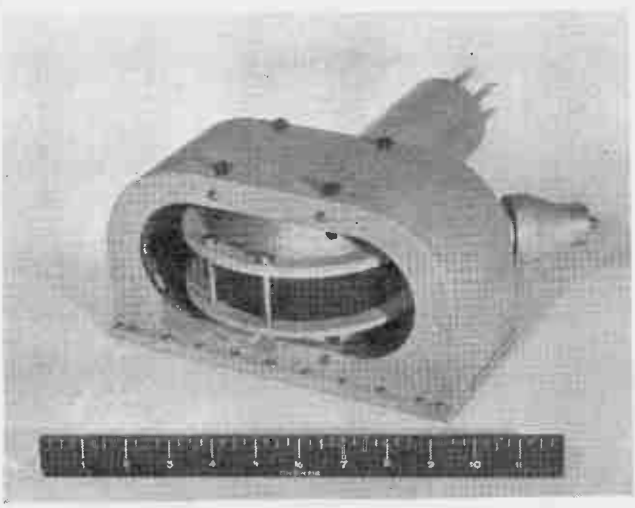
Fig. 7. *Microwave oscillator system.* (*Mullard*)



*Pullin multi-range test set fitted with perspex cover*

*G.E.C. S-band M-type backward-wave oscillator*



# Correspondence

*Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.*

### Uncorrelated Grid Noise

SIR,—Dr. Bell's letter in your January issue raises a number of points of interest on which I venture to express my opinion.

First, while the statement on displacement and convection currents quoted from C. J. Bakker's paper of 1941 ought to read "induced current" in place of "displacement current" and "convection current at the grid plane" instead of "convection current" (in general the latter varies from place to place), the *calculations* in that paper are certainly not incorrect. On the other hand, calculation of the induced current in the cathode–grid space in a space-charge limited state cannot be carried out by summing the pulses of current resulting from the passage of individual electrons (or their Fourier components), because the pulses are not mutually independent. The method is valid only for spaces containing a very thin distribution of charge.

Secondly, the effect of the transit time $T_2$ in the grid–anode space of a triode is known[1] and it has no direct effect on correlation. The effect is to modify the basic formula for the grid noise by the extra factor $(1 + 2\,T_2/T_1)^2$, where $T_1$ is the transit time from the potential minimum to the grid plane. In the formula expressed in terms of the electronic input damping $G_T$ of the common-cathode circuit, the extra factor is:

$$\frac{(1 + 2\,T_2/T_1)^2}{1 + \frac{44}{9}(T_2/T_1) + 5\,(T_2/T_1)^2}$$

The above relations are limited to $V_a \gg V_{eff}$ and $(\omega T_1)^2 \ll 1$, $(\omega T_1)^3$ and higher powers being negligible.

Thirdly, at least two effects may account for a component of grid noise that is uncorrelated with the shot noise.

(1) A wide distribution in the value of $T_1$ resulting from a coarse grid pitch can produce the *effect* of uncorrelation[2] by phase spreading. In my opinion, this effect is less important than the next.

(2) The elastic reflection of a small fraction of the electrons striking the anode can produce quite a large uncorrelated component in the grid noise[3]. I have recently worked out the effect in detail, using the accepted theory of noise and the accepted transit time theory to the full, with the result:

$$\overline{\delta i_g^2} = 2eI_a\,\delta f.\,\frac{(\omega T_1)^2}{9}\Bigg\{\underbrace{\Gamma^2\left[1+\frac{3}{2}r+(2+4r)\frac{T_2}{T_1}\right]^2}_{\text{Correlated with shot noise}} + \underbrace{r\left(\frac{3}{2}+4\,\frac{T_2}{T_1}\right)^2}_{\text{Uncorrelated}}\Bigg\}$$

where $\Gamma^2$ is the usual space-charge reduction factor and $r$ is the fraction of electrons reflected at the anode. $I_a$ is the d.c. to the anode and $e$ is the negative electronic charge.

With $T_2/T_1 = 0{\cdot}3$, $r = 0{\cdot}03$ and $\Gamma^2 = 0{\cdot}05$, the ratio of uncorrelated to correlated components is about 1·6 : 1, while with $\Gamma^2 = 0{\cdot}1$, the ratio is about 0·8 : 1. Some additional uncorrelated noise in the cathode–grid space can result from a lossy oxide cathode coating. The equation is in fair agreement with the experimental curve given in Fig. 1, reference (3).

Of greater interest is the formula for triode noise factor which includes the effects of both transit angle spread (accounted for by the factor $s$) and electron reflection. For small transit angles, the formula can be written in the following approximate form, provided $G_s + G_c \ll g_m$ and the input circuit is suitably tuned:

$$N \approx 1 + \frac{T_cG_c}{T_oG_s} + \left(\frac{S^2}{4} + \frac{16r}{\Gamma^2}\right)\frac{G_T}{G_s} + \frac{R_{eq}}{G_s}\left[G_s + G_c + \left(\frac{S^2}{16} + \frac{13r}{\Gamma^2}\right)G_T\right]^2$$

when $T_2/T_1 = 0{\cdot}3$. Putting $r = 0{\cdot}03$, $\Gamma^2 = 0{\cdot}1$ and giving $s$ the maximum realistic value 1, then

$$N \approx 1 + \frac{T_cG_c}{T_oG_s} + 5\,\frac{G_T}{G_s} + \frac{R_{eq}}{G_s}\,(G_s + G_c + 4\,G_T)^2$$

which is in a form known to agree substantially with experiment in the v.h.f. band. In these formulae, $G_s$ = source conductance, $G_c$ = input coupling-circuit conductance (including cathode coating losses) at an effective resultant temperature $T_c$, $R_{eq}$ = equivalent noise resistance and $T_o$ is standard source temperature (°K). $G_T$ is the electronic input damping conductance, excluding the effect of reflected electrons.

*Princes Risborough, Bucks.* I. A. HARRIS
29th January 1957.

**REFERENCES**

[1] A. van der Ziel, "Induced Grid Noise in Triodes", *Wireless Engineer*, 1951, Vol. 28, p. 226.
[2] J. R. Stahmann, "Correlation between Induced Grid Noise and Tube Noise", *Trans. Inst. Radio Engrs*, 1955, Vol. E.D.2, No. 1, p. 1.
[3] T. E. Talpey and A. B. Macnee, "The Nature of the Uncorrelated Component of Grid Noise", *Proc. Inst. Radio Engrs*, 1955, Vol. 43, p. 449.

SIR,—While I agree with many of Mr. Harris's comments, particularly the adjustment for grid–anode transit-time, I do not think all is well with the analysis.

In the first place, I do not believe it is true to say that the electron transits which contribute to induced grid noise are mutually dependent to a substantial extent. Moullin[1] performed a calculation to show that with reasonable current-densities the electrons show little interaction with each other as individuals. Although the Schottky-North theory of the space-charge smoothing of noise implies such interaction, that theory is not supported by the results of crucial experiments: experimental studies of partition noise do not accord with the calculations based on 'compensating pulses' so well as with calculations based on a random distribution of independent electrons; the comparison of cylindrical with plane diodes shows a reasonable agreement between experimental data and theoretical analysis based on the independent-transit treatment[2,3]; and in beam tubes, the noise factor appears to be successfully calculated in terms of random velocity modulation of the beam leaving the gun. Of course there is interaction *in the immediate neighbourhood of the potential minimum*, but if this part of the transit contributes significantly to the grid noise there will be total-emission noise as well as induced grid noise.

I must confess to being puzzled by the argument that elastic reflections will give uncorrelated noise—or must one re-write the statement of the authors in question and call it *differently* correlated noise instead of *uncorrelated?* If an electron oscillates through the valve several times before coming to rest on the anode, the consequent grid pulses must be quite specifically correlated with the anode pulses: so is it the argument that the time (or phase) relationship between grid and anode currents for such electrons will not be the same as for single-transit electrons ?

If one specifies the condition that "the input circuit is suitably tuned" in order to compare experimental noise figures with theory, should one not require that experiment agree with theory in deciding what is the 'suitable' condition ? The very thorough investigation by Houlding and Glennie[4] showed a systematic discrepancy between theoretical and experimental values of optimum de-tuning: the discrepancy was systematic in the sense that it was (a) always in the same direction and (b) increased in fractional amount with increasing frequency. I have since calculated that due allowance for the timing of primary anode and grid current pulses, and for the delay in occurrence of the current pulse due to induced grid voltage, gives a good explanation of the form of the results of Houlding and Glennie without having recourse to the reflected electrons which have so frequently been invoked to explain apparent discrepancies between experimental and theoretical values of noise.

*The University of Birmingham.* D. A. BELL
1st April 1957.

**REFERENCES**

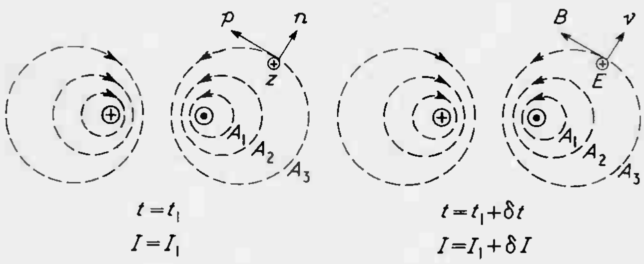
[1] E. B. Moullin, "Spontaneous Fluctuations of Voltage", Oxford University Press, 1938, pp. 101-106.
[2] D. A. Bell and H. O. Berktay } *J. Electronics*, March 1957
[3] D. A. Bell }
[4] N. Houlding and A. E. Glennie, "Experimental Investigation of Grid Noise" *Wireless Engr*, 1954, Vol. 31, p. 35.

## Moving Flux Explanation of Transformer Action

SIR,—In dealing with the rotating fields of three-phase machinery, we are accustomed to the idea that a moving magnetic field may be regarded as emanating from stationary coils. In other contexts there is reluctance to grant motion to the field apart from that of its source. Particularly in disfavour is the explanation of transformer action as an instance of flux-cutting, with moving flux sweeping past the stationary conductors.

Writing in *Wireless Engineer* about alleged sterility of the flux concept W. A. Tripp[1] says "what would have to be added to the flux concept would be some term, which indicates the rate at which flux streams by any given point in space due to current change". Such a velocity will be defined and will be shown to lead to the correct value for the transformer e.m.f.

Some care is needed, when we speak of the velocity of a magnetic field. It must not be supposed that there is a unique and tangible set of lines of force with a certain velocity. Magnetic and electric fields are really the private property of the observers, who perceive them, since different values are recorded by different observers in relative motion. Usually there is one of many possible observers, whose field is especially simple ; perhaps it is unchanging in magnitude or phase, or is free from an electric component. His velocity is the one that might unguardedly be described as *the* velocity of the magnetic field.




If a given magnetic field is that of a complex current system, let the components of current in one direction, say the $z$ components, be separated. For these currents, the magnetic vector potential $A$ and the induced electric field $E$ are also everywhere in the $z$ direction. Let a cross-section of the field on a plane of constant $z$ be examined.

A line of force of $B$ is defined to be such that $B$ lies along the line at every point. By definition curl $A = B$ ; it follows that, because $B$ can have no component normal to the line of force, $A$ must be constant everywhere on the line. This may be verified by taking local co-ordinates $n$ normal to, and $p$ parallel to, the line of force.

$$B_p = \frac{\partial A_z}{\partial n} - \frac{\partial A_n}{\partial z}$$

$$B_n = \frac{\partial A_p}{\partial z} - \frac{\partial A_z}{\partial p}$$

$A_n$, $A_p$ and $B_n$ are zero, so that $\partial A_z/\partial p$ is zero and $B_p = \partial A_z/\partial n$. Thus lines of force of $B$ are lines of constant $A$ and may be labelled by their $A$ value.

When there is a change in current, $A$ becomes a function of both time and position. An increment $\delta A$ in $A$ is given by:

$$\delta A = \frac{\partial A}{\partial n} \cdot \delta n + \frac{\partial A}{\partial t} \cdot \delta t$$

After such a change, lines of force labelled with the former values of $A$ are to be found in new positions. Let an observer O′ be assigned the task of moving so as to remain with a given line of force. For him the value of $A$ must not change, $\delta A = 0$. Therefore, his velocity along the normal must be:

$$v_n = \frac{\delta n}{\delta t} = -\frac{\partial A_z/\partial t}{\partial A_z/\partial n}$$

This is the velocity that a stationary observer O would assign to the magnetic field. Let it be substituted in the flux-cutting formula for the induced electric field

$$\mathbf{E} = \mathbf{B} \times \mathbf{v},$$

in which $\mathbf{v}$ is the velocity of the field relative to O. Putting $B$ also in terms of $A$, we find that:

$$E_z = B_p \cdot v_n = -\partial Az/\partial t$$

Repeating the argument for the other components of $E$, it is verified that $\mathbf{E} = -\partial A/\partial t$, which is independently known to be correct.

In a practical problem there would be no point in calculating the induced e.m.f. from the flux-cutting law, if this involved first finding and differentiating the vector potential, since $E = -\partial A/\partial t$ gives the result directly. However, the exercise has shown that the pattern of a changing field may be associated with a natural and definable velocity, the use of which leads to an accepted result. This demonstration of a theoretical basis for their belief may be welcomed by those engineers, who are accustomed to think of all examples of electromagnetic induction as attributable to flux-cutting of some kind.


*Dept. of Electrical Engineering,* D. MIDGLEY
*University of St. Andrews, Dundee.*

19th March 1957.

### REFERENCE


[1] W. A. Tripp, "High-frequency Phenomena", *Wireless Engineer*, January 1955, p. 21.


## Transistor Cut-Off Frequency

SIR,—The temperature dependence of the $\alpha$ cut-off frequency of junction transistors is commonly ignored, and although this may be a justified procedure for many purposes, it may not always be permissible. The cut-off frequency of germanium p.n.p. transistors falls by nearly 0·5 % for 1° C rise in temperature, and it is possible that many people do not realise the magnitude of the effect. The reason for this may be that the early theory of Bardeen and Shockley[1] leads to a comparatively small temperature dependence. More recent experimental figures[2] show that Bardeen and Shockley's theory is not borne out in practice.

The $\alpha$ cut-off frequency, $f_{c0}$, for alloyed junction transistors is given by [3]

$$f_{c0} = K \frac{D}{W^2} \quad \ldots \quad (1)$$

where

$D$ = diffusion constant for minority carriers in the base region of the transistor ;

$W$ = base width ;

$K$ = constant.

$D$ is related to the carrier mobility, $\mu$, by

$$D = \frac{kT}{q} \cdot \mu \quad \ldots \quad (2)$$

where

$k$ = Boltzmann's constant ;

$T$ = absolute temperature ;

$q$ = electronic charge.

Inserting (2) in (1) and retaining only the temperature dependent quantities we have

$$f_{c0} \propto T\mu \quad \ldots \quad (3)$$

Bardeen and Shockley's theory[1] gave $\mu \propto T^{-3/2}$, yielding

$$f_{c0} \propto T^{-0.5} \quad \ldots \quad (4)$$

Experimentally[2] the correct relation for n-type germanium (germanium p.n.p. transistor) is $\mu \propto T^{-2.33}$, yielding

$$f_{c0} \propto T^{-1.33} \quad \ldots \quad (5)$$

For germanium n.p.n. transistors the corresponding expression is

$$f_{c0} \propto T^{-0.66} \quad \ldots \quad (6)$$

The dependence of $f_{c0}$ on temperature for the experimental figures [equ. (5)] is clearly greater than the older theory would predict [equ. (4)] for a germanium p.n.p. transistor. The difference is not so great for the n.p.n. transistor.

Experimental checks have been carried out over a wide range of values of $f_{c0}$ (300 kc/s–20 Mc/s) for germanium p.n.p. transistors, and the results are in reasonably good agreement with the prediction. The theoretical dependence at room temperature (25° C) is a decrease of $f_{c0}$ of 0·45 % per 1° C rise in temperature.


*Mullard Research Laboratories,*
*Salfords, Surrey.* L. G. CRIPPS

4th April 1957.

### REFERENCES


[1] J. Bardeen and W. Shockley, "Deformation Potentials and Mobilities in Non-Polar Crystals", *Phys. Rev.*, 1950, Vol. 80, p. 72.
[2] F. J. Morin, "Lattice-Scattering Mobility in Germanium", *Phys. Rev.*, 1954, Vol. 93, p. 62.
[3] R. L. Pritchard, "Frequency Variation of Current-Amplification Factor for Junction Transistors", *Proc. Inst. Radio Engrs*, 1952, Vol. 40, p. 1476.

# New Books

**Television Engineering. Principles and Practice. Vol. III: Waveform Generation**
By S. W. Amos, B.Sc.(Hons.), A.M.I.E.E. and D. C. Birkinshaw, M.B.E., M.A., M.I.E.E. Pp. 226 with 132 illustrations. Published by arrangement with the B.B.C. for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 30s. (Postage 11d.)

"The third volume of a textbook on television engineering written by members of the B.B.C. Engineering Division, primarily for the instruction of the Corporation's staff. The work is intended to provide a comprehensive survey of modern television principles and practice." There are sections on the generation of sine, rectangular, sawtooth and parabolic waves.

**The Theory of Linear Antennas**
By Ronold W. P. King (Gordon McKay Professor of Applied Physics, Harvard University). Pp. 944. Harvard University Press, distributed in Great Britain by Geoffrey Cumberlege, Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 160s.

"This is the first systematic and comprehensive survey of linear antennas, including circuit and field properties." Both theoretical and experimental aspects of the subject are treated, and the author takes especial care to correlate theory with experiment. Extensive tables, charts and curves are including, so that the theoretically-derived and experimentally-verified results may be more easily applied in practice.

**Television Explained**
By W. E. Miller, M.A.(Cantab.), M.Brit.I.R.E. Revised by E. A. W. Spreadbury, M.Brit.I.R.E., Associate Editor of *Wireless & Electrical Trader*. Pp. 184. Published by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 12s. 6d. (Postage 9d.)

This is the sixth edition of the book, which has been revised, enlarged and, in part, re-written in the light of recent developments. "The book assumes a knowledge of the ordinary sound-radio receiver, but no previous knowledge of television circuits." It is non-mathematical.

**Radio Telemetry**
By Myron H. Nichols and Lawrence L. Rauch. Pp. 461. John Wiley & Sons Inc., New York. Available in the United Kingdom from Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 96s.

The second edition of this American book contains additional descriptive material covering telemetry systems in current use or in development.

**The Electrical Production of Music**
By Alan Douglas, M.I.R.E. Pp. 223. Macdonald & Co. (Publishers) Ltd., 16 Maddox Street, London, W.1. Price 28s.

Contents: The physics of musical instruments, musical scales and intervals, noise and starting transients, electrical tone or waveform generators, electrical tone formation, loudspeakers, existing limitations and possible future trend of research.

**A.C. Synchro Systems for Civil Aircraft**
Pp. 27. Published by the Radio Communication and Electronic Engineering Association, 11 Green Street, Mayfair, London, W.1. Price 10s.

Contains information about the installation and testing of synchro systems and a code of practice for data transmission between interconnecting systems.

**F.B.I. Register of British Manufacturers—1957**
Pp. 1124. Published for the Federation of British Industries by Kelly's Directories Ltd., and Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 42s. (Post free.)

Classified buyers' guide, addresses of companies, information about trade associations, proprietary names, trade marks, etc. French, German and Spanish glossaries.

**Les Redresseurs de Courant dans L'Industrie**
By L. Lecorguillier. Pp. 283. Editions Eyrolles, 61 Boulevard Saint-Germain, Paris 5e, France. Price Fr. 2845. (Post paid.)

Deals mainly with high-power rectification, but mentions some low-power applications including those of point-contact crystal rectifiers.

**"Wireless and Electrical Trader" Year Book 1957**
Pp. 360. Published by Trader Publishing Co. Ltd., Dorset House, Stamford Street, London, S.E.1.

A new feature is a section giving details of domestic electric appliances reviewed during 12 months in *Wireless and Electrical Trader*.

**Théorie des Circuits de Télécommunication**
By Vitold Belevitch. Pp. 384. Chapters on linear systems, Kirchoff's laws, power in passive networks, filters, inductances and transformers, amplifiers, transient response, and network synthesis. Libraire Universitaire, 10 rue de la Monnaie, Louvain, Belgium. Price Fr. (Belgian) 450.

**British Plastics Year Book 1957**
Pp. 716. Published by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 42s. (Postage 1s. 9d.)

Classified guide to products and manufacturers in the plastics industry.

**Lehrbuch der drahtlosen Nachrichtentechnik.** Vol. 5: Fernsehtechnik. Part 1: Grundlagen des Elektronischen Fernsehens
By F. Schröter, R. Theile and G. Wendt. Pp. 772. Springer-Verlag, Reichpietschufer 20, Berlin W.35, Germany. Price D.M. 88.50.

**Elektrische und magnetische Potentialfelder**
By H. Buchholtz. Pp. 552. Springer-Verlag, Reichpietschufer 20, Berlin, W.35, Germany. Price D.M. 72.

**The j-ω or Symbolic Method**
By Harry Stockman, S.D. Pp. 312. S.E.R. Co., 543 Lexington Street, Waltham, Mass., U.S.A. Price $3.50.

## BRITISH STANDARDS

**Safety Requirements for Radio or other Electronic Apparatus for Acoustical or Visual Reproduction**
B.S. 415: 1957. Covers mains-supplied equipment, and auxiliary equipment such as battery chargers. Price 6s.

**Papers for Electrical Purposes**
B.S. 698: 1956. The 1936 standard revised in the light of recent experimental work. Price 7s. 6d.

**Aminoplastic Moulding Materials**
B.S. 1322: 1956. Price 5s.

**Organic Baking Impregnating Varnishes for Electrical Purposes**
B.S. 2778: 1956. Price 3s.

**Field Rheostats and Rheostats for Other Purposes**
B.S. 280: 1957. Revised version of standard issued in 1928. Price 5s.

**Machine Screw Nuts, Pressed Type (B.A. and Whitworth Form Threads)**
B.S. 2827: 1957. General dimensions and screw thread limits for sizes 6 B.A. to 0 B.A. and from $\frac{3}{32}$–48 Whitworth to $\frac{3}{8}$ B.S.W. and B.S.F. Price 2s. 6d.

**British Standards Year Book 1957**
Pp. 480. Price 15s. (Postage 1s. 6d.)

Contains a complete numerical list of the British Standards and Codes of Practice current on 1st January 1957, and information about the B.S.I. and its services.

British Standards Institution, Sales Branch, 2 Park Street, London, W.1.

## INSTRUMENTS, ELECTRONICS AND AUTOMATION EXHIBITION

### Programme of Conference

**8th May.** "The New Age", Lord Halsbury, F.R.I.C., F.Inst.P., at 11. "Computer Controlled Machine Tools", J. N. Toothill, C.B.E., and "Electronically Controlled Machine Tools", C. A. Sparkes, at 3. "Automatic Gauging", L. Loxham, at 4.

**9th May.** "Nuclear Power", Sir Claude Gibb, K.B.E., D.Sc., F.R.S., at 11. "Controlling and Research Reactor", R. J. Cox, B.Sc., and "The Place of Analog Computers in Reactor Control", J. Walker, M.A., at 3. "Radio Isotopes in the Nucleonic Industry", H. Seligman, Ph.D., at 3.45.

**10th May.** "Instruments—A Career with a Future", F. Dunsheath, C.B.E., D.Sc., M.A., at 11. "The Technologist—His Training and Reward", G. L. D'Ombrain, Ph.D.Eng., at 3. "Training for Research", J. Thomson, M.A., D.Sc., at 3.45.

**13th May.** "Instrumentation in Medicine", Professor J. Rotblat, D.Sc.(Lond.), D.Sc.(Warsaw), Ph.D., at 11. "The Artificial Heart Lung", D. G. Melrose, B.M., B.C.H., at 3. "Electronic Instruments for Clinical Tests with Radioactive Isotopes", N. Veall, B.Sc., and E. W. Pulsford, B.Sc., at 3.45.

**14th May.** "Instrumentation in Industry", Sir Ewart Smith, M.A., at 11. "Instrumentation in the Textile Industries", J. E. Fielden, M.Sc., and "Instrumentation in the Paper Industries", B. W. Balls, B.Sc., at 3. "Fuel Efficiency in all Industries", R. Clare, B.Sc., and "Instrumentation in the Food Industry", A. J. Goodall, B.Sc., at 4.

**15th May.** "The Electronic Office", Sir Walter Puckey, at 11. "Production Control Procedures using a Computer", J. W. Grant, at 3. "Electronics in Banking", L. Temple, at 3.45.

**16th May.** "Communications and the Future", Sir Gordon Radley, C.B.E., Ph.D.(Eng.), at 11. "Recent Developments in Marine Radar", A. L. P. Milwright, at 3. "Air Navigation", T. G. Thorne, at 3.45.

These meetings will be held in the Grand Hall, Olympia, and tickets are available only at the Exhibition.

## MANUFACTURERS' LITERATURE

**Marconi Instruments 1957.** Catalogue of signal generators and allied equipment, frequency meters, voltmeters, power meters, distortion meters, field-strength meters, transmission monitors, deviation meters, oscilloscopes, spectrum response analysers, standing-wave meters, Q meters, bridges, industrial X-ray apparatus, moisture meters and pH meters. Pp. 276.
*Marconi Instruments Ltd., St. Albans, Herts.*

**Components by Harwin.** Catalogue of terminal lugs, taper receptacles, moulding inserts, terminal panels and group boards, insulators, terminals and handles. Pp. 13 + 22 data sheets and price list.
*Harwin Engineers Ltd., Nibthwaite Road, Harrow, Middx.*

**High-Conductivity Copper Alloys.** Composition, production, physical and mechanical properties of cadmium copper, chromium copper, silver copper and tellurium copper, 25 tables. Pp. 54.
*Copper Development Association,* 55 *South Audley Street, London, W.*1.

**Mullard Pocket Data Book, Autumn 1956.** Valve data. Pp. 67.
*Mullard Ltd., Mullard House, Torrington Place, London, W.C.*1.

**Ferranti Valves and Television Tubes (1956 edition).** Valve data. Pp. 118.
*Ferranti Ltd., Electronic Sales Dept., Gem Mill, Chadderton, Oldham, Lancs.*

**Solartron 1956.** Annual review of the Solartron electronic group. Pp. 23.
*Solartron Electronic Group Ltd., Thames Ditton, Surrey.*

## MEETINGS

**I.E.E.**

15*th May.* "Transistor Circuits and Applications", by A. G. Milnes, D.Sc.

23*rd May.* Annual General Meeting, followed at 6.30 by lecture on "General Applications of Digital Computers", by A. D. Booth, D.Sc., Ph.D.

*These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.*2, *and will commence at* 5.30.

**Brit. I.R.E.**

22*nd May.* "Barium Titanate Storage Cells", by G. Campbell, to be held at 6.30 at the London School of Hygiene and Tropical Medicine, Keppell Street, Gower Street, London, W.C.1.

**The Television Society**

10*th May.* Annual General Meeting to be held at 7 o'clock at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.

**The Society of Instrument Technology**

28*th May.* Annual General Meeting to commence at 6 o'clock, followed by an address by Sir Harold Hartley, K.C.V.O., C.B.E., M.C., F.R.S., at Manson House, Portland Place, London, W.1.

**British Sound Recording Association**

24*th May.* Annual General Meeting to be held at Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, at 7.15.

## STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

*Values for March* 1957

| Date 1957 March | MSF 60 kc/s Frequency deviation from nominal :* parts in $10^9$ |
|---|---|
| 1 | +2 |
| 2 | +2 |
| 3 | +2 |
| 4 | +2 |
| 5 | +2 |
| 6 | +2 |
| 7 | +2 |
| 8 | +2 |
| 9 | +2 |
| 10 | +2 |
| 11 | +2 |
| 12 | +2 |
| 13 | +2 |
| 14 | +2 |
| 15 | +2 |
| 16 | +2 |
| 17 | +3 |
| 18 | +3 |
| 19 | +3 |
| 20 | +3 |
| 21 | N.M. |
| 22 | +3 |
| 23 | N.M. |
| 24 | +3 |
| 25 | +3 |
| 26 | +3 |
| 27 | +3 |
| 28 | +3 |
| 29 | +3 |
| 30 | +3 |
| 31 | +3 |

* *Nominal frequency is defined to be that frequency corresponding to a value of* 9 192 631 830 *c/s for the N.P.L. caesium resonator. N.M. = Not Measured.*

# Abstracts and References

COMPILED BY THE RADIO RESEARCH ORGANIZATION OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND PUBLISHED BY ARRANGEMENT WITH THAT DEPARTMENT

*The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses. Copies of articles or journals referred to are not available from* Electronic & Radio Engineer. *Application must be made to the individual publisher concerned.*



## ACOUSTICS AND AUDIO FREQUENCIES

534.131 : 548.0]+621.372.412 1298

**Simple Modes of Vibration of Crystals.**—R. D. Mindlin. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1462–1466.) Exact mathematical solutions are derived for rectangular parallelepipeds and thin plates with traction-free faces. Specific orientations and ratios of dimensions are assumed.

534.213-8 1299

**Ultrasonic Attenuation Caused by Thermoelastic Heat Flow.**—K. Lücke. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1433–1438.) Computed and measured values of the attenuation in single crystals of Zn, Cu and Al agree in order of magnitude; for polycrystalline substances the thermoelastic attenuation is much smaller than the measured attenuation.

534.231 1300

**Successful Method of Attack on Plane Progressive Finite Waves.**—R. D. Fay. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 910–914.) In the method presented the conservation criteria at any point of the sound field are expressed in terms of the instantaneous values of the speed of propagation, particle velocity, excess pressure and excess density. These criteria, together with the adiabatic assumption, determine explicit relations between any two of these quantities. For waves of finite amplitude equilibrium values at zero particle velocity, as well as the speed of propagation, are found to depend on the intensity. The increment in the speed of propagation does not agree with that obtained by classical methods of analysis. The discrepancy is found to be due to the omission in the classical forms of the continuity criterion of a term that specifies the effect of the rate of change in the speed of propagation.

534.232 : 546.431.824-31 1301

**Higher Modes of Radial Vibrations in Short, Hollow Cylinders of Barium Titanate.**—C. V. Stephenson. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 928–929.) The forbidden and allowed modes of radial vibrations in hollow barium titanate cylinders are discussed. The predicted and measured resonance frequencies for the first three modes of elements with external/internal diameter ratios of 8·30, 2·85 and 2·13 are in good agreement.

534.322.3 1302

**Calculation of the Loudness of Complex Noise.**—S. S. Stevens. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 807–832.)

534.417 1303

**New Method for the Calibration of a Plane Hydrophone.**—A. R. Laufer & G. L. Thomas. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 951–958.) The method described involves the measurement of the radiation pressure of a standing-wave system.

534.614-8 1304

**Simple Form of the 'Sing-Around' Method for the Determination of Sound Velocities.**—G. W. Ficken, Jr, & E. A. Hiedemann. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 921–923.) The method is based on the determination of a pulse repetition rate which is a known function of the ultrasonic pulse velocity in the material under test. The errors are less than 1%.

534.614-8 1305

**Ultrasonic Stroboscopes for the Study of Ultrasonic Fields.**—W. L. Gessert & E. A. Hiedemann. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 944–950.)

534.833 : 621.395.6 1306

**Electronic Control of Noise, Vibration, and Reverberation.**—H. F. Olson. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 966–972.) Description of some active systems for the reduction or absorption of sound or vibrations.

534.84 1307

**The Application of Phase-Coherent Detection and Correlation Methods to Room Acoustics.**—C. L. S. Gilford & M. W. Greenway. (*B.B.C. Engng Div. Monographs*, Nov. 1956, No. 9, pp. 1–14.) Methods of displaying the acoustic properties of a room are discussed. A phase-coherent modification of the pulsed-glide technique [307 of 1953 (Somerville & Gilford)] has been developed in which the microphone output is modulated by the original frequency of excitation before being applied to the c.r.o. Further modifications involving cross-correlation and phase-reversal counting are also described.

534.84 1308
**The Effect of Room Shape on Steady-State Sound Transmission Characteristics: Part 1—Theoretical Consideration for Fan-Shaped Room. Part 2—Experimental Investigation using Model Rooms.**—T. Nimura & K. Shibayama. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, March 1956, Vol. 7, No. 4, pp. 199-217.)

534.862.4 1309
**Application and Arrangement of Loudspeakers in Sound-Reproduction Installations.**—D. Kleis. (*Tijdschr. ned. Radiogenoot.*, Sept. 1956, Vol. 21, No. 5, pp. 237–254.) Conditions for satisfactory reproduction in halls and living rooms are discussed with particular reference to the ratio between directly and indirectly received sound. Differences in the requirements for speech and music are indicated; concentrated grouping of loudspeakers is more appropriate in the former case and distributed arrangements in the latter. Advantages may be afforded by two-channel systems in some cases.

621.395.61 1310
**Measurement of Noise-Cancelling Effectiveness of Microphones.**—L. M. Levine & J. Hershkowitz. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 973–976.)

621.395.61.089 1311
**Absolute Calibration of Microphones at Audible and Infrasonic Frequencies.**—V. Gavreau & A. Calaora. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1840–1842.) The technique used involves measurement of the amplitude of the displacement of particles by the sound wave; an arrangement including an ultrasonic radiator and detector and c.r.o. indicator is used.

621.395.623.7 : 534.862.4 1312
**The Bass-Reflex Radiator in Acoustics.**—F. J. v. Leeuwen. (*Tijdschr. ned. Radiogenoot.*, Sept. 1956, Vol. 21, No. 5, pp. 195–235.) The mechanical impedance at the back of a loudspeaker cone is computed from the electrical impedance at the terminals of the loudspeaker at different frequencies, and the acoustical parameters of the associated enclosure are hence deduced. The calculated frequency response of the system is in good agreement with measured values. Application of the results to the design of enclosures for given loudspeakers is described; design graphs are included.

621.395.625.3 1313
**Noise in Magnetic Recording Tapes.**—D. H. Howling. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 977–987.) A theoretical and experimental investigation is made into the mechanism of noise in magnetic media as used in magnetic recording.

621.395.625.3 1314
**Eight-Channel Recording on ¼-in. Magnetic Tape with a Stationary-Tape Playback.**—J. C. Barton. (*J. sci. Instrum.*, Nov. 1956, Vol. 33, No. 11, pp. 415–419.) "A method of constructing multichannel magnetic heads is described and their performance reported. The problem of interference between channels is discussed and details given of a new technique for reducing this interference. The playback equipment consists of an eight-channel head mounted on an electrically maintained tuning fork so that it picks up signals from a stationary tape. Signals from each channel are switched electrically in time succession and, after amplification, displayed simultaneously on an oscilloscope. It is possible to resolve pulses recorded along the tape at a separation of 0·1 mm. Precautions necessary for observing very small signals are discussed."

621.395.625.3 : 621.397.5 : 535.623 1315
**A Magnetic-Tape System for Recording and Reproducing Standard F.C.C. Colour-Television Signals.**—Olson, Houghton, Morgan, Artzt, Zenel & Woodward. (See 1592.)

## AERIALS AND TRANSMISSION LINES

621.315.212 : 621.3.018.44 1316
**Transient Analysis of Coaxial Cables considering Skin Effect.**—R. L. Wigington & N. S. Nahman. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 166–174.) Curves are presented by which the response of any length of cable may be predicted given one point on the attenuation/frequency curve. Theoretical and experimental results are compared.

621.372 + 621.396.677.8 1317
**Electromagnetic Transmission Characteristics of a Lattice of Infinitely Long Conducting Cylinders.**—Z. A. Kaprielian. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1491–1502.) Four theoretical treatments of the general problem are given with their advantages, disadvantages and realms of validity.

621.372.2 1318
**Distributed-Parameter Variable Delay Lines using Skewed Turns for Delay Equilization.**—Lewis & Frazier. (See 1354.)

621.372.2 : 621.315.61 1319
**Reflectionless Transmission through Dielectrics and Scattering Potentials.**—I. Kay & H. E. Moses. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1503–1508.) "A complete solution is given for the problem of constructing a plane stratified dielectric medium having the property that at a fixed frequency and polarization a plane wave at any angle of incidence will be transmitted without reflection by the medium."

621.372.2 : 621.317.34 : 621.317.729 1320
**An Investigation into some Fundamental Properties of Strip Transmission Lines with the Aid of an Electrolytic Tank.**—B. G. King : J. M. C. Dukes. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, p. 72.) Comment on 2283 of 1956 and author's reply.

621.372.2 : 621.317.343 : 621.317.729 1321
**Measurement of the Characteristic Impedance of Uniform Lines by means of the Electrolyte Tank.**—Koch. (See 1533.)

621.372.2+621.372.8] : 621.372.543.2 1322
**Direct-Coupled-Resonator Filters.**—Cohn. (See 1361.)

621.372.8 1323
**The Constants of Waveguides: Extension of Abraham's Line Theory.**—H. J. Hoehnke. (*Arch. Elektrotech.*, 20th Sept. 1956, Vol. 42, No. 7, pp. 426–448.) A definition of 'apparent line constants' was given by Abraham (*Ann. Phys., Lpz.*, 1901, Vol. 6, pp. 217–241) in terms of electrical potentials and magnetic current functions which could be easily evaluated to give the capacitance and inductance coefficients. The applicability of this treatment is extended by introducing the electric and magnetic energy densities. The relation between the effective and the apparent constants is investigated. Complex lossy structures including stratified dielectric guides are considered.

621.372.8 1324
**Surface Finish and Attenuation of Aluminium Waveguides.**—J. Allison & F. A. Benson. (*Electronic Engng*, Jan. 1957, Vol. 29, No. 347, pp. 36–38.) The attenuation of a rectangular drawn Al waveguide (measured at 9·3 kMc/s) is compared with figures previously obtained for drawn copper and brass and electroplated guides. Measurements of surface roughness of Al waveguides show that it may be reduced by chemical or electrolytic polishing. Information on the surface texture of cast and sprayed guides is given.

621.372.8 1325
**A Nonresonant Waveguide Window.**—A. E. Barrington & J. T. Hyman. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 35–38.) Use is made of the fact that a dielectric slab of any thickness may be inserted in a waveguide without affecting the characteristic wave impedance to E modes, at a particular frequency related to the dielectric constant and the guide dimensions. The frequency bandwidth is examined and design curves given. Application to vacuum-tight seals for high-power oscillators and amplifiers is suggested.

621.372.8.029.65 1326
**Helix Waveguide.**—S. P. Morgan & J. A. Young. (*Bell Syst. tech. J.*, Nov. 1956, Vol. 35, No. 6, pp. 1347–1384.) A helix waveguide constructed of closely wound turns of insulated copper wire covered with a lossy jacket is investigated theoretically using the sheath helix model. Approximate formulae are given for the propagation constants of lossy modes, and numerical values are given for waveguides of zero pitch as functions of the jacket parameters and waveguide diameter in regions where the approximate formulae are no longer valid.

621.396.67 **1327**

**An Experimental Study of the Disk-Loaded Folded Monopole.**—E. W. Seeley. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 27–28.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 715.

621.396.676.2 **1328**

**An Experimental Investigation of Cavity-Mounted Helical Antennas.**—A. Bystrom, Jr, & D. G. Berntsen. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 53–58.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 715.

621.396.677 **1329**

**Some Data for the Design of Electromagnetic Horns.**—E. H. Braun. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 29–31.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 715.

621.396.677 **1330**

**Small Horn Aerial with Improved Area Efficiency.**—A. Knopf. (*Nachrichtentech. Z.*, Sept. 1956, Vol. 9, No. 9, pp. 408–410.) The efficiency of a parabolic-cylinder aerial, expressed as a percentage of that of an ideal uniformly illuminated plane radiating area, can be doubled by fitting a phase-retarding iris along the middle of the horn.

621.396.677 **1331**

**A Mechanically Simple Foster Scanner.**—R. C. Honey & E. M. T. Jones. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 40–46.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 715.

621.396.677 **1332**

**Radiation Patterns of Unsymmetrically Fed Prolate-Spheroidal Antennas.**—H. A. Myers. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 58–64.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, pp. 715–716.

621.396.677 : 523.16 **1333**

**Two-Dimensional Aerial Smoothing in Radio Astronomy.**—Bracewell. (See 1412.)

621.396.677.012 : 523.16 **1334**

**Measurements of the [polar] Diagrams of Aerials using Extra-terrestrial Sources of R.F. Radiation.**—N. L. Kaidanovski. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, p. 683.) Note on the dependence of the polar characteristics, obtained by using the sun as source, on the aerial beam width relative to the angular diameter of the sun and to the solar brightness distribution.

621.396.677.012.029.6 : 523.16 **1335**

**Radio-Astronomical Methods of Investigating Aerials.**—V. S. Troitski. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 601–612.) The theory of a method of determining aerial losses, efficiency and directional characteristics at v.h.f. and u.h.f. by using extraterrestrial radio sources is developed on the basis of thermodynamic considerations and, in particular, the application of Kirchhoff's law of radiation. The minimum aerial dimensions required for reception of radiation at wavelengths between 3·2 and 300 cm from various extraterrestrial sources are tabulated together with the incident flux from and angular dimensions of the sources. Practical details are briefly discussed and experimental results are mentioned. For a brief account see *Zh. tech. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 485–486.

621.396.677.029.5 **1336**

**Directional Aerial Systems of Medium- and Long-Wave Broadcast Transmitters.**—W. Berndt. (*Telefunken Ztg*, June 1956, Vol. 29, No. 112, pp. 75–86. English summary, p. 132.) Technical survey of seven installations erected in Europe between 1934 and 1954.

621.396.677.3 **1337**

**Optimum Linear Aerials.**—V. L. Pokrovski. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 593–600.) The current distribution in linear broadside arrays is considered, using Tchebycheff-Akhiezer polynomials ; the optimum solution can be obtained not only for radiator spacings of $d \geqslant \lambda/2$, but also for $d < \lambda/2$.

621.396.677.32 **1338**

**The Radiating Properties of End-Fire Aerials.**—J. Brown & J. O. Spector. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 27–34.) The theoretical radiation pattern (e.g., of dielectric rod and Yagi aerials) is determined by the transverse field distribution at the end of the aerial due to the surface wave. A simple relationship between the beam width and the ratio of the wavelength of the surface wave to that in free space is then obtained. Advantages over the theories of Mallach (1604 of 1949) and Horton & Watson (1297 of 1949) are considered. Theoretical and experimental patterns for several end-fire aerials are compared, and good agreement is obtained if radiation from the feed is taken into account.

621.396.677.71 **1339**

**Analysis of a Terminated-Waveguide Slot Antenna by an Equivalent-Circuit Method.**—L. B. Felsen. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 16–26.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 715.

621.396.677.75 **1340**

**Ferrite-Rod Antennas Operate in X-Band.**—F. Reggia, E. G. Spencer, R. D. Hatcher & J. E. Tompkins. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 159–161.) The ferrite in a typical antenna forms a dielectric rod radiator coupled to a waveguide, and may have a 20 : 1 gain for a beam width of 28 degrees and v.s.w.r. of 1·2. Arrays can be made by spacing the rods along the waveguide or by magnetic coupling from resonant cavities. By using the Faraday effect, mode switching, array scanning and beam lobing are possible.

## AUTOMATIC COMPUTERS

681.142 **1341**

**Definitions of Terms for Program-Controlled Electronic Computers.**—(*Nachrichtentech. Z.*, Sept. 1956, Vol. 9, No. 9, pp. 434–436.) About 40 proposed terms are listed with their definition and English equivalent.

681.142 **1342**

**The Design and Applications of a General-Purpose Analogue Computer.**—R. J. A. Paul & E. L. Thomas. (*J. Brit. Instn Radio Engrs*, Jan. 1957, Vol. 17, No. 1, pp. 49–73.) The design and construction are considered in detail with particular emphasis on amplifier gain, bandwidth and phase shift. A computer whose design is based on this analysis and has some novel features is described. Its use on a variety of problems illustrates its wide range of application. See also 2299 of 1956 (Paul).

681.142 **1343**

**Use of Analogue Computers for Solving Boundary Problems, Algebraic, Transcendental and Integral Equations.**—I. M. Vitenberg & E. A. Gluzberg. (*Avtomatika i Telemekhanika*, July 1956, Vol. 17, No. 7, pp. 590–600.)

681.142 **1344**

**Radioactive-Fall-Out Computer.**—(*Electronic Ind. Tele-Tech*, Sept. 1956, Vol. 15, No. 9, pp. 67..136.) Electronic analogue techniques are used in a new computer to make rapid predictions of fall-out based on wind velocities and particle sizes.

681.142 : 621.374.3 **1345**

**V.H.F. Pulse Techniques and Logical Circuitry.**—Rosenheim & Anderson. (See 1374.)

## CIRCUITS AND CIRCUIT ELEMENTS

621.3 : 539.169 **1346**

**Effects of Radiation on Electronic Components.**—R. D. Shelton. (*Electronic Ind. Tele-Tech*, Sept. 1956, Vol. 15, No. 9, pp. 57..126.) Methods of testing for damage resulting from exposure to nuclear radiation are discussed and effects on various classes of component are described. Gamma radiation is mainly harmful to the insulation of resistors and capacitors; transistors and all devices depending on an ordered crystal lattice are very susceptible to neutron bombardment.

621.3.048 : 621.315.616.9 **1347**

**Problems in Casting Electronic Components.**—H. G. Manfield. (*Elect. Mfg*, Oct. 1955, Vol. 56, No. 4, pp. 142–144.) Precautions to be taken in applying casting resins to resistors, capacitors, rectifiers, iron-core components and instrument wires are noted.

621.316.5.064.43 **1348**

**The Erosion of Electrical Contacts by the Normal Arc.**—W. B. Ittner, III, & H. B. Ulsh. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 63–68.) "Within the experimental errors the material transfer from the cathode was found to be directly proportional to the total charge passed in the arc—a relationship first proposed by R. Holm [*Electrical Contacts*, 1946]. It is shown that, for most practical purposes, the cathode 'normal arc' transfer can be calculated with a reasonable accuracy according to the formula given by Llewellyn Jones [3436 of 1946]."

621.318.4.011.1 **1349**

**The Short-Circuited Turn.**—T. Roddam. (*Wireless World*, March 1957, Vol. 63, No. 3, pp. 114–117.) The equivalent circuit is examined mathematically and the practical implications of the analysis in commonly met situations are considered.

621.318.4.011.32 **1350**

**Mutual Inductance of Two Coaxial Circular Cylindrical Coils with a Layer of Contiguous Turns of Fine Wire.**—R. Cazenave. (*Ann. Télécommun.*, Sept. 1956, Vol. 11, No. 9, pp. 174–179.) Calculations are made for the two particular cases in which the coils are (*a*) axially coextensive, and (*b*) axially adjacent.

621.318.5 **1351**

**Mathematical Theory of the Synthesis of Contact (1,*k*)-Poles.**—G. N. Povarov. (*C. R. Acad. Sci. U.R.S.S.*, 1st Nov. 1955, Vol. 111, No. 1, pp. 102–104. In Russian.)

621.319.4.012 **1352**

**The Effective Power** [dissipation] **of a Lossy Capacitor Loaded by a Train of Rectangular Pulses.**—H. Eisenlohr. (*Frequenz*, Sept. 1956, Vol. 10, No. 9, pp. 292–293.) Formulae are derived based on an equivalent series circuit of loss-free capacitor and resistance; they are applicable to different types of dielectric loss.

621.372 : 621-526 **1353**

**A Less-than-Minimum-Phase-Shift Network.**—R. F. Destebelle, C. J. Savant & C. J. Savant, Jr. (*Electronic Ind. Tele-Tech*, Sept. 1956, Vol. 15, No. 9, pp. 60–61 . . 106.) The minimum phase shift attainable in a linear network for a given attenuation can be reduced by introducing nonlinear circuits, thus preventing instability. A servo system is described in which instability in a high-*Q* tuned amplifier is prevented by use of a phase-sensitive demodulator.

621.372.2 **1354**

**Distributed-Parameter Variable Delay Lines using Skewed Turns for Delay Equalization.**—F. D. Lewis & R. M. Frazier. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 196–204.) An analysis of the method of equalization is given, and the performance of experimental variable delay lines is discussed.

621.372.4 : 621.376.32 : 621.314.7 **1355**

**Equivalent Reactances using Junction-Type Semiconductor Triodes.**—L. N. Kaptsov & K. S. Rzhevkin. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 670–679.) Transistor analogues of reactance-valve circuits are discussed.

621.372.412 + [534.131 : 548.0 **1356**

**Simple Modes of Vibration of Crystals.**—Mindlin. (See 1298.)

621.372.413 **1357**

**Change of Characteristic Frequencies of Electromagnetic Resonators.**—Yu. N. Dnestrovski. (*C. R. Acad. Sci. U.R.S.S.*, 1st Nov. 1956, Vol. 111, No. 1, pp. 94–97. In Russian.) The perturbation of the resonance frequencies of cavities by small changes in the shape of the cavity or by the insertion of small ideally conducting bodies is calculated by a method of successive approximations. The general perturbation formula obtained is in agreement, in the case of a conducting sphere, with the formula obtained by Maier & Slater (2265 of 1952). The general method can also be used in calculating the changes in the characteristic values due to changes of $\epsilon$ and $\mu$ inside the cavity.

621.372.413 **1358**

**Cavity with Linear Tuning, for Metre and Decimetre Wavelengths.**—C. Brot & A. Soulard. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1848–1850.) A coaxial cavity is described in which the inner conductor comprises the combination of a fixed tube and an axial plunger. Displacement of the plunger within the tube varies the lumped capacitance without varying the distributed inductance. To avoid disturbing the edge effects, the plunger carries with it a teflon plug with a metal base, which is under spring pressure from the opposite side.

621.372.413 : 537.533 : 530.145 **1359**

**Quantum Effects in the Interaction between Electrons and High-Frequency Fields: Vacuum Fluctuation Phenomena.**—I. R. Senitzky. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1486–1491.) Previous calculations (369 and 3186 of 1955) gave a divergent result for the dispersion, due to the quantum properties of the field, in the velocity of an electron passing through a cavity. By a transformation the divergence has been eliminated and the mean velocity increment and the dispersion obtained.

621.372.5 : 621.376.3 : 621.3.018.78 **1360**

**Frequency-Modulation Distortion in Linear Networks.**—Brown. (See 1581.)

621.372.543.2 : [621.372.2+621.372.8 **1361**

**Direct-Coupled-Resonator Filters.**—S. B. Cohn. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 187–196.) Specific design formulae are given for lumped-constant elements, waveguide, and strip or other TEM transmission line, and for pass-band response functions of the maximally flat or Tchebycheff types. Practical results compared with theoretical responses show that the formulae are accurate for large bandwidths.

621.372.55 : 621.397.24 **1362**

**New Equalizers for Local TV Circuits.**—H. M. Thomson. (*Bell Lab. Rec.*, Sept. 1956, Vol. 34, No. 9, pp. 346–349.) Equalizer units for the A2A system, which are required to equalize over the frequency range from about 100 c/s to 4·5 Mc/s for cable lengths from a fraction of a mile upwards, include eight fixed equalizers in a bridged-T network together with three compound equalizers having adjustable frequency characteristics and an all-pass phase-equalizing section.

621.372.56.029.6 : 621.372.8 **1363**

**A Secondary Microwave Attenuator.**—H. A. Prime. (*J. sci. Instrum.*, Nov. 1956, Vol. 33, No. 11, pp. 448–449.) The arrangement described comprises a flexible resistive vane which is 'bowed' into the middle of the waveguide by means of a micrometer screw; the screw is shielded by the vane so that it does not cause reflections.

621.372.632 **1364**

**High-Frequency Power Rating. Application of Theory to a Mixer Stage with Known Nonlinear Characteristic.**—H. Fark. (*Frequenz*, Sept. 1956, Vol. 10, No. 9, pp. 294–296.) Equations with relevant curves and tables are given for diode mixer circuits.

621.372.632 **1365**

**Frequency Conversion by means of a Nonlinear Admittance.**—C. F. Edwards. (*Bell Syst. tech. J.*, Nov. 1956, Vol. 35, No. 6, pp. 1403–1416.) Mathematical analysis is presented for a heterodyne conversion transducer which uses a nonlinear capacitor and a nonlinear resistor in parallel. Curves are given showing the change in admittance and gain with change in the characteristics of the nonlinear element. The conditions under which a conjugate match is possible are specified and conclusions indicate that a nonlinear capacitor alone is the preferred element for modulators, and a nonlinear resistor alone is best for converters.

621.372.632 :621.373.423 **1366**

**The Serrodyne Frequency Translator.**—R. C. Cumming. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 175–186.) A linear sawtooth waveform causes transit-time modulation of an S-band travelling-wave valve to produce up to 57-Mc/s frequency translation. The loss for a translation of 30 Mc/s is 1 dB for 20 dB rejection of unwanted frequencies. The effect of certain practical factors in limiting the performance are discussed and a general spectrum analysis is given, applicable to problems where arbitrary modulating waveforms are used.

621.373.4/.5 **1367**

**The Theory of Oscillators.**—W. Herzog & E. Frisch. (*Nachrichtentech. Z.*, July, Sept. & Oct. 1956, Vol. 9, Nos. 7, 9, & 10, pp. 310–314, 420–423 & 449–455.) Analysis of oscillation conditions in a circuit comprising a pentode valve and a 3-terminal network is applied to derive general design principles for a valve or transistor oscillator insensitive to load changes, and the stability and efficiency of a tuned oscillator are discussed.

621.373.421.13 **1368**

**How to Design Colpitts Crystal Oscillators.**—H. E. Gruen. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 146–150.) Design data are presented as performance graphs for typical circuits.

621.373.43 **1369**

**Second-Order Nonlinear Systems. Applications to Electronics.**—L. Sideriades. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1850–1852.) Analysis relevant to the operation of non-sinusoidal oscillators is presented.

621.373.44 **1370**

**A Versatile Rectangular-Pulse Generator.**—G. O. Crowther, L. H. Light & C. F. Hill. (*Electronic Engng*, Jan. 1957, Vol. 29, No. 347, pp. 8–12.) Description of an instrument for generating positive or negative pulses of up to 100 V and of 1 μs–12 ms duration, with repetition frequency 1 c/s–150 kc/s. A variable-delay triggering facility is provided.

621.373.52 : 621.314.7 **1371**

**Analysis of a Nearly Harmonic Oscillator with Semiconductor Triode at Frequencies Above α Cut-Off.**—K. S. Rzhevkin, L. A. Logunov & L. N. Kaptsov. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 647–653.) Analysis is presented for a grounded-base transistor oscillator. Experimental results indicate that the upper frequency limit is about six times the α-cut-off frequency, this being somewhat lower than the calculated limit. The calculated and measured frequency/emitter-current and frequency/collector-voltage characteristics with a point-contact transistor and a junction transistor are presented graphically.

621.373.52 : 621.314.7 **1372**

**Analysis of Processes in the Blocking Oscillator with Semiconductor Triode.**—K. Ya. Senatorov & G. N. Berestovski. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 654–669.)

621.374.3 : 621.317.755 **1373**

**Transistors Generate Geometric Scale.**—E. Gott & J. H. Park, Jr. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 180–183.) Fast and slow sawtooth voltages are generated and compared in a discriminator. When equal, the fast generator recycles to produce a chain of pulses spaced in geometric progression.

621.374.3 : 681.142 **1374**

**V.H.F. Pulse Techniques and Logical Circuitry.**—D. E. Rosenheim & A. G. Anderson. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 212–219.) Selection of components and design of circuits for using 10-mμs pulses in an experimental digital computer with a pulse repetition frequency of 50 Mc/s.

621.374.4 : 621.385.029.6 **1375**

**Frequency Division using a Reflex Klystron.**—E. N. Bazarov & M. E. Zhabotinski. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 680–681.) Theory and a brief note on the practical realization are given.

621.375.1 : 512.3 **1376**

**Application of the Method of Orthogonal Polynomials in Solving some Problems in the Analysis and Synthesis of Multistage Amplifiers.**—S. V. Samsonenko. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 623–626.) The relations between output signal, input signal and system parameters are analysed.

621.375.2 : 621.372.542.2 **1377**

**Stagger-Tuned Low-Pass Amplifier with High Cut-Off Frequency.**—G. Mahler. (*Frequenz*, Sept. & Oct. 1956, Vol. 10, Nos. 9 & 10, pp. 296–303 & 319–328.) The optimum value of the product of bandwidth and amplification obtainable for a given frequency characteristic is calculated. It can be achieved by using two-terminal sections in cascade-connected nonidentical stages of Tchebycheff type. The design of a 40-Mc/s 50-dB low-pass amplifier is given as an example; in theory its amplification over the pass band does not change by more than ±2%. The use of quadripole sections in amplifiers with nonidentical stages is also investigated.

621.375.2.024 : 621.314.58 : 621.314.63 **1378**

**Silicon Diode Chopper Stabilizes D.C. Amplifier.**—L. Fleming. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 178–179.) "Stability of 100 microvolts per hour is possible with high-back-resistance silicon diodes in contrast with 2 millivolts an hour using direct-coupled thermionic amplifiers. Input impedance is 100 times greater than with germanium crystals. Practical biological amplifier also uses phase detector that cuts rectified d.c. requirement."

621.375.2.121 : 621.397.5 **1379**

**Wide-Band Amplifier Design.**—J. Kason. (*Electronic Engng*, Jan. 1957, Vol. 29, No. 347, pp. 39–41.) A discussion of practical design procedure for a band-I amplifier with 30-Mc/s bandwidth.

621.375.2.122 **1380**

**Heater Voltage Compensation for D.C. Amplifiers.**—J. B. Earnshaw. (*Electronic Engng*, Jan. 1957, Vol. 29, No. 347, pp. 31–35.) The concept of a fictitious voltage source to represent heater voltage fluctuations is examined and a detailed analysis of three compensation circuits together with experimental results is given.

621.375.4 **1381**

**The Neutralization of Selective Transistor Amplifiers.**—G. Meyer-Brötz. (*Arch. elekt. Übertragung*, Sept. 1956, Vol. 10, No. 9, pp. 391–397.) Various neutralizing circuits are discussed and the influence of frequency and operating conditions on their performance is investigated.

621.375.4 : 621.314.7 **1382**

**The Stabilization of the D.C. Operating Point of Junction Transistors.**—Guggenbühl & Schneider. (See 1611.)

621.375.4 : 621.316.825 **1383**

**Thermistors Compensate Transistor Amplifiers.**—A. J. Wheeler. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 169–171.) Temperature compensation of class-B push-pull transistor amplifiers is necessary to minimize distortion and prevent runaway. Typical compensating circuits using thermistors are described and equations for calculating component values and restrictions on use of two types of thermistor material are given. Design technique gives an approximation to the desired linear decrease in bias with increase in ambient temperature.

621.376.22 : 621.385.5 **1384**

**A Simple Square-Law Circuit with High Frequency Response.**—H. N. Coates. (*Electronic Engng*, Jan. 1957, Vol. 29, No. 347, pp. 41–42.) "By applying a signal to both control and suppressor grids of a pentode valve, it is possible to balance out changes in the valve anode current proportional to the signal fundamental and to generate a component proportional to its square, which is available without additional filtering and consequent restriction of bandwidth."

## GENERAL PHYSICS

530.12 **1385**

**Variation of Integrals and the Field Equations in the Unitary Field Theory.**—H. A. Buchdahl. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 1142–1145.)

530.145 **1386**

**Exact Quantum Dynamical Solutions for Oscillator-Like Systems.**—M. Kolsrud. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 1186–1188.)

534.01 : 621.373 **1387**

**Subharmonic and Superharmonic Oscillations of a Bilinear Vibrating System.**—C. P. Atkinson & L. O. Heflinger. (*J. Franklin Inst.*, Sept. 1956, Vol. 262, No. 3, pp. 185–190.) Response curves of a bilinear vibrating system obtained with an electronic analogue system are presented. The existence of superharmonic and subharmonic components is shown, and their relation to the natural frequency range of the free vibrations is discussed. Numerical values of the circuit parameters of the analogue system are given in an appendix.

535.23 : 535.36 **1388**

**Radiative Transfer with Distributed Sources.**—R. G. Giovanelli & J. T. Jefferies. (*Proc. phys. Soc.*, 1st Nov. 1956, Vol. 69, No. 443B, pp. 1077–1084.) Expressions are derived for the total intensity of the diffuse radiation in composite media.

536.758 **1389**

**Calculation of Entropy for some Special Probability Distributions.**—M. M. Bakhmet'ev. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 613–622.) Probability distributions which can be approximately expressed by geometrical progressions are discussed.

537.2 **1390**

**Generalization of Coulomb's Fundamental Law.**—B. Konorski. (*Arch. Elektrotech.*, 20th Sept. 1956, Vol. 42, No. 7, pp. 381–397.) Comprehensive analysis is presented for electrostatic systems comprising two spheres.

537.523 : 621.314.6 **1391**

**Studies of Rectification in a Gas (Nitrogen) Discharge between Coaxial Cylindrical Electrodes : Part 1—Theory of Rectification in A.C. Silent Discharges. Part 2—Rectification in Semiozonizers.**—V. L. Talekar. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 205–238.) An equation is developed connecting the rectification and the applied potential in discharge tubes of GM-counter type. An expression is derived for the limiting frequency below which the theory should be valid. An experimental investigation at 50 and 500 c/s is reported to determine the effects of pressure, interelectrode distance, etc., on rectification in semiozonizers or Maze-type counters. Results are in agreement with theory.

537.525.3 **1392**

**Investigation of Photoelectrically Effective U.V. Radiation from a Corona Discharge in $H_2$ and $O_2$.**—W. Bemerl & H. Fetz. (*Z. angew. Phys.*, Sept. 1956, Vol. 8, No. 9, pp. 424–429.)

537.533 **1393**

**Diffraction and Interference Fringes in Electron Optics : Fresnel Diffraction, Young's Apertures and Fresnel's Biprism.**—J. Faget & C. Fert: L. de Broglie. (*C. R. Acad. Sci., Paris*, 17th Dec. 1956, Vol. 243, No. 25, pp. 2028–2029.) Experiments were made using circular or linear sources and a magnetic lens interposed in the path of the beam between the diffracting object and the screen; results are reproduced photographically. The appended note by de Broglie emphasizes the importance of the work, which shows that the wave associated with the electron constitutes a long coherent wave-train.

537.533 : 535.215 **1394**

**Examination of Metals Subjected to Mechanical Constraint using the Photoemission Microscope.**—R. Goutte, C. Guillaud & R. Arnal. (*C. R. Acad. Sci., Paris*, 17th Dec. 1956, Vol. 243, No. 25, pp. 2026–2028.) An investigation was made of the photoemission from Au, Ag and Pd strips with and without applied tension. The surfaces were illuminated obliquely by ultraviolet radiation and a magnification of about 30 was obtained on the luminescent screen. The emission is estimated to increase by about 10% up to rupture point.

537.533 : 537.56 **1395**

**Effective Cross-Sections of Neutral Hydrogen, Helium and Argon Atoms for Electron Collisions.**—H. W. Drawin. (*Z. Phys.*, 21st Sept. 1956, Vol. 146, No. 3, pp. 295–313.)

537.533 : 621.38.032.21 **1396**

**Material** [presented] **at the All-Union Conference on Cathode Electronics (Kiev, 25th-29th November 1955).**—(*Bull. Acad. Sci. U.R.S.S., sér. phys.*, Sept. 1956, Vol. 20, No. 9, pp. 975–1076. In Russian.) Digests of 10 papers and full texts of the following are presented (see also 80 of 1957) :

Some Results and Problems in the Field of Cathode Electronics.—N. D. Morgulis (pp. 977–992).

Secondary-Electron Emission (Position and Prospects).—L. N. Dobretsov (pp. 994–1007).

Secondary-Electron Emission from Dielectrics and Metals.—A. R. Shulman (pp. 1008–1022).

Some Anomalies of the Secondary-Electron Emission Characteristics of Magnesium Alloys.—V. N. Lepeshinskaya (pp. 1025–1028).

Secondary-Electron Emission of Nickel-Based Alloys.—B. S. Kul'varskaya (pp. 1029–1037).

Influence of Electron Bombardment on Photoelectron Emission of Complex Photocathodes.—L. N. Bykhovskaya (pp. 1052–1064).

Influence of Adsorbed Films of Barium Atoms and Barium Oxide Polar Molecules on the Electron Work Function of Tungsten, Gold and Germanium.—V. M. Gavrilyuk (pp. 1071–1075).

537.533.74 **1397**

**Analytical Representation of Hartree Potentials and Electron Scattering.**—W. J. Byatt. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1298–1300.) Gives analytical fits to the Hartree curves for 19 neutral atoms.

537.533.8 : 535.215 **1398**

**The Correlation between Secondary Emission and Photoelectric Emission in Low-Pressure Discharges.**—W. Kluge & A. Schulz. (*Z. Phys.*, 21st Sept. 1956, Vol. 146, No. 3, pp. 314–319.) Experiments on cathodes with caesium oxide or caesium antimonide coatings are reported; the results indicate that the same emission centres are responsible for secondary electrons and photoelectrons.

537.56 : 538.6 : 523.752 **1399**

**Simulation of Solar Prominence in the Laboratory.**—Bostick. (See 1419.)

537.562 : 538.6 **1400**

**Controlled Fusion Research—an Application of the Physics of High-Temperature Plasmas.**—R. F. Post. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 134–160; *Rev. mod. Phys.*, July 1956, Vol. 28, No. 3, pp. 338–362.) A review of the implications and the physical conditions required for the generation of power from controlled fusion reactions. It is suggested that the fusion fuel may exist in the form of a plasma confined by, say, a magnetic field, and the electrodynamic properties of such a system are investigated.

538.114 **1401**

**Ferromagnetic Sphere in a Strong Field.**—B. M. Fradkin. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 1048–1059.) Magnetic induction in the sphere, remagnetization of a previously magnetized sphere and the magnetic moment of the sphere are investigated, taking account of the demagnetizing effect of the surface. The hysteresis loops are approximated by rectangles.

538.3 **1402**

**New Approach to the Quantum Theory of the Electron.**—H. C. Corben. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 1179–1185.) A theoretical treatment of quantized fields avoiding expansion in plane waves, relates free-electron theory to Maxwell's equations, the Dirac neutrino equation and motion in an e.m. field.

538.561 : 537.534.8 **1403**

**Emission of Electromagnetic Radiation by the Impact of Positive Ions of Hydrogen on Metal Surfaces.**—R. M. Chaudhri, M. Y. Khan & A. L. Taseer. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1492–1493.) One photon is emitted from a nickel surface for about $10^5$ incident protons of energy 300–3 000 eV. The wavelength of the radiation lies between 3 300 and 4 000 Å.

538.561 : 539.185 : 539.154.3 **1404**

**Cherenkov Radiation of Neutral Particles with a Magnetic Moment.**—N. L. Balazs. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1220–1222.) The Cherenkov radiation caused by magnetic and electric dipoles is calculated. In the visible spectrum the energy loss per unit path per unit frequency range for a neutron is $10^{-15}$ that for an electron.

538.566 **1405**

**Exterior Electromagnetic Boundary-Value Problems for Spheres and Cones.**—L. L. Bailin & S. Silver. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 5–16.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 715.

538.566 **1406**

**Fields in Imperfect Electromagnetic Anechoic Chambers.**—R. F. Kolar. (*RCA Rev.*, Sept. 1956, Vol. 17, No. 3, pp. 393–409.) A method is presented for predicting the performance of anechoic chambers from transmission-line measurements on small samples of the absorbent material used for the walls. The calculated results are supported by measurements made in front of a wall 12 ft square.

538.566 : 535.43]+534.26 **1407**

**High-Frequency Scattering.**—T. T. Wu. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1201–1212.) Scattering by a circular cylinder and by a sphere is treated by considering the creeping waves on the universal covering space. This enables the total scattering cross-section of the obstacle to be found; but the method can be extended to give additional results, such as the current distribution on the obstacle.

538.566 : 535.43 **1408**

**Approximation Method for Short Wavelength or High-Energy Scattering.**—L. I. Schiff. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1481–1485.) "The approximation method developed in a recent paper [*ibid.*, 15th July 1956, Vol. 103, No. 2, pp. 443–453] is extended to the scattering theory of Maxwell's equations and of the Schrödinger equation with spin-orbit interaction."

538.566 : 535.43 **1409**

**Back-Scattering for Arbitrary Angles of Incidence of a Plane Electromagnetic Wave on a Perfectly Conducting Spheroid with Small Eccentricity.**—Y. Mushiake. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1549–1556.) The scattering of a plane e.m. wave by a perfectly conducting spheroid with small eccentricity is treated by expanding the scattered field in a series of spherical vector wave functions. An expression for the first-order solution of the back-scattered field is obtained for arbitrary angles of incidence of a plane wave. The numerical values of echo areas computed from the first-order expression are shown for various cases and rough experimental results are discussed.

538.612 **1410**

**A Theory of Magnetic Double Refraction.**—A. D. Buckingham & J. A. Pople. (*Proc. phys. Soc.*, 1st Nov. 1956, Vol. 69, No. 443B, pp. 1133–1138.) A theory of the birefringence produced in a substance perpendicular to a strong magnetic field.

538.63 **1411**

**Theory of Galvanomagnetic Phenomena in Metals.**—I. M. Lifshits, M. Ya. Azbel' & M. I. Kaganov. (*Zh. eksp. teor. Fiz.*, July 1956, Vol. 31, No. 1(7), pp. 63–79.) A theory for metals in strong magnetic fields is presented; no special assumptions regarding the law of conduction, electron dispersion or the form of the collision integral are made.

## GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 : 621.396.677 **1412**

**Two-Dimensional Aerial Smoothing in Radio Astronomy.**—R. N. Bracewell. (*Aust. J. Phys.*, Sept. 1956, Vol. 9, No. 3, pp. 297–314.). Theory developed previously for the one-dimensional case [1638 of 1955 (Bracewell & Roberts)] is generalized. The basic processes of interpolating and filtering data are discussed. Details of technique for the restoration of smoothed data are presented. The flux density of a source is shown to be given exactly by summing one in four of the isolated values observed at the 'peculiar intervals' associated with the Fourier components of the spatial temperature distribution.

523.165 **1413**

**Effects of a Ring Current on Cosmic Radiation. Impact Zones.**—E. C. Ray. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1459–1462.) An investigation of the effects of a ring current on the '0900' (geomagnetic local time) impact zone of flare-associated increases in cosmic-ray intensity has been carried out for 55 trajectories. For particles of rigidities 2, 6, and 10 kMV travelling vertically towards the earth, the longitude of impact may be shifted by ring currents by up to half an hour.

523.165 : 523.75 **1414**

**Time Variations of Cosmic-Ray Intensity.**—R. R. Brown. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 639–646.) "The time variations of cosmic-ray intensity associated with a large solar flare and a period of strong solar activity are reported. A possible interpretation of these semi-regular time variations in terms of matter emanating from the sun is considered."

523.5 : 621.396.11 **1415**

**Phase Changes and Resonance Effects in Radio Echoes from Meteor Trails.**—J. S. Greenhow & E. L. Neufeld. (*Proc. phys. Soc.*, 1st Nov. 1956, Vol. 69, No. 443B, pp. 1069–1076, plate.) A discussion of the resonance effects which occur when the ionization column has diffused to such a diameter that the dielectric constant at the centre reaches $-1 \cdot 4$. The measurements are in good agreement with the phase changes predicted by the theory of scattering of radio waves from meteor trails.

523.5 : 621.396.11 : 551.510.535 **1416**

**Long-Range Meteoric Echoes via F-Layer Reflections.**—J. T. de Bettencourt & W. A. Whitcraft, Jr. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 72–76.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 716.

523.5 : 621.396.11.029.62 : 551.510.535 **1417**

**A Theory of Long-Duration Meteor-Echoes Based on Atmospheric Turbulence with Experimental Confirmation.**—H. G. Booker & R. Cohen. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 707–733.) The theory assumes that a meteor trail is rendered rough by the action of small eddies in the atmosphere. If loss of electrons from the trail is neglected, the field strength of a long-duration meteor echo in its decay phase should be inversely proportional to the cube of time subsequent to formation of the trail. This is verified experimentally in the early part of the decay. Measurements of the frequency dependence of the echo are related to the results of v.h.f. ionospheric scatter transmission. An important part of the phenomenon of radio echoes from meteor trails has itself to be interpreted in terms of incoherent scattering due to atmospheric turbulence.

523.72.029.6 : 523.75 **1418**

**On the Association of Solar Radio Emission and Solar Prominences.**—J. P. Wild & H. Zirin. (*Aust. J. Phys.*, Sept. 1956, Vol. 9, No. 3, pp. 315–323.) Cinematograms of prominences made during the years 1949–1955 have been compared with records of solar radiation at 167 Mc/s. No close correlation was found between limb events and variations of r.f. radiation, but some eruptions were found to be associated with simultaneous radio bursts. Three such cases are discussed in detail. A study of the limb passages of large sunspots indicated that spot groups showing looped prominences and downward streaming from the corona tended to produce radio noise storms. This result is ascribed to the fact that the seat of such storms must lie in the corona and in the presence of strong ordered magnetic fields.

523.752 : 537.56 : 538.6 **1419**

**Simulation of Solar Prominence in the Laboratory.**—W. H. Bostick. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 1191–1193.) Two plasma sources having an electric potential difference were located at the poles of a horseshoe magnet at a pressure $\approx 30\,\mu$ Hg. A plasma glow is formed at each source with streamers following the magnetic field between sources. The streamers resemble the curved solar prominences between two sunspots of opposite magnetic characteristics as in Alfven's theory (*Cosmical Electrodynamics*, 1950, p. 88), but with current flowing along the prominence. The theory of streamer formation is mentioned briefly.

550.383 **1420**

**Measurements at Sea of the Vertical Gradient of the Main Geomagnetic Field during the *Galathea* Expedition.**—J. Esbersen, P. Andreasen, J. Egedal & J. Olsen. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 593–624.) Three relative self-recording magnetometers were lowered to depths of 500 to 5 000 m to test the fundamental theory of Blackett for the main geomagnetic field. Trial results were against the theory—in accordance with gradient measurements in mines.

550.384 **1421**

**The Lunar-Diurnal Magnetic Variation and its Relation to the Solar-Diurnal Variation.**—J. Egedal. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 748–749.) An abnormally large lunar-diurnal variation of the vertical magnetic component was found to exist at Amberley (New Zealand) during the night hours.

550.385 **1422**

**On the Geomagnetic Storm Effect.**—E. N. Parker. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 625–637.) The high electrical conductivity of the region around the earth invalidates customary models for producing storm fields with impressed current systems. The main phase of a storm implies upward displacement of magnetic lines of force. Two models are developed quantitatively, based on heating of the upper atmosphere and on gravitational capture of interplanetary hydrogen.

550.385 **1423**

**Notes on the Morphology of SC** [sudden commencements].—T. Oguti. (*Rep. Ionosphere Res. Japan*, June 1956, Vol. 10, No. 2, pp. 81–90.)

550.385 : 551.510.535 **1424**

**Studies on P.S.C.** [polar sudden commencements].—Y. Kato & T. Watanabe. (*Rep. Ionosphere Res. Japan*, June 1956, Vol. 10, No. 2, pp. 69–79. Discussion, pp. 79–80.) "Facts obtained from observation of p.s.c.

suggest that its origin is outside the ionosphere. Particularly, the daily behaviour of the horizontal perturbing vector of p.s.c. can be explained by the shielding effect of the nonuniform ionosphere."

550.389 **1425**

**A Method of Interpolating Magnetic Data under Conditions of Mutual Consistency.**—A. J. Zmuda & J. F. McClay. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 667–672.) Rigorous relations connecting surface variations of different elements are introduced into interpolation formulae needed with discrete data, so that resulting charts are mutually consistent.

551.510.53 : 551.593 **1426**

**Distribution in the Upper Atmosphere of Sodium Atoms Excited by Sunlight.**—T. M. Donahue, R. Resnick & V. R. Stull. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 873–879.) Theoretical calculations of the density of sodium atoms in the $^2P_{3/2}$ state at 70–100 km, taking into account the effect of resonance absorption on direct and earth-reflected radiation.

551.510.53 : 551.593 **1427**

**A Calculation of the Sodium Dayglow Intensity.**—T. M. Donahue. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 663–666.) Calculation of the resonance scattering from a sodium layer between 70 and 100 km is based on the density of sodium excited by the sun.

551.510.53 : 551.593 **1428**

**On the Remarks of D. R. Bates and B. L. Moiseiwitsch (1956) regarding the $O_3$ and [excited] $O_1$ Hypotheses of the Excitation of the OH Airglow.**—V. I. Krassovsky. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, pp. 49–51.) Comment on paper noted in 3042 of 1956.

551.510.535 **1429**

**A Dynamo Theory of the Ionosphere.**—M. Hirono & T. Kitamura. (*J. Geomag. Geoelect.*, March 1956, Vol. 8, No. 1, pp. 9–23.) The differential equations of the dynamo theory are solved by numerical integration, taking account of the daily variation of the anisotropic conductivity. It is shown that the observed magnitude of the winds in the E region is consistent with the requirements of the dynamo theory and that at night some part of the electrons in the lower F region will descend into the E region in middle latitudes.

551.510.535 **1430**

**Observation at Akita of Ionospheric Drift.**—Y. Ogata. (*Rep. Ionosphere Res. Japan*, June 1956, Vol. 10, No. 2, pp. 91–92.)

551.510.535 **1431**

**Ionosphere Electron-Density Measurements with the Navy Aerobee-HI Rocket.**—J. E. Jackson, J. A. Kane & J. C. Seddon. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 749–751.) A description of electron-density measurements made on 29th June 1956, from the E region up to the lower $F_2$ region, above White Sands, New Mexico.

551.510.535 **1432**

**Studies of the E layer of the Ionosphere: Part 1—Some Relevant Theoretical Relationships.**—E. V. Appleton & A. J. Lyon. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, pp. 1–11.) The Chapman continuity equation refers to electron density at constant height whereas measurements refer to the peak of a layer and require some modification of the equation (see *The Physics of the Ionosphere*, 1955, p. 20). The theory is now extended to include changes in Chapman's basic assumptions. The following have been investigated: (*a*) vertical gradients in the scale height of the ionized gas and the effective recombination coefficient, (*b*) loss of electrons by attachment, (*c*) the introduction of a vertical transport term.

551.510.535 **1433**

**Ionospheric Reflections from Heights Below the E Region.**—J. B. Gregory. (*Aust. J. Phys.*, Sept. 1956, Vol. 9, No. 3, pp. 324–342.) Observations were made during the period February–July 1955, using high-sensitivity pulse equipment operating at 1·75 Mc/s and capable of detecting low ionospheric regions with voltage reflection coefficients exceeding $4 \times 10^{-6}$. Day-time reflections were received from several levels between 95 and 53 km, and continuous reflections from a region with a lower boundary at about 85 km. The frequency of occurrence and the strength of these lower-level reflections increases markedly during winter. Correlation between decreases in strength of E-region reflections and increases in strength of lower-level reflections is demonstrated from records of high absorption conditions during winter days.

551.510.535 **1434**

**Cusp-Type Anomalies in Variable-Frequency Ionospheric Records.**—G. H. Munro & L. H. Heisler. (*Aust. J. Phys.*, Sept. 1956, Vol. 9, No. 3, pp. 343–358.) "Anomalous cusps which frequently appear at the high-frequency end of ionosonde records of the $F_2$ region are explained as the result of modification of the ion distribution during the passage of typical travelling disturbances. They indicate the presence, not of vertical stratification but of horizontal gradients of ionization causing oblique reflection. It is suggested that other anomalous cusps are of similar origin. Anomalies on records of the $F_1$ region are also shown to be caused by travelling disturbances."

551.510.535 **1435**

**Divergence of Radio Rays in the Ionosphere.**—G. H. Munro & L. H. Heisler. (*Aust. J. Phys.*, Sept. 1956, Vol. 9, No. 3, pp. 359–372.) Travelling disturbances in the ionosphere are investigated by examining the differences between the traces for the ordinary and extraordinary rays on *h'f* and *h't* records. Results of numerous observations confirm the theoretical prediction of the divergence of the two rays in the F region at Sydney, indicating an actual separation of the order of 30 km near the maximum of ionization. They also indicate that a travelling disturbance always has an apparent vertical component of progression, assumed to result from a forward tilt in the front of the disturbance.

551.510.535 : 523.51 **1436**

**Meteorite Impacts to Altitude of 103 Kilometres.**—O. E. Berg & L. H. Meredith. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 751–754.) A new type of meteorite-impact detector is described. Above 85 km one impact per cm² per 57 sec was recorded.

551.510.535 : 523.78 **1437**

**Drift Measurement of the E Layer during the Solar Eclipse 30 June 1954.**—L. Harang & K. Pederson. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, pp. 44–45.) An apparent change in direction was due to the changeover from normal E to $E_s$ reflections at the maximum phase of the eclipse.

551.510.535 : 538.566 **1438**

**The Scattering of Electromagnetic Waves by Plasma Oscillations.**—Hokkyo. (See 1565.)

551.510.535 : 550.385 **1439**

**Disturbances in the $F_2$ Region of the Ionosphere associated with Geomagnetic Storms.**—T. Sato. (*Rep. Ionosphere Res. Japan*, June 1956, Vol. 10, No. 2, pp. 35–48.) The extent to which these variations in the $F_2$ region can be accounted for as resulting from vertical drift of electrons is examined in relation to geomagnetic observations at Watheroo.

551.510.535 : 550.385 **1440**

**Daily Variations of the Electrical Conductivity of the Upper Atmosphere as deduced from the Daily Variations of Geomagnetism: Part 2—Non-equatorial Regions.**—H. Maeda. (*Rep. Ionosphere Res. Japan*, June 1956, Vol. 10, No. 2, pp. 49–68.) Results of previous studies are interpreted from the point of view of the anisotropy of ionospheric conductivity. A formula for the world distribution of ionospheric conductivity is proposed. Part 1: 1719 of 1956.

551.510.535 : 621.396.11 **1441**

**Turbulence in the Ionosphere with Applications to Meteor Trails, Radio-Star Scintillation, Auroral Radar Echoes, and Other Phenomena.**—H. G. Booker. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 673–705.) Irregularities in electron density responsible for incoherent scattering of radio waves in the ionosphere are discussed, assuming isotropic turbulence in the neutral molecules, with allowance for the effect of the earth's magnetic field on associated irregularities in the density of the charged particles. The atmospheric model used is based on rocket observations. Tentative formulae deduced for large and small eddies, depend on a quantity $w$, which is the rate of supply of turbulence energy to the large eddies and also the rate of removal of turbulence energy from the small eddies, measured per unit mass of atmosphere. Resulting values of $w$ are higher in the ionosphere than the troposphere but are shown to be possible and reasonable. Among other applications considered is the possibility of radio communication via incoherent scattering in the F region. 43 references.

551.510.535 : 621.396.11 **1442**

**The Absorption of Short Radio Waves in the Ionosphere.**—J. D. Whitehead. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, pp. 12–19.) Measured reflection coefficients ($\rho$) in England for frequencies ($f$) in the range 2–4 Mc/s can be represented by $-\log \rho = C + B/(f+f_L)^2$. $C$ varies with solar zenith angle but $B$ does not whereas $B$ depends on solar activity while $C$ does not. $B$ is very variable and controls the abnormally high winter absorption. Since $C$ is not zero, appreciable absorption must occur outside the non-deviating region.

551.510.535 : 621.396.11 **1443**

**The Nondeviative Absorption of High-Frequency Radio Waves in Auroral Latitudes.**—S. Chapman & C. G. Little. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, pp. 20–31.) This is higher and more variable than absorption at lower latitudes. It is also much less patchy than auroral forms would indicate if auroral particles were directly responsible for it. It is suggested that slow-speed auroral particles cause direct ionization down to about 80–90 km and that they may also generate X rays which penetrate down to 80 or even 40 km to cause ionization and nondeviative absorption at high latitudes. The mechanism is investigated and tentative tables of data are given.

551.510.535 : 621.396.11 **1444**

**Some Measurements of Ionospheric Absorption at Delhi.**—S. N. Mitra & S. C. Mazumdar. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, pp. 32–43.) "The results of some measurements of ionospheric absorption taken at Delhi during June 1954 to December 1955 are described. The measurements were carried out on 5 and 2·5 Mc/s. A brief description of the experimental set-up is included in the paper. The analysis of data shows that the diurnal variation of absorption gives $|\log \rho| \propto (\cos \chi)^{0\cdot 62}$. The value of $\alpha\mathcal{N}$ has been indicated from the observed value of the 'relaxation time'. The absorption at night has been observed to be considerable at our latitude. It has been postulated from the low value of the exponent in the diurnal variation factor, the magnitude of the relaxation time, and from direct measurements of absorption on $E_s$ and F echoes, that the main absorption is probably taking place in the D region."

551.510.535 : 621.396.11 **1445**

**Simultaneous Signal-Strength Measurements on Continuous and Pulsed Radio-Wave Transmissions Reflected from the Ionosphere.**—Rao & Ramana. (See 1568.)

551.510.535 : 621.396.11 : 523.75 **1446**

**Ionospheric Absorption Observed on the 23rd February 1956 at Kjeller and Tromsö.**—F. Lied. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, p. 48.) Absorption was abnormally high during daylight.

551.510.535 "1956" : 621.396.11 **1447**

**Ionosphere Review, 1956.**—T. W. Bennington. (*Wireless World*, March 1957, Vol. 63, No. 3, pp. 145–146.) The rapid increase in solar activity during 1956 is related to corresponding changes in ionospheric critical frequencies and radio communications.

551.594.21 **1448**

**Initial Electrification Processes in Thunderstorms.**—R. Gunn. (*J. Met.*, Feb. 1956, Vol. 13, No. 1, pp. 21–29.) An analysis of thunderstorm electrification processes in clouds entirely above freezing temperature leads to a quantitatively correct explanation of the principal observed features of the earliest phases of electrification.

551.594.5 **1449**

**The Aurora in Middle and Low Latitudes.**—S. Chapman. (*Nature, Lond.*, 5th Jan. 1957, Vol. 179, No. 4549, pp. 7–11.) A brief review of reports on the occurrence of the aurora in the lower latitudes with a note on the I.G.Y. program of observations.

551.594.5 **1450**

**On the Energy Distribution of Secondary Auroral Electrons.**—D. R. Bates, M. R. C. McDowell & A. Omholt. (*J. atmos. terr. Phys.*, Jan. 1957, Vol. 10, No. 1, pp. 51–53.) The result of calculations on the impact of protons on neon.

551.594.6 **1451**

**The Recording of the Mean Level of Atmospherics at Kilometre and Myriametre Wavelengths.**—F. Carbenay. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1904–1906.) Records obtained at Bagneux on a wavelength of 11 km are reproduced. Comparison of records of mean level and of successive peaks, obtained with receivers of different bandwidths, indicates that the atmospherics have the properties of short pulses, defining the operating threshold of the receiver.

551.594.6 : 621.396.11.029.4 **1452**

**Low-Frequency Electromagnetic Radiation 10-900 Cycles per Second.**—J. Aarons. (*J. geophys. Res.*, Dec. 1956, Vol. 61, No. 4, pp. 647–661.) The spectrum of atmospherics received on a site remote from man-made interference was analysed with a narrow-band (2–6-c/s) amplifier. Diurnal patterns show a maximum around local midnight, with a peak in the band between 40 and 200 c/s. Radiation at the gyrofrequency of the sodium ion may have given an increase in narrow-band energy near 33 c/s, observed for several hours. A hypothesis for the origin of the 'dawn chorus' is presented.

551.594.6 : 621.396.11.029.4 **1453**

**Extremely-Low-Frequency Electromagnetic Waves: Part 1—Reception from Lightning. Part 2—Propagation Properties.**—L. Liebermann. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1473–1483.) The received fields, at frequencies below 500 c/s and distances of several thousand kilometres were observed by recording waveforms of atmospherics. Two main types of waveform were found. Diurnal variations in propagation were small. Waveforms of atmospherics were examined in terms of waveguide theory. Only one of the two main types considered could be explained by using a simple model for the earth-ionosphere waveguide. The conductivity of the ionosphere and variations in absorption were deduced.

## LOCATION AND AIDS TO NAVIGATION

621.396.932 **1454**

**The Analysis of Radio Bearings in the Presence of Rotating Fields.**—H. Gabler, G. Gresky & M. Wächtler. (*Arch. elekt. Übertragung*, Sept. 1956, Vol. 10, No. 9, pp. 383–391.) The influence of out-of-phase reflections on the indication of a c.r.o. direction finder is similar to the effects of in-phase reflections causing the main bearing error. Experiments on board the research ship 'Gauss' confirm the theoretical results.

621.396.932 **1455**

**A New Ship's Direction-Finder with Visual Indication : Telegon III.**—A. Troost. (*Telefunken Ztg*, June 1956, Vol. 29, No. 112, pp. 109–116. English summary, pp. 134–135.) The system described uses a new type of 'magic eye' indicator, which shows two luminous lines of equal length for the minimum-signal setting of the goniometer. Aural balance indication is also available. For description of the original Telegon, see 139 of 1952 (Runge el al).

621.396.96 **1456**

**Radar Back-Scattering Cross-Sections for Nonspherical Targets.**—P. N. Mathur & E. A. Mueller. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 51–53.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 715.

621.396.96 **1457**

**Radar Terrain Return at Near-Vertical Incidence.**—R. K. Moore & C. S. Williams, Jr. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 228–238.) A mathematical analysis of the back-scatter of radiation pulses from the ground, with particular reference to the deformation of the pulses. Results are applicable to radio altimeters.

621.396.96.029.6 : 551.578 **1458**

**The Effect of 'Hydrometeors' on Centimetre Waves.**—B. Abild. (*Elektronische Rundschau*, Sept. 1956, Vol. 10, No. 9, pp. 249–252.) The term 'hydrometeors' is used to indicate regions of precipitation in the atmosphere. Reflection and attenuation effects occurring at these regions are discussed with reference to their dependence on wavelength. For observations on clouds, the optimum operating wavelength for radar equipment is around 5 mm. Technical data are tabulated for British and U.S. commercially available 3-cm-λ weather radar equipment, and an outline is given of investigations in Germany.

## MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 : 546.23 : 537.533.9 **1459**

**Volume Generated Currents and Secondary Effects in Amorphous Selenium Films.**—W. E. Spear. (*Proc. phys. Soc.*, 1st Nov. 1956, Vol. 69, No. 443B, pp. 1139–1147.) The films, between 3 and 9 $\mu$ thick, were subjected to electron bombardment, and the resulting current studied in relation to the average depth of penetration of the bombarding beam.

535.215 : 546.482.21 **1460**

**Photoelectron Emission from CdS.**—Yu.A. Shuba. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 1129–1135.) The object of this experimental investigation was to obtain data on the energy structure and the mechanism of the interaction between light and electrons in CdS. The results give support to the concept of the exciton mechanism of the interaction and indicate that the photoelectric constants of the material may vary during photoelectron emission.

535.215 : 547.9 **1461**

**Photo- and Semi-conduction of Aromatic Hydrocarbon Crystals.**—L. E. Lyons & G. C. Morris. (*Proc. phys. Soc.*, 1st Nov. 1956, Vol. 69, No. 443B, pp. 1162–1164.) A discussion of the spectral dependence of the photocurrent in a series of compounds not previously known to be photoconductors.

535.37 **1462**

**The Luminescence of Inorganic Crystalline Substances.**—(*J. Phys. Radium*, Aug./Sept. 1956, Vol. 17, Nos. 8/9, pp. 609–832.) This issue is devoted to papers presented and discussed at an international conference in Paris in May 1956. Short abstracts in English are given. Recent experimental work on the effects of chemical composition and external influences is analysed to illustrate or modify various theories regarding the mechanism of luminescence. The following papers are included:

The Luminescence of Electronically Active Solids.—H. W. Leverenz (pp. 612–615).

The Photoluminescence of Calcium Metaantimoniate Activated with Bismuth.—R. Bernard & J. Janin (pp. 616–619).

Some Observations on Energy Transfer in Halophosphates.—J. L. Ouweltjes (pp. 641–644).

The Intensification Effect due to Metals of the Iron Group and the Height of the Fermi Level in Luminescent Sulphides.—N. Arpiarian (pp. 674–678).

The Luminescence Efficiency of Crystal Phosphors.—V. V. Antonov-Romanovsky (pp. 694–698).

Theoretical and Experimental Investigations of some Properties of Electron Traps and Luminescent Centres in Sulphides.—D. Curie (pp. 699–704).

Infrared Emission from Germanium.—P. Aigrain & C. Benoit à la Guillaume (pp. 709–711).

The Effect of the Field and Temperature on the Brightness Waveforms in Electroluminescence.—J. Mattler (pp. 725–730).

The Spectral Distribution of the Electroenhancement Effect in CdS-ZnS Mixtures Activated by Manganese and Silver.—G. Destriau (pp. 734–736).

The Intensification and Quenching of Luminescence in Manganese-Activated Zinc Sulphides by Alternating Electric Fields.—H. Gobrecht & H. E. Gumlich (pp. 754–757).

The Mechanism of Electroluminescence.—R. Goffaux (pp. 763–768).

Electroluminescent Capacitors in Oscillatory Circuits.—A. Luyckx, M. Weiler & A. J. Stokkink (pp. 769–772).

Electrical and Optical Properties of some Semiconductors: Zinc Oxide, Zinc Sulphide, Selenium.—R. Freymann, Y. Balcou, M. L. Blanchard, H. Corneteau, M. Freymann, B. Hagène, M. Hagène, M. LePage, J. Meinnel & R. Rohmer (pp. 806–812).

535.37 **1463**

**Solid-State Luminescence Theory and Oscillator Strengths in KCl : Tl.**—R. S. Knox & D. L. Dexter. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1245–1252.) Comparison of experimental and theoretical results indicates defects in the existing quantitative theory.

535.37 **1464**

**Cathodoluminescence Spectra of Alkali Halides.**—B. D. Saksena & L. M. Pant. (*Z. Phys.*, 14th Sept. 1956, Vol. 146, No. 2, pp. 205–216. In English.)

535.37 : 546.472.21 **1465**

**Luminescence in ZnS : Cu,Cl Single Crystals.**—T. B. Tomlinson. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 293–300.) The impurity responsible for the green and blue bands in 'spectrographically pure' single crystals of ZnS is proved to be Cu, in the presence of Cl.

535.37 : 546.472.21 **1466**

**Flashes of Luminescence in Zinc-Sulphide Phosphors and the Two-Stage Excitation Mechanism.**—N. A. Tolstoi. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1956, Vol. 111, No. 3, pp. 582–584. In Russian.)

535.376 **1467**

**Electroluminescence.**—D. W. G. Ballentyne. (*Wireless World*, March 1957, Vol. 63, No. 3, pp. 128–132.) Sustained emission of light can be obtained from an unexcited phosphor by suspending it in the dielectric of a capacitor to which an alternating field is applied. Recent progress is described and possible applications to illumination, television, and storage of binary-code numerical data are discussed briefly. For full paper, see *Marconi Rev.*, 4th Quarter 1956, Vol. 19, No. 123, pp. 160–175.

537.226/.228.1 : 546.431.824-31 **1468**

**The Effect of the Polarization Conditions on the Piezoelectric Properties of Barium Titanate.**—S. V. Bogdanov, B. M. Vul & R. Ya. Razbash. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 958–962.) Polycrystalline $BaTiO_3$ elements must be polarized in a strong d.c. field. With specimens of appreciable thickness (15–25 mm), fields of the order of 30–50 kV/cm have to be used, with the attendant inconvenience and possible damage to the specimen. Lower polarizing voltages can be used if the temperature at which polarization is carried out is raised; the dielectric strength is not affected [*Zh. eksp. teor. Fiz.*, May 1950, Vol. 20, No. 5, pp. 465–470 (Vul et al.)]. This has been confirmed experimentally; but even at temperatures approaching the Curie point, the polarizing voltage should not be below 5 kV/cm.

537.226/.227 **1469**

**Dynamic Theory of the Ion Lattices of Ferroelectric Crystals in Static Conditions.**—V. Kh. Kozlovski. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 963–976.)

537.226/.227 **1470**

**Thiourea, a New Ferroelectric.**—A. L. Solomon. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, p. 1191.) Crystals are orthorhombic at room temperature. With electrodes on (010) faces, a pronounced dielectric anomaly is found at −104·8°C. The coercive field is less than 1 000 V/cm at 60 c/s and −110°C.

537.226/.227 : 546.431.824-31 **1471**

**Discontinuous Field-Induced Transitions in Barium Titanate Above the Curie Point.**—M. E. Drougard. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1559–1560.)

537.226/.227 : 546.431.824-31 **1472**

**Dielectric Losses and Electrical Conductivity of Barium Titanate Ceramics Cooled Below the Phase Transition at 120°C.**—J. Meisinger. (*Z. angew. Phys.*, Sept. 1956, Vol. 8, No. 9, pp. 422–424.) Measurements were made on specimens of pure $BaTiO_3$ and on specimens including $CrO_3$ or $WO_3$ cooled rapidly from 500°C to room temperature. Losses were observed to be high immediately after the cooling process, but decreased exponentially with time, the decrease being more rapid with higher storage temperatures up to 80°C.

537.226 **1473**

**Conference on the Electrical and Physico-chemical Properties of Solid Dielectrics** [Tomsk, September 1955].—S. S. Gutin. (*Uspekhi fiz. Nauk*, Aug. 1956, Vol. 59, No. 4, pp. 755–763.) Report on over 30 papers presented at the conference.

537.311.31 : 621.396.822 **1474**

**Noise in Metallic Conductors.**—H. Bittel & K. Scheidhauer. (*Z. angew. Phys.*, Sept. 1956, Vol. 8, No. 9, pp. 417–422.) Current noise in metallic conductors due to imperfections in the crystalline structure is investigated. A material constant is introduced which is independent of the specimen geometry, and conditions are sought under which very low values of this constant can be determined. On this basis, noise measurements were made on various types of resistance wire over the frequency range 45 c/s–11·7 kc/s; no current noise was observed, though the sensitivity of the test arrangement was very high. Noise observed previously in commercial wire resistors [1891 of 1955 (Bittel & Storm)] is probably due to secondary effects rather than to any inherent property of the resistance material.

537.311.33 **1475**

**Theory of the Swept Intrinsic Structure.**—W. T. Read, Jr. (*Bell Syst. tech. J.*, Nov. 1956, Vol. 35, No. 6, pp. 1239–1284.) "The electric field and the hole and electron concentrations are found for reverse biased junctions in which one side is either intrinsic (*i*) or so weakly doped that the space charge of the carriers cannot be neglected. The analysis takes account of space charge, drift, diffusion and nonlinear recombination. A number of figures illustrate the penetration of the electric field into a *p-i-n* structure with increasing bias for various lengths of the *i* region. For the junction between a highly doped and a weakly doped region, the reverse current increases as the square root of the voltage at high voltages; and the space charge in the weakly doped region approaches a constant value that depends on the fixed charge and the intrinsic carrier concentration. The mathematics is greatly simplified by expressing the equations in terms of the electric field and the sum of the hole and electron densities."

537.311.33 **1476**

**Scattering of Electrons by Lattice Vibrations in Nonpolar Crystals.**—W. A. Harrison. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1281–1290.) A theoretical analysis gives an estimate of the relative importance of acoustical-mode and optical-mode scattering in monatomic nonmetals. The temperature dependence of mobility thus indicated is compared with experimental results on electrons and holes in Si and Ge.

537.311.33 **1477**

**A Graphical Method for Determining the Chemical Potential of Semiconductors.**—L. L. Korenblit & A. A. Shteinberg. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 927–937.) A method is proposed using a glass sheet illuminated from below. A transparent sheet ruled with millimetre squares is placed on the glass and also two tracings with 'universal' graphs. By appropriately displacing these sheets with respect to one another, the chemical potential and its temperature dependence are determined. This method has been used for investigating electrical and thermoelectric properties of semiconductors, and some results of these investigations are reported.

537.311.33 **1478**

**Rate Limitation at the Surface for Impurity Diffusion in Semiconductors.**—F. M. Smits & R. C. Miller. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1242–1245.) "When a rate limitation exists at the surface for impurity diffusion in semiconductors, the appropriate boundary condition is equivalent to the radiation boundary condition for the conductance of heat in solids. The intentional introduction of an additional external rate limitation allows the measurement of partition coefficients. Solutions to the diffusion equation are summarized and the resulting impurity distributions are discussed."

537.311.33 **1479**

**Lifetime Measurements of Excess Carriers in Semiconductors.**—N. J. Harrick. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1439–1442.) The carriers are created by illuminating one end of the semiconductor with visible light; their distribution is determined by absorption of infrared radiation. Provided the carrier concentration is not large the electric-field term may be neglected; hence the local diffusion length and carrier lifetime are directly related to the carrier distribution. The method is illustrated by measurements on Ge.

537.311.33 : 537.312.8/.9 **1480**

**Elastoresistance and Magnetoresistance in Multivalley Semiconductors with an Axis of Symmetry.**—R. W. Keyes. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 279–292.) "A multivalley model of the energy bands of a crystal with an axis of 3, 4 or 6 fold symmetry is described. The anisotropy in the properties of a single valley is expressed in terms of two second rank tensors: $\alpha$, the effective mass tensor, and $\beta$, a tensor which relates the energy of an electronic state to the elastic strain. Expressions for the fourth rank magnetoresistance and elastoresistance tensors in terms of $\alpha$ and $\beta$ are derived."

537.311.33 : 537.312.8 **1481**

**Longitudinal Magnetoresistance in the Quantum Limit.**—P. N. Argyres & E. N. Adams. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 900–908.) Theoretical considerations show that, contrary to usual Boltzmann theory, the magnetoresistance of a semiconductor at low temperatures in a very large magnetic field is field-dependent. Under lattice-scattering conditions magnetoresistance is always positive, but may become negative when impurity scattering occurs. Experimental evidence tends to confirm the theory.

537.311.33 : 537.32 **1482**

**Theory of Transport Effects in Semiconductors: Thermoelectricity.**—P. J. Price. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1223–1239.) The phenomenological theory of thermoelectric effects in a cubic or isotropic electronic conductor is developed, and the general formulae obtained are applied to a two-band semiconductor. The evaluation of data for mixed semiconductors is discussed and experimental results for Ge are analysed· The effects of a strong magnetic field and of strain are considered.

537.311.33 : 537.323 : 535.215.9 **1483**

**The Photo-thermoelectric Phenomenon in Semiconductors.**—L. J. van der Pauw & D. Polder. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 239–240.) Tauc's theory (*Czech. J. Phys.*, Dec. 1955, Vol. 5, No. 4, pp. 528–536) is extended to include the effect of temperature-dependence of the energy gap and of carrier mobilities on the photo-thermoelectric voltage.

537.311.33 : 537.323 : 546.811-17 **1484**

**Thermoelectric Power of Grey Tin.**—A. N. Goland & A. W. Ewald. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 948–953.) Results are given of measurements in the temperature range 77°–270° K, using pure samples (always *n*-type) and both *n*-type and *p*-type impurities. The temperature dependence of electron and hole mobility is discussed.

537.311.33 : 538.6 **1485**

**Faraday Effect in Semiconductors.**—M. I. Klinger & M. M. Chaban. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 938–940.) Most of the existing methods for determining the effective mass of current carriers are based on measurements of thermo-e.m.f., Hall constant, etc. These quantities are not strongly dependent on the effective mass; it is suggested that more accurate results are obtainable from a consideration of the Faraday effect.

537.311.33 : 538.63 **1486**

**Anisotropic Galvanomagnetic Effects in Semiconductors.**—J. R. Drabble & R. Wolfe. (*Proc. phys. Soc.*, 1st Nov. 1956, Vol. 69, No. 443B, pp. 1101–1108.) "The 'many-valley' theory of the galvanomagnetic effects in cubic semiconductors proposed by Abeles and Meiboom [147 of 1955] is extended to include semiconductors belonging to any crystal class. The theory is applied to the crystal class $\bar{3}$ m. Explicit expressions for the components of the conductivity, Hall conductivity and magnetoconductivity tensors are derived for a six-valley model in which the energy extrema lie on the reflection planes in **k**-space. These expressions are consistent with preliminary measurements on a single crystal of *n*-type bismuth telluride in which all the galvanomagnetic effects are anisotropic."

537.311.33 : 539 **1487**

**Interaction of Nonpolar Crystal Vibrations with Electric Fields.**—V. S. Mashkevich & K. B. Tolpygo. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1956, Vol. 111, No. 3, pp. 575–577. In Russian.) The interaction in homopolar-lattice diamond-type crystals is discussed theoretically. Experimental evidence of the interaction in Si and Ge was noted in 2030 of 1955 (Lax & Burstein).

537.311.33 : [546.28+546.289 **1488**

**Volatile Impurities in Silicon and Germanium.**—H. A. Papazian & S. P. Wolsky. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, p. 1561.) Mass-spectrograph studies show the presence of carbon in silicon and carbon and nitrogen in germanium.

537.311.33 : [546.28+546.289 **1489**

**Growth of Large-Diameter Silicon and Germanium Crystals.**—W. R. Runyan. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, p. 1562.) 6-in.-diameter Ge and 4-in.-diameter Si crystals have been grown.

537.311.33 : 546.28 **1490**

**Dislocation Etch Pits in Silicon Crystals.**—F. L. Vogel, Jr, & L. C. Lovell. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1413–1415.) Mercuric nitrate added to a modified CP-4 polish-etch solution increases the definition of the dislocation etch pits.

537.311.33 : 546.28 **1491**

**Diffusion of Aluminium in Single-Crystal Silicon.**—R. C. Miller & A. Savage. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1430–1432.) The diffusion was in an all-silicon system whereas in previous work a quartz phase was present. The values of diffusivity agree with those of Fuller and Ditzenberger (3095 of 1956), but the concentrations of Al in the Si are larger and in agreement with values calculated from the Al-Si solidus and the distribution coefficient of Al in Si at the Si melting point.

537.311.33 : 546.28 **1492**

**Properties of Silicon Doped with Manganese.**—R. O. Carlson. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 937–941.) Mn acts as a donor impurity, with distribution coefficient $\approx 10^{-5}$. Only one donor level, at $0 \cdot 53 \pm \cdot 03$ eV from the conduction level, has been detected. The limit of donor concentration obtained by adding Mn to a silicon melt was $\approx 5 \times 10^{14}$ cm$^{-3}$. Mn reduces recombination lifetime and may act as an electron trap. Temperature effects are discussed.

537.311.33 : 546.28 : 535.215 **1493**

**Photoconductivity in Indium-Doped Silicon.**—J. S. Blakemore. (*Canad. J. Phys.*, Sept. 1956, Vol. 34, No. 9, pp. 938–948.) Measurements have been made at temperatures from 63° to 90°K. The long-wave limit of spectral response and the bulk electrical properties are both consistent with an ionization energy of 0·16 eV for the In centres. An apparent variation of quantum efficiency in the range 5–8 $\mu$ is noted. The results suggest an effective recombination coefficient of about $10^{-6}$ cm$^3$/s at 90°K, rising steeply on cooling; this demands a much more active recombination mechanism than is provided by existing theories.

537.311.33 : 546.281.26 **1494**

**Observation at Low Temperature of the Debye Dipolar Absorption of SiC : Levels Near 0·01 to 0·03 eV.**—M. Freymann, R. Goffaux, M. Hagène & J. LeBot. (*C. R. Acad. Sci., Paris*, 17th Dec. 1956, Vol. 243, No. 25, pp. 2048–2050.)

537.311.33 : 546.289 **1495**

**The Measurement of Drift Mobility in Germanium at High Electric Fields.**—A. F. Gibson & J. W. Granville. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 259–266.) The emitter and collector contacts of a conventional drift-mobility specimen are replaced by a light-spot and a section of waveguide respectively. The increase in microwave absorption due to the injected carriers is used as a measure of their density. The technique may be used advantageously at high electric field strengths and when the minority-carrier lifetime is small. An experimental value of $5 \cdot 8 \times 10^{-6}$ cm.sec$^{-1}$ is determined for the saturated drift velocity of electrons in Ge.

537.311.33 : 546.289 : 535.215 **1496**

**The Stationary Distribution of Excess Charge Carriers in Germanium during its Partial Illumination.**—S. V. Bogdanov. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 917–926.) Unidimensional analysis is presented for a thin homogeneous specimen of Ge partly illuminated. Surface recombination is neglected. The distribution of excess carriers in the illuminated and non-illuminated regions is determined; it obeys an exponential law. The associated space charge and internal field are also determined. A potential difference is set up between the illuminated and non-illuminated parts which increases with illumination, diffusion length and specific resistance.

537.311.33 : 546.3-1-289-28 **1497**

**Conduction Band Structure of Germanium-Silicon Alloys.**—M. Glicksman & S. M. Christian. (*Phys. Rev.*, 1st Dec. 1956, Vol. 104, No. 5, pp. 1278–1279.) Galvanomagnetic measurements at room temperature show that in alloys with Si content greater than 23% the electronic conduction takes place in energy minima which are spheroids oriented along the [100] axes in the reduced zone.

537.311.33 : 546.431-31 **1498**
: 621.385.032.216

**Electrical Conductivity of Barium Oxide Single Crystals as a Function of Temperature and Excess Barium Density.**—R. T. Dolloff. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1418–1426.)

537.311.33 : 546.561-31 **1499**

**Linear and Quadratic Zeeman Effects and the Diamagnetism of the Exciton in a Cuprous Oxide Crystal.**—E. F. Gross & B. P. Zakharchenya. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1956, Vol. 111, No. 3, pp. 564–567. In Russian.)

537.311.33 : 546.873.221 **1500**

**Electrical Properties of Bismuth Chalcogenides : Part 1 — Electrical Properties of Bismuth Sulphide $Bi_2S_3$.**—P. P. Konorov. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 1126–1128.) The electrical conductivity and thermo-e.m.f. of polycrystalline compressed specimens was investigated over the range from room temperature to 600°K. The main conclusion reached is that the material is a typical semiconductor with an energy gap of 1 eV.

537.311.33 : 547 : 535.215 **1501**

**Electrical Conductivity and Photoconductivity of Phthalocyanines.**—A. T. Vartanyan & I. A. Karpovich. (*C. R. Acad. Sci. U.R.S.S.*, 21st Nov. 1956, Vol. 111, No. 3, pp. 561–563. In Russian.) Metal-free phthalocyanine (ph) and Cu-, Zn-, and Mg-phthalocyanine complexes were investigated. The specific conductivities of ph, ph-Cu and ph-Zn, prepared by sublimation in vacuum and subsequent heat treatment at 200°, are of the order of $10^{-12}$–$10^{-13}$ $\Omega^{-1} \cdot$cm$^{-1}$ at room temperature and increase with temperature according to the formula $\sigma = \sigma_0 \exp(-\epsilon/2kT)$, where $\epsilon \approx 1 \cdot 7$–$1.8$ eV. The conductivity of ph-Mg is about $10^3$ times higher, due to oxygen impurity; $\epsilon \approx 1 \cdot 2$ eV. Over the range 0°–150° the temperature dependence of the photocurrent is given by $i_{ph} = a \exp(-\epsilon_{ph}/2kT)$, where $\epsilon_{ph}$ lies between 0·5 and 0·65 eV. At temperatures below 0° the law deviates from the exponential type. Optical activation energies lie between 1·53 and 1·61 eV, thermal activation energies being about 0·2 eV higher.

537.311.33 : 621.314.7 **1502**

**Grain-Boundary Transistors.**—H. F. Mataré. (*Elektronische Rundschau*, Aug. & Sept. 1956, Vol. 10, Nos. 8 & 9, pp. 209–211 & 253–255.) Semiconductor crystal-lattice defects and the resulting grain boundaries are investigated (see also 3086 and 3764 of 1956). The artificial production of these conditions and their application in transistors are outlined. The electrical properties of the lattice defects were examined by means of special micro-manipulating equipment described.

537.312.62 **1503**

**Surface Energies in Superconductors.**—H. W. Lewis. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 942–947.) "A variational method is applied to calculate the surface energy at the normal/superconducting interface in a superconductor. Both the Casimir-Gorter theory, as formulated by Bardeen [*ibid.*, 1st May 1954, Vol. 94, No. 3, pp. 554–563], and the phenomenological energy-gap model are used. A comparison is made with the available experimental data."

537.312.62 : 534.23-8 **1504**

**Ultrasonic Attenuation at Low Temperatures for Metals in the Normal and Superconducting States.**—W. P. Mason & H. E. Bömmel. (*J. acoust. Soc. Amer.*, Sept. 1956, Vol. 28, No. 5, pp. 930–943.)

537.32 : 549.212 **1505**

**Anisotropic Thermoelectric Effects in Graphite.**—A. R. Ubbelohde & J. Orr. (*Nature, Lond.*, 26th Jan. 1957, Vol. 179, No. 4552, pp. 193–194.)

538.22 **1506**

**Magnetic Structures of the Polymorphic Forms of Manganous Sulphide.**—L. Corliss, N. Elliott & J. Hastings. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 924–928.) Measurements of neutron diffraction patterns and magnetic susceptibility of all three polymorphic forms. Possible lattice ordering schemes are discussed.

538.22 : 538.653.1 **1507**

**Magnetic Susceptibility of NiO and CuO Single Crystals.**—J. R. Singer. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 929–932.) Measurements of change-over from isotropic to anisotropic susceptibility with mechanical stress during annealing.

538.221 **1508**

**'Lozenge' and 'Tadpole' Domain Structures on Silicon-Iron Crystals.**—

L. F. Bates & P. F. Davis. (*Proc. phys. Soc.*, 1st Nov. 1956, Vol. 69, No. 443B, pp. 1109–1111, plates.)

538.221 **1509**

**Investigation of Palladium-Nickel-Copper Ternary Alloys.**—J. Cohen. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1845–1847.)

538.221 **1510**

**Influence of the Curie Point on the Oxidation of Magnetite $Fe_3O_4$, Iron, Nickel, and some Iron Alloys.**—L. Seigneurin & H. Forestier. (*C.R. Acad. Sci., Paris*, 17th Dec. 1956, Vol. 243, No. 25, pp. 2052–2054.)

538.221 : 538.632 **1511**

**Theory of Hall Effect of Ferromagnetics.**—N. S. Akulov & A. V. Cheremushkina. (*Zh. eksp. teor. Fiz.*, July 1956, Vol. 31, No. 1(7), pp. 152–153.) Brief note on the theory presented by Karplus and Luttinger (698 of 1955). The discrepancy noted between the theoretical and experimental relations of the Hall constant and resistivity is attributed to the existence of a Hall effect of a second kind.

538.221 : 539.16 **1512**

**Influence of Pile Irradiation on the Magnetic Properties of Zinc Ferrite.**—H. Forestier, G. Eischen & G. Guiot-Guillain. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1842–1845.) Thermomagnetic analysis indicates the existence of a Curie-point effect in $ZnO.Fe_2O_3$ exposed to neutron bombardment. The effect disappears if the period of heat treatment is sufficiently prolonged.

538.221 : 539.23 **1513**

**Resonance and Reversal Phenomena in Ferromagnetic Films.**—R. L. Conger & F. C. Essig. (*Phys. Rev.*, 15th Nov. 1956, Vol. 104, No. 4, pp. 915–923.) Experimental results demonstrate the proportionality between magnetization reversal time and magnetic-resonance-absorption line width.

538.221 : 621.318.134 **1514**

**The Permeability of Copper Ferrite in Rapidly Varying Fields: Effects in the Curie Region.**—K. Stierstadt. (*Z. Phys.*, 14th Sept. 1956, Vol. 146, No. 2, pp. 169–186.) The temperature variation of the reversible permeability of various specimens of Cu ferrite was investigated at frequencies between 15 and 60 Mc/s, using a resonance arrangement. The fine structure of the $\mu/T$ curves indicates that the magnetization process just below the Curie point is different from that at lower temperatures. The crystallographic transition of $Fe.CuFe.O_4$ at about 360°C and the reversible and irreversible formation of $Fe_2.CuFe_3.O_8$ are discussed in detail.

538.222 **1515**

**The Magnetic Properties of $Mg_2Sn$.**—L. L. Korenblit & A. P. Kolesnikov. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 941–944.) An experimental investigation was carried out which showed that the paramagnetism of an impurity $Mg_2Sn$ is most probably associated with the paramagnetism of the free electron gas in the $Mg_2Sn$ crystal.

539.232 **1516**

**Type of Ion Migration in a Metal/Metal-Oxide System.**—O. Flint & J. H. O. Varley. (*Nature, Lond.*, 19th Jan. 1957, Vol. 179, No. 4551, pp. 145–146.) A technique is outlined for determining the nature of ion migration in a small electric field at room temperature. Experiments were carried out on two Zr electrodes covered with thin oxide layers and separated by a sintered compact of zirconia.

539.234 **1517**

**Electron-Diffraction Study of the Formation of Aluminium-Antimony Alloys as Thin Films.**—P. Michel. (*C. R. Acad. Sci., Paris*, 17th Dec. 1956, Vol. 243, No. 25, pp. 2063–2065.) Films formed by the simultaneous or successive evaporation of Al and Sb were studied.

621.3.013.782 : 538.221 **1518**

**Magnetic Shielding with Multiple Cylindrical Shells.**—W. G. Wadey. (*Rev. sci. Instrum.*, Nov. 1956, Vol. 27, No. 11, pp. 910–916.) Formulae are given for computing the shielding ratio for any number of concentric shells of contemporary high-permeability materials. Both static and alternating fields are considered; in the static case end-effect data are also given.

621.316.825 **1519**

**Thermistors for High Temperatures.**—P. T. Oreshkin. (*Bull Acad. Sci. U.R.S.S., tech. Sci.*, Aug. 1956, No. 8, pp. 128–130. In Russian.) The electrical properties of oxides of Al, Mg, Zn and mixtures of Al and Mg oxides were investigated at temperatures of up to 1 570°. Results are presented graphically for $Al_2O_3$.

621.318.13 : 621.372.56.029.6 **1520**

**Manufacture of Reduced Iron Powder for the Microwave Attenuator.**—A. Nishioka. (*Rep. elect. Commun. Lab., Japan*, Aug. 1956, Vol. 4, No. 8, pp. 16–19.) A grain size of less than 5 $\mu$ was achieved by a method based on the reduction of ferric oxalate. The process is described and the prevention of oxidation is outlined. In another article (*ibid.*, pp. 33–36) the author discusses methods for the assessment of particle size distribution in such powders.

621.318.13 : 621.372.56.029.64 **1521**

**Microwave Dissipative Material.**—M. Y. El-Ibiary. (*Electronic Radio Engr*, March 1957, Vol. 34, No. 3, pp. 103–107.) The material is made by loading a cold-setting resin with carbonyl-iron powder. The properties are controllable and reproducible. Measurements at 3 cm $\lambda$ are compared with theory but only qualitative agreement is found.

621.318.134 : [537.226+538.22].029.6 **1522**

**Ferrites with Low Losses at U.H.F.**—R. G. Mirimanov, L. G. Lomize & N. V. Ryumshina. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 681–682.) A brief note on ferrites containing some, or all, of the following: $Fe_2O_3$, MgO, $MnC_2$ and calcium titanate. The loss tangent, tan $\delta$, is about $10^{-3}$ in the 3-cm-$\lambda$ band, $\mu$ varies between about 0·4 and 0·9 for the different ferrites and $\epsilon$ between 6·9 and 38.

621.357.53 : 621.384.613 **1523**

**On Internally Metallizing a Betatron Toroid by Vacuum Deposition.**—K. R. Allen, F. Ashworth & G. Siddall. (*J. sci. Instrum.*, Nov. 1956, Vol. 33, No. 11, pp. 445–446.) The practical details given are generally relevant to the production of coatings on the internal surface of apparatus.

621.357.7 **1524**

**Materials used in Radio and Electronic Engineering: Part 5—The Electrodeposition of Metals.**—(*J. Brit. Instn Radio Engrs*, Jan. 1957, Vol. 17, No. 1, pp. 35–47.) A survey covering the uses of electroplated coatings, their principal features, treatment after plating and the testing of the deposit. A summary of British Standards Institution and Ministry of Supply specifications is given.

## MATHEMATICS

512.99 **1525**

**Minimization of Boolean Functions.**—E. J. McCluskey, Jr. (*Bell Syst. tech. J.*, Nov. 1956, Vol. 35, No. 6, pp. 1417–1444.)

512.99 **1526**

**Detection of Group Invariance or Total Symmetry of a Boolean Function.**—E. J. McCluskey, Jr. (*Bell Syst. tech. J.*, Nov. 1956, Vol. 35, No. 6, pp. 1445–1453.)

517.512.2 **1527**

**A Simplified Procedure for Finding Fourier Coefficients.**—J. F. Gibbons. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, p. 243.)

## MEASUREMENTS AND TEST GEAR

621.317.18 : 621.373.421.1 **1528**

**Grid-Dip Oscillator.**—H. B. Dent. (*Wireless World*, March 1957, Vol. 63, No 3, pp. 121–123.) A c.r. tuning indicator replaces the grid-current indicator. The instrument can be used up to 120 Mc/s.

621.317.3 : 621.387.001.4 **1529**

**Method of Tracing the Dynamic Control Characteristic of a Thyratron.**—Dehors & Maizières. (See 1621.)

621.317.328 : 621.396.81.029.62 **1530**

**Measurement of Height-Gain at Metre Wavelengths.**—Saxton, Kreielsheimer & Luscombe. (See 1578.)

621.317.335+621.317.411].029.6 : 621.318.134 **1531**

**Measurement of the Parameters of Ferrites at U.H.F.**—V. V. Nikol'ski. (*Radiotekhnika i Elektronika*, April & May 1956, Vol. 1, Nos. 4 & 5, pp. 447–468 & 638–646. Correction, *ibid.*, June 1956, Vol. 1, No. 6, p. 888.) Theory is presented of the experimental determination of the permeability tensor and the permittivity of ferrites by cavity-resonator methods. Spherical, cylindrical and disk specimens in cylindrical or quadrangular-prism resonators are considered. Experimental results obtained by different methods are compared.

621.317.34 : 621.317.729 : 621.372.2 **1532**

**An Investigation into some Fundamental Properties of Strip Transmission Lines with the Aid of an Electrolytic Tank.**—B. G. King : J. M. C. Dukes. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, p. 72.) Comment on 2283 of 1956 and author's reply.

621.317.343 : 621.317.729 : 621.372.2 **1533**

**Measurements of the Characteristic Impedance of Uniform Lines by means of the Electrolyte Tank.**—H. O. Koch. (*Frequenz*, Sept. 1956, Vol. 10, No. 9, pp. 277–283.) The method described avoids the use of high frequencies. Details of the apparatus and test results are given, and potential sources of error are discussed.

621.317.35 **1534**

**A Method for the Continuous Recording of Harmonics.**—H. Nottebohm. (*Elektronische Rundschau*, Sept. 1956, Vol. 10, No. 9, p. 256.) The method of distortion-factor measurement described achieves a high degree of resolution over a continuous frequency spectrum. By means of a pulse-controlled electronic switch, a stepped curve is produced which is a frequency-transposed approximation to the signal waveform; this is analyzed in the normal way.

621.317.382.029.64 : 537.533 **1535**

**Microwave Power Measurements employing Electron-Beam Techniques.**—H. A. Thomas. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 205–211.) An electron beam is accelerated transversely across an evacuated section of waveguide supporting a $TE_{10}$ mode. The transit time is adjusted to give maximum interaction of the field with the electrons. The energy gained by the latter is measured in terms of a d.c. stopping potential which in turn can be related to the field. The power flow is then calculated from the Poynting vector. Some preliminary measurements with a 20-W c.w. source are described.

621.317.4 **1536**

**Comparison of Methods of Magnetic Field Measurement.**—V. Andresciani. (*Piccole Note Ist. super. Poste e Telecomunicazioni*, Sept./Oct. 1956, Vol. 5, No. 5, pp. 629–643.) The accuracy of measurements made by means of bismuth spirals and by ballistic fluxmeter is compared with that obtainable by the nuclear-resonance meter [3480 of 1956 (Andresciani & Sette)], and the relative advantages of the methods are assessed. The error due to rapid probe withdrawal in the ballistic method is calculated.

621.317.431 **1537**

**Simple 60-c/s Hysteresis Loop Tracer for Magnetic Materials of High or Low Permeability.**—D. H. Howling. (*Rev. sci. Instrum.*, Nov. 1956, Vol. 27, No. 11, pp. 952–956.) Designed for use with long specimens such as wires or tape.

621.317.44 : 538.632 : 537.311.33 **1538**

**The Self-Field Error in the Measurement of the Tangential Field Strength in Iron by means of the Hall Effect.**—F. Kuhrt & W. Hartel. (*Arch. Elektrotech.*, 20th Sept. 1956, Vol. 42, No. 7, pp. 398–409.) The error due to the magnetic field associated with the current through the semiconductor plate is evaluated, and its dependence on the geometrical and physical properties of the plate is discussed for three different arrangements. Field strengths of the order of a millioersted can be measured.

621.317.7 : 537.54 : 621.396.822.029.6 **1539**

**The Noise of Gas-Discharge Tubes and its Application to Microwave Noise Measurements.**—E. Suchel. (*Elektronische Rundschau*, Sept. 1956, Vol. 10, No. 9, pp. 242–246.) A neon-filled noise diode suitable for insertion into waveguides, and a test circuit for noise-figure measurements in the 3-cm-$\lambda$ region are described.

621.317.72 **1540**

**An Electrostatic Null Detector.**—J. Hart & A. G. Mungall. (*J. sci. Instrum.*, Nov. 1956, Vol. 33, No. 11, pp. 411–412.) A simple arrangement for use in a high-resistance bridge circuit comprises a movable plate suspended between two fixed plates. The sensitivity is better than 0·5 V, and the device has been used for potential measurements from 0 to 1 000 V; its capacitance is about 3 pF.

621.317.729 **1541**

**Electrolytic Tank, Design and Applications.**—P. A. Kennedy & G. Kent. (*Rev. sci. Instrum.*, Nov. 1956, Vol. 27, No. 11, pp. 916–927.) Survey of theory and design, with description of the Harvard tank and discussion of experimental errors.

621.317.733 : 538.569.4.029.6 **1542**

**Accurate Method for Measurement of Microwave Attenuation.**—J. A. Fulford & J. H. Blackwell. (*Rev. sci. Instrum.*, Nov. 1956, Vol. 27, No. 11, pp. 956–958.) The change in microwave power fed to a thermistor is compared with an equal amount of l.f. (1-kc/s) power supplied to the same thermistor through a precision attenuator. The comparison is effected by restoring the balance of a bridge containing two thermistors in an arrangement which compensates against drift in the microwave power output.

621.317.737 : 621.385.029.6 **1543**

**An X-Band Magnetron *Q*-Measuring Apparatus.**—J. R. M. Vaughan : J. R. G. Twistleton. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, p. 6.) Comment on 2493 of 1956 and author's reply.

621.317.755 : 621.314.7.001.4 **1544**

**Characteristic Tracer for Power Transistors.**—S. Kramer & R. Wheeler. (*Electronic Ind. Tele-Tech*, Sept. 1956, Vol. 15, No. 9, pp. 58–59 . . 88.) C.r.o. equipment capable of dealing with peak power levels up to 1 kW is described.

621.317.755 : 621.374.3 **1545**

**Transistors Generate Geometric Scale.**—Gott & Park. (See 1373.)

621.317.761 **1546**

**Heterodyne Frequency Meter for Pulsed and Continuous Frequency Measurements.**—H. P. Hirschl. (*Aust. J. appl. Sci.*, Sept. 1956, Vol. 7, No. 3, pp. 205–214.) A meter for the range 2–100 Mc/s is described. It is accurate to within 100 c/s per Mc/s for pulses of duration $>50\ \mu s$; the shielding is such that the instrument can be used close to a transmitter.

621.317.761 **1547**

**An Electronic Device for the Absolute and Relative Measurement of Frequencies between 10 and 200 000 c/s.**—A. Drigo & M. Pizzo. (*Ricerca sci.*, Sept. 1956, Vol. 26, No. 9, pp. 2739–2746.) The equipment described consists of an electronic scaler counting the half-waves of the same sign in an electrical oscillation. It is gated photoelectrically by a pendulum, and an accuracy within 0·1% is claimed.

621.317.784 : 621.314.63 **1548**

**A Crystal-Diode Wattmeter.**—G. Zinsli. (*Bull. schweiz. elektrotech. Ver.*, 29th Sept. 1956, Vol. 47, No. 20, pp. 893–901.) The instrument described is built up from a number of resistors and Ge diodes; it operates on the principle of multiplying together two voltages by rectification and double difference formation. The frequency range is 0–100 kc/s.

## OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.2-8 **1549**

**Pulsed F.M. tests Ultrasonic Propagation.**—R. R. Unterberger. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 143–145.) A sonar system for seismic research, using a frequency-sweep sine-wave generator and a wide-band (165–240 kc/s) receiver, which may be gated to accept any part of the variable-frequency cycle.

535.341-1 : 621.317.733 **1550**

**Simple Aid to Infrared Intensity Measurements.**—C. B. Arends & D. F. Eggers, Jr. (*Rev. sci. Instrum.*, Nov. 1956, Vol. 27, No. 11, pp. 939–940.) An electromechanical device for accurate determination of absorption intensity directly from spectral curves.

536.531 **1551**

**The Zero Stability of the Symmetrical Hot-Wire Bridge.**—R. Schneider. (*Arch. tech. Messen*, Sept. 1956, No. 248, pp. 199–202.) The influence of manufacturing tolerances, current fluctuations and ambient temperature on stability is investigated.

539.16.08 **1552**

**The Measurement of Radioactivity.**—D. Taylor. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 7–14.) Chairman's address, Measurement and Control Section. An instrument is described for the continuous monitoring of $\alpha$-active material in solution with $\gamma$- and $\beta$-active matter also present. The ultimate sensitivity of radioactive assay, and measurements relating to human body radioactivity, radiation dosage and nuclear reactors are also considered.

621-52 : 681.142 **1553**

**Ship Stabilization: Automatic Controls, Computed and in Practice.**—J. Bell. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 20–26.) Predictions by step-by-step and analogue methods are given, the functioning of the analogue computer being described and examples of results presented. Some practical results from sea experience and a brief account of a stabilizing demonstration on a model are included.

621.316.728 : [621.314.63+621.314.7 **1554**

**Power Regulation by Semiconductors.**—F. H. Chase. (*Elect. Engng, N.Y.*, Sept. 1956, Vol. 75, No. 9, pp. 818–822.) Applications of semiconductor diodes and transistors in power regulators are described.

621.384.6 **1555**

**Problems in the Radio Engineering and Electronics of Powerful Cyclic Accelerators of Heavy Charged Particles.**—A. L. Mints. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 543–559.) A survey, with particular reference to the phasotron (synchrocyclotron) and the synchrophasotron (proton synchroton) of the U.S.S.R. Academy of Sciences. The former accelerates protons to energies up to 700 MeV, the latter to 10 kMeV. The projected 50-kMeV synchrophasotron is also mentioned.

621.384.622 **1556**

**Achromatic Beam Translation Systems for Linear Accelerators.**—K. L. Brown. (*Rev. sci. Instrum.*, Nov. 1956, Vol. 27, No. 11, pp. 959–963.) Magnetic deflection systems which dispose of secondary particles and give translation without energy dispersion.

621.385.833 **1557**

**Distribution of Electron Density over an Electron - Optical Image.**—I. G. Stoyanova. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 990–995). Report of an experimental investigation to determine the effect of the atomic weight of the substance under observation, the amount of the substance and the accelerating voltage on the distribution of electron density over electron-microscope images.

621.385.833 **1558**

**The Experimental Determination of Focal Lengths and Principal Planes of Asymmetric Unipotential Electron Lenses.**—C. W. F. Everitt & K. J. Hanssen. (*Optik, Stuttgart*, Sept. 1956, Vol. 13, No. 9, pp. 385–398.) Whereas four shadow images are generally necessary for the determination of asymmetric lenses, it is shown that three images will suffice for the special case of unipotential lenses. A description of a simple test method is illustrated by experimental results.

621.385.833 **1559**

**Geometrical Aberrations in Strong-Focusing** [electron] **Lenses.**—M. Y. Bernard & J. Hue. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1852–1854.) Third-order equations of the electron trajectories in e.s. and magnetic lenses are derived and discussed.

621.385.833 **1560**

**Calculation of the Induction and its Derivatives along the Axis of a Magnetic Electron Lens** [with the form of a figure] **of Revolution.**—M. Laudet. (*C. R. Acad. Sci., Paris*, 5th Dec. 1956, Vol. 243, No. 23, pp. 1855–1857.)

621.387.4 **1561**

**The Spreading of the Discharge in Self-Quenching Counter Tubes: Part 1.**—E. Huster & E. Ziegler. (*Z. Phys.*, 21st Sept. 1956, Vol. 146, No. 3, pp. 281–294.) Experimental evidence indicates that the discharge is spread along the tube by photons.

621.387.4 **1562**

**Standard Deviation of Dead-Time Correction in Counters.**—L. L. Campbell. (*Canad. J. Phys.*, Sept. 1956, Vol. 34, No. 9, pp. 929–937.) A formula is derived for the standard deviation of the corrected count for random events.

621.397.6 : 535.623 **1563**

**High-Resolution Flying-Spot Scanner for Graphic Arts Colour Applications.**—L. Shapiro & H. E. Haynes. (*RCA Rev.*, Sept. 1956, Vol. 17, No. 3, pp. 313–329.) Description of slow-speed scanning and reproducing systems serving respectively as input and output devices for an electronic computer providing colour correction in the production of half-tone plates for colour printing. A 10-in. kinescope simultaneously scans three precisely registered colour separation plates. Four images representing the required printing-ink colours are recorded photographically in sequence from a second kinescope.

621.56: 537.311.33: 537.322.1: 536.581 **1564**

**Thermoelectric Micro-refrigerators.**—E. K. Iordanishvili & L. S. Stil'bans. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 945–957.) Semiconductor thermoelements have been developed in which the Peltier effect is used for lowering temperature by more than 60° in the region of room temperature. Refrigerators using these elements have been constructed; for small volumes (under 1 litre) this type of refrigerator is an improvement on both the absorption and the compression types. Theory is discussed and results are given of an experimental investigation into the following: (*a*) three-stage refrigeration by means of a thermo-battery; (*b*) combined refrigeration (first stage — compression machine, second and third stages—thermoelectric refrigerators); (*c*) thermostatic control of small volumes for use in radio equipment, etc.

## PROPAGATION OF WAVES

538.566 : 551.510.535 **1565**

**The Scattering of Electromagnetic Waves by Plasma Oscillations.**—N. Hokkyo. (*J. Geomag. Geoelect.*, March 1956, Vol. 8, No. 1, pp. 1–8.) The theory of plasma oscillations is applied to the problem of the scattering of waves of frequency about 1 kMc/s in the ionosphere E layer. It is assumed that regions exist in which the electrons oscillate coherently; these regions are effective in scattering waves of frequencies about $\omega_p$ $(c/v)$, where $\omega_p$ is the plasma frequency, $c$ the velocity of light, and $v$ the mean velocity of thermal agitation. The influence of the size of the oscillating region is studied.

621.396.11 **1566**

**Approximate Formula for the Distance of the** [radio] **Horizon in the Presence of Superrefraction.**—V. A. Fok. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 560–574.) The formula derived applies to an atmospheric duct near the earth's surface, in which the refractive index varies parabolically with height.

621.396.11 : 551.510.535 **1567**

**The Present State of Research in the Field of Ionospheric Scatter Propagation.**—J. Grosskopf. (*Nachrichtentech. Z.*, Sept. 1956, Vol. 9, No. 9, pp. 393–403.) Report based on papers published in *Proc. Inst. Radio Engrs*, Oct. 1955, Vol. 43, No. 10 (see 234 of 1956). See also 554 of February.

621.396.11 : 551.510.535 **1568**

**Simultaneous Signal-Strength Measurements on Continuous and Pulsed Radio-Wave Transmissions Reflected from the Ionosphere.**—B. R. Rao & K. V. V. Ramana. (*Curr. Sci.*, Sept. 1956, Vol. 25, No. 9, pp. 284–285.) Measurements were made on oblique-incidence c. w. signals on 9·54 Mc/s and on vertical-incidence pulse signals at the equivalent frequency of 3·15 Mc/s, over short afternoon periods. The correlation coefficient for the two signal strengths is about 0·5, indicating that absorption in the D layer is the factor responsible for the observed variations.

621.396.11.012.3 **1569**

**Reflection Point and Angle Nomographs.**—Z. Prihar. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 184–186.) For computing propagation paths involving diffraction around an obstacle.

621.396.11.029.6 **1570**

**Propagation of Radio Waves near the Horizon in the Presence of Super-refraction.**—V. A. Fok, L. A. Vainshtein & M. G. Belkina. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 575–592.) Development of formula (see 1566). Numerical results are given for a particular parabolic *M*-profile for wavelengths of 3·33, 10, 30 and 90 cm.

621.396.11.029.6 **1571**

**Beyond-the-Horizon Propagation in Microwave Radio Systems.**—(*Elect. Commun.*, June 1956, Vol. 33, No. 2.) The main part of this issue is devoted to a group of papers on microwave propagation and communication systems, with the following titles:—

Microwave Communication Beyond the Horizon.—A. G. Clavier (pp. 108–116).

Beyond-the-Horizon 3 000-Mc/s Propagation Tests in 1941.—A. G. Clavier & V. A. Altovsky (pp. 117–132).

Investigation of Very-High-Frequency Non-optical Propagation Between Sardinia and Minorca.—J. M. Clara & A. Antinori (pp. 133–142).

900-Mc/s Pulse-Time-Modulation Beyond-the-Horizon Radio Link.—F. J. Altman, R. E. Gray, A. G. Kandoian & W. Sichak (pp. 143–150).

Simplified Diversity Communication System for Beyond-the-Horizon Links.—F. J. Altman & W. Sichak (pp. 151–160).

Configurations for Beyond-the-Horizon Diversity Systems.—F. J. Altman (pp. 161–164).

Design Chart for Tropospheric Beyond-the-Horizon Propagation.—F. J. Altman (pp. 165–167).

Range of Multichannel Radio Links between 30 and 10 000 Mc/s.—H. Carl (pp. 168–173).

621.396.11.029.62 **1572**

**Correlation in V.H.F. Propagation over Irregular Terrain.**—R. S. Kirby & F. M. Capps. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. AP-4, No. 1, pp. 77–85.) For abstract, see *Proc. Inst. Radio Engrs*, May 1956, Vol. 44, No. 5, p. 716.

621.396.11.029.62 : 621.396.812 **1573**

**Investigation on Propagation in the 100-Mc/s Band.**—J. Grosskopf. (*Nachrichtentech. Z.*, Sept. 1956, Vol. 9, No. 9, pp. 430–433.) Interim note of results of measurements in progress for the transmission paths Bielstein–Darmstadt (90·6 Mc/s) and Wrotham–Krefeld (93·5 Mc/s). The investigations cover the effect of scatter on wave polarization, the variation of field strength as a function of height and vertical pressure gradient, and fading over a 225-km path.

621.396.11.029.64/.65 **1574**

**Back-Scattering Characteristics of the Sea in the Region from 10 to 50 kMc/s.**—J. C. Wiltse, S. P. Schlesinger & C. M. Johnson. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 220–228.) Measurements were made with c.w. Doppler systems operating on several frequencies simultaneously. Data relate to vertical, horizontal and circular polarization and to the cross-polarized component of vertically polarized waves. The back-scattering cross-section was nearly independent of frequency, but increased as the angle of incidence was reduced.

## RECEPTION

621.376.23 **1575**

**Coherent and Incoherent Detectors.**—R. Kitai. (*Electronic Radio Engr*, March 1957, Vol. 34, No. 3, pp. 96–99.) "The responses of the 'linear' diode detector and the coherent ('phase-sensitive') detector to combined signals and random noise are compared for signal-to-noise ratios less than and greater than unity. It is shown that for amplitude-modulated signals coherent detection gives an output signal-to-noise ratio 3 dB better than that with the linear detector. For unmodulated signals much larger improvements can be effected by restricting the post-detector bandwidth."

621.376.23 : 621.396.822 **1576**

**Some Statistical Properties of Signal plus Narrow-Band Noise Integrated over a Finite Time Interval.**—L. C. Maximon & J. P. Ruina. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1442–1448.)

621.396.621 : 621.396.812.3 **1577**

**On the Method of Space-Diversity Reception by Aerial Selection.**—W. Kronjäger, B. Lenhart & K. Vogt. (*Nachrichtentech Z.*, Sept. 1956, Vol. 9, No. 9, pp. 424–430.) A single-receiver, two-aerial system is described and results of comparative s.w. reception tests are shown. For Al transmission, a typical figure for the gain of the system over a normal reception system is 9 dB which is equal to that for a two-receiver diversity system.

621.396.81.029.62 : 621.317.328 **1578**

**Measurement of Height-Gain at Metre Wavelengths.**—J. A. Saxton, K. S. Kreielsheimer & G. W. Luscombe. (*Electronic Radio Engr*, March 1957, Vol. 34, No. 3, pp. 89–95.) A captive balloon was used to raise a v.h.f. receiver and telemetering transmitter. Continuous comparisons were made of field strength measured with the balloon-borne receiver and with another receiver on the ground. Some typical examples of results obtained are given. Circuit diagrams of the telemetering transmitter and frequency meter are included.

621.396.812.3.029.55 **1579**

**Fading of Long-Distance Radio Signals and a Comparison of Space and Polarization-Diversity Reception in the 6–18 Mc/s Range.**—G. L. Grisdale, J. G. Morris & D. S. Palmer. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 39–51.) "The rapid component of the variation of signal strength from distant radio transmitters operating in the 6–18-Mc/s frequency band has been examined experimentally, and the results of the measurements are compared with various statistical laws which have been suggested from theoretical considerations. The rapid component of fading is found to agree closely with a Rayleigh distribution. A characteristic time-constant for the rapid fading is suggested and its value determined for a number of distant stations. Measurements have also been made of the correlation between signal strength variations in two spaced aerials and in two aerials at the same place but set at right angles. From these results a comparison of space and polarization diversity is made. It is concluded that both systems could, on average, give equal performance. The two diversity systems were also compared in operation on a telegraph circuit between Barbados and England, the number of telegraphic distortions being counted in each aerial in turn. There was no significant difference between the two systems. By combining the fading-law results and the diversity-correlation results, the improvement due to diversity may be expressed in terms of an equivalent power gain; the gain is higher on communication circuits which are initially good than on those which are poor."

621.396.82 : 537.222 **1580**

**Calculation of the Mutual Capacitances between Bodies of Small Dimensions.**—A. Ya. Breitbart & I. L. Lyudmirski. (*Zh. tekh. Fiz.*, May 1956, Vol. 26, No. 5, pp. 1094–1105.) The mutual capacitances between sources of interference and radio receiver aerials are investigated. Formulae of an accuracy sufficient for practical purposes are derived. The formulae have been verified experimentally.

## STATIONS AND COMMUNICATION SYSTEMS

621.376.3 : 621.3.018.78 : 621.372.5 **1581**

**Frequency-Modulation Distortion in Linear Networks.**—R. F. Brown. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 52–62.) "The paper surveys the somewhat confusing historical background of this subject and after discussion of some essential basic concepts presents a detailed analysis of the problem of small-order distortion. An attempt has been made, using the work of Medhurst [2503 of 1954], to present the results in a form suitable for computer programming. Special attention is given to networks which satisfy the minimum-phase condition, because thereby distortion becomes expressible in terms of the amplitude response alone. The results show in a visual yet quantitative manner the error involved in the use of the quasi-stationary solution."

621.391.1 **1582**

**Inaugural Address** [of I.E.E. President].—G. Radley. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 1–6.) The Director-General, G.P.O., considered world telecommunication, with particular reference to the post-war growth of the British inland telephone network and the transatlantic telephone cable. Communication by radio forward scattering was not thought to be competitive (except perhaps for television) with more conventional h.f. point-to-point radio or cable on long world routes.

621.396 (540) 1583

**Development and Coordination of Wireless Activities in India.**—V. Sundaram. (*J. Instn Telecommun. Engrs, India*, June/Sept. 1956, Vol. 2, Nos. 3/4, pp. 149–152.) Standardization and system problems dealt with by the Indian Radio and Cable Board since its creation in 1952 are briefly reviewed within the framework of the First Five-Year Plan. Special aspects of communication and electronics developments are dealt with in separate papers in the same issue.

621.396.11.029.6 1584

**Beyond-the-Horizon Propagation in Microwave Radio Systems.**—(See 1571.)

621.396.41 : 621.376.56 1585

**Multichannel Transmission by means of Amplitude-Multiplex.**—K. Radius. (*Nachrichtentech. Z.*, Sept. 1956, Vol. 9, No. 9, pp. 403–407.) Description of a simple two-channel system of coded p.a.m., with an assessment of tolerances in respect of overshoot and level fluctuation.

621.396.65 : 621.376.3 : 621.396.812.3 1586

**Accumulation of Noise in F.M. Radio-Relay Systems Produced by Fading of the Signal.**—Yu. B. Sindler. (*Radiotekhnika i Elektronika*, May 1956, Vol. 1, No. 5, pp. 627–637.) Analysis is presented of noise in a multisection system, taking into account the effect of amplitude limiting in the receivers.

621.396.65 : 621.39 1587

**Radio Links in General Communication Networks.**—H. Pressler. (*Elektrotech. Z., Edn A*, 11th September 1956, Vol. 77, No. 18, pp. 612–619.) Early work (e.g. by Hertz) on point-to-point transmissions is outlined and some details are given of the radio-link system operated by the German Federal Post Office.

621.396.712.029,55 1588

**The 100-kW Short-Wave Broadcasting Transmitters for** [the station at] **Jülich.**—W. Burkhardtsmaier. (*Telefunken Ztg*, June 1956, Vol. 29, No. 112, pp. 92–102. English summary, p. 133.) Description and some design and test data of the a.m. transmitters for the 5·3–26·8-Mc/s frequency range. Plans for these were discussed earlier by Kreutzträger (3405 of 1955).

## SUBSIDIARY APPARATUS

536.581 : 621.56 : 537.311.33 : 537.322.1 1589

**Thermoelectric Micro-refrigerators.**—Iordanishvili & Stil'bans. (See 1564.)

621.316.722.1 1590

**New-Type A.C. Automatic Voltage Regulator.**—Y. Imamizu, M. Take & Y. Suzuki. (*Rep. elect. Commun. Lab., Japan*, Aug. 1956, Vol. 4, No. 8, pp. 29–32.) The equipment described uses a feedback circuit controlling a saturable reactor. In comparison with conventional types it shows improvements in efficiency, power factor, waveform and a reduction of weight and dimensions.

## TELEVISION AND PHOTOTELEGRAPHY

621.397.5 : 535.623 1591

**The Colour Vector in Television.**—(*Electronic Radio Engr*, March 1957, Vol. 34, No. 3, pp. 100–102.) Explains with vector diagrams how a colour may be expressed as the sum of primary colour vectors, and from these may be derived 'luminance' and 'chrominance', suitable quantities for electrical representation and transmission.

621.397.5 : 535.623 : 621.395.625.3 1592

**A Magnetic-Tape System for Recording and Reproducing Standard F.C.C. Colour-Television Signals.**—H. F. Olson, W. D. Houghton, A. R. Morgan, M. Artzt, J. A. Zenel & J. G. Woodward. (*RCA Rev.*, Sept. 1956, Vol. 17, No. 3, pp. 330–392.) Modifications to the system described previously [2517 of 1954 (Olson et al.)] include reduction of tape speed from 30 to 20 ft/s, improvements to the heads to give better resolution, and addition of a channel for carrying combined highs. A.m. and f.m. systems for reproducing the sound are described. The equipment is described fully, with illustrations.

621.397.5 : 621.396.664 1593

**Picture-Tube Sound Monitoring.**—J. R. Greenwood. (*Wireless World*, March 1957, Vol. 63, No. 3, pp. 140–144.) The raster at the top of the picture monitor tube carries a visual display of a characteristic of the sound program.

621.397.5.08 1594

**The Measurement and Specification of Nonlinear Amplitude Response Characteristics in Television.**—S. Doba, Jr. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 161–165.) The gradient gain of a system is defined as a means of expressing tone rendition, and its practical application is discussed. The terms 'differential gain' and 'differential phase', adopted by the I.R.E., are extended to apply to the overall system used for either monochrome or colour television.

621.397.6 : 535.623 1595

**High-Resolution Flying-Spot Scanner for Graphic Arts Colour Applications.**—Shapiro & Haynes. (See 1563.)

621.397.61 1596

**Television Camera Channel Design.**—J. E. Attew. (*Electronic Radio Engr*, March 1957, Vol. 34, No. 3, pp. 80–89.) A light-weight equipment consisting of a camera control unit with full programming facilities, and, separated by up to 1 200 ft of cable, a camera and electronic viewfinder. A photoconductive camera tube giving compactness and high signal/noise ratio is used. The performance is discussed, schematic circuits given, and details of time-base, amplifier and correction circuits are discussed with diagrams.

621.397.61 1597

**Single-Carrier System for Sound and Video.**—B. Wolfe. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 151–153.) Description of a system for emergency operation during breakdown of the sound-channel transmitter.

621.397.61 1598

**New Portable TV Camera-Transmitters.**—A. E. Look. (*Electronic Ind. Tele-Tech*, Sept. 1956, Vol. 15, No. 9, pp. 52–53 . . 130.) Description of transistor-equipped apparatus weighing 28 lb and making independent operation possible for periods of three hours or more at locations up to a mile from the pickup receiver.

621.397.611 : 621.314.7 1599

**Miniature ITV Camera uses Drift Transistors.**—L. E. Flory, G. W. Gray, J. M. Morgan & W. S. Pike. (*Electronics*, 1st Jan. 1957, Vol. 30, No. 1, pp. 138–142.) Description and circuit of a transistor-operated television camera for industrial closed-circuit systems, using a standard television receiver as monitor. Camera power consumption is 5·2 W on mains or 15-V battery operation.

621.397.611.2 1600

**Image Orthicon for Pickup at Low Light Levels.**—A. A. Rotow. (*RCA Rev.*, Sept. 1956, Vol. 17, No. 3, pp. 425–435.) It is shown that signal/noise ratio is a direct function and time lag an inverse function of beam modulation depth, which in turn can be increased by increasing the spacing between glass target and mesh screen. A tube with a spacing of 0·15 in. is described; this is usable at light levels as low as $10^{-4}$ ft-lambert.

621.397.62 1601

**Fifteen Circuits for Restoration of the Direct Component** [in television receivers].—S. Albert. (*Télévision*, Sept. 1956, No. 66, pp. 196–199.) Some relatively little known circuits are included.

621.397.62 : 621.374.35 1602

**The Use of Germanium and Vacuum Diodes Connected in Series for Black-Level Clamping in Television Receivers.**—W. Dillenburger & E. Sennhenn. (*Frequenz*, Sept. 1956, Vol. 10, No. 9, pp. 283–286.) Although linearity tests on this circuit, which is extensively employed in German sets, reveal noticeable distortion. the effect on picture quality is negligible and the capacitance at the grid of the clamped stage is reduced by about 10 pF.

621.397.82 1603

**Television Interference Problem.**—J. P. Grant : A. H. Hooper. (*Wireless World*, March 1957, Vol. 63, No. 3, pp. 102–103.) Beats due to unidentified causes occur at a coastal site screened from direct radiation.

621.397.5 **1604**

**Television Engineering, Principles of Practice : Vol. 2—Video-Frequency Amplification.** [Book Review]—S. W. Amos & D. C. Birkinshaw. Publishers: Iliffe, London, 1956, 272 pp., 35s. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 303–304.) ". . . there is a rapidly increasing body of people who will find just the severely practical information they need . . ."

## TRANSMISSION

621.396.61.029.6 : 621.375.2 **1605**

**AN/TRC-24 Transmitter—R.F. Power Stages.**—E. L. LeBright & P. J. Bearer. (*Bell Lab. Rec.*, Oct. 1956, Vol. 34, No. 10, pp. 388–392.) Description of the power amplifier stages of a transmitter for multichannel telephony for military purposes. The frequency band from 100 to 400 Mc/s is covered by two plug-in units. Coaxial cavities rather than coil-type inductors are used for the 100–225-Mc/s unit. The 225–400-Mc/s unit incorporates a frequency doubler ; the coaxial cavities used here are of a folded-back construction. Tetrode valves are used.

## VALVES AND THERMIONICS

621.314.63 : 546.28 : 537.533.9 **1606**

**Note on the Reduction of Carrier Lifetime in *p-n* Junction Diodes by Electron Bombardment.**—W. Miller, K. Bewig & B. Salzberg. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1524–1527.) The reverse transient current and the static *I/V* characteristics of the junctions were measured before and after varying times of bombardment by 2-MeV electrons. The variation of the reverse current with time agrees with theory and the inverse minority-carrier lifetime is a linear function of the bombardment time. Marked changes occur in the asymptotic resistance and voltage intercepts which do not agree with *p-n* junction theory. A suggested explanation is that the diode behaves as a *p-i-n* junction.

621.314.63.029.65 : 546.28 **1607**

**Wafer-Type Millimetre-Wave Rectifiers.**—W. M. Sharpless. (*Bell Syst. tech. J.*, Nov. 1956, Vol. 35, No. 6, pp. 1385–1402.) A wafer-type silicon point-contact rectifier and holder designed primarily for use as the first detector in mm-wave receivers are described. Measurements on a group of units at 5·4 mm $\lambda$ indicate an average conversion loss of 7·2 dB and a noise ratio of 2·2 ; the i.f. output impedance at 60 Mc/s is 340 $\Omega$. Methods of estimating the values of the circuit parameters of a point-contact rectifier are given in an appendix.

621.314.632 : 546.28 **1608**

**Anomalous Characteristics of Silicon Point-Contact Rectifiers.**—D. J. Kyte. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 247–258.) Discontinuities in the reverse current/voltage characteristics follow the application of narrow pulses of voltage in the forward direction, if certain critical pulse voltages are exceeded. These critical voltages, which are temperature-dependent, are common to most units. A tentative explanation is based on the formation of minority-carrier traps near the rectifying contact.

621.314.7 : 537.311.33 **1609**

**Grain-Boundary Transistors.**—Mataré. (See 1502.)

621.314.7 : 621.317.3 **1610**

**Emitter/Base Impedances of Junction Transistors.**—R. E. Burgess. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 301–302.) A correction necessary to the equivalent-circuit values used by Evans (2903 of 1956) is pointed out.

621.314.7 : 621.375.4 **1611**

**The Stabilization of the D.C. Operating Point of Junction Transistors.**—W. Guggenbühl & B. Schneider. (*Arch. elekt. Übertragung*, Sept. 1956, Vol. 10, No. 9, pp. 361–375.) The temperature dependence and the manufacturing spread of transistor d.c. parameters are investigated with reference to experiments on Ge and Si types and production samples. Circuits using resistance networks for stabilizing d.c operation of transistors are described; satisfactory results were achieved. The a.c. performance of stabilizing circuits, and the use of temperature-sensitive elements are also discussed.

621.314.7.001.4 : 621.317.755 **1612**

**Characteristic Tracer for Power Transistors.**—Kramer & Wheeler. (See 1544.)

621.383 : 546.682.86 **1613**

**An Infrared Photocell based on the Photoelectromagnetic Effect in Indium Antimonide.**—C. Hilsum & I. M. Ross. (*Nature, Lond.*, 19th Jan. 1957, Vol. 179, No. 4551, p. 146.) The schematic arrangement and the spectral sensitivity curve of a typical cell are given.

621.383.001.4 **1614**

**Tracer Experiments in Photocells.**—W. E. Turk. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 267–269.) A method is developed for observing the distribution of Cs in vacuum photocells by a radioactive tracer technique.

621.385.029.6 **1615**

**The Performance of Space-Charge Diodes at Ultra-high Frequencies considering a Maxwellian Velocity Distribution.**—H. Paucksch. (*Nachrichtentech. Z.*, Sept. 1956, Vol. 9, No. 9, pp. 410–414.) An integral equation for the small-signal displacement current in a plane parallel diode is given which can be solved by numerical methods. Values of admittance and slope in a practical example are at variance with Müller's solution (*Hochfrequenztech. u. Elektroakust.*, May 1933, Vol. 41, No. 5, pp. 156–167; 1933 Abstracts, p. 443).

621.385.029.6 **1616**

**Notes on the Multi-reflection Klystron.**—B. Meltzer. (*Electronic Radio Engr*, March 1957, Vol. 34, No. 3, pp. 109–112.) 100% efficiency is possible in principle if transit times are correct. The mode of operation, the electrode system required, and the effect of incorrect transit times are discussed.

621.385.029.6 : 621.317.737 **1617**

**An X-Band Magnetron *Q*-Measuring Apparatus.**—J. R. M. Vaughan : J. R. G. Twistleton. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, p. 6.) Comment of 2493 of 1956 and author's reply.

621.385.032.216 : 537.311.33 : 546.431-31 **1618**

**Electrical Conductivity of Barium Oxide Single Crystals as a Function of Temperature and Excess Barium Density.**—R. T. Dolloff. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1418–1426.)

621.387 : 621.316.722.1 : 621.396.822 **1619**

**Gas-Filled Voltage Stabilizers.**—K. B. Reed & J. F. Dix. (*Electronic Radio Engr*, March 1957, Vol. 34, No. 3, p. 113.) Note of noise measurements in the frequency range 20 c/s–10 Mc/s confirming remarks of Benson (972 of March).

621.387 : 621.318.57 **1620**

**Operation of a Cold-Cathode Gas Triode in a High-Impedance Self-Biasing Circuit.**—M. Silver. (*Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, pp. 239–242.) Explanation of spurious triggering and suggested cures.

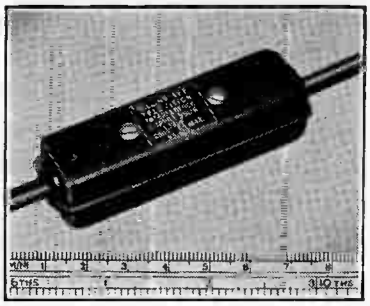
621.387.001.4 : 621.317.3 **1621**

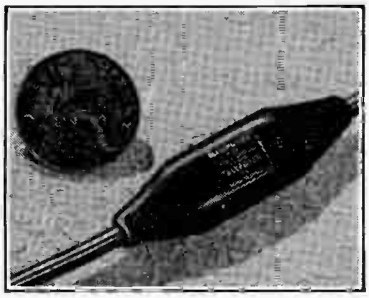
**Method of Tracing the Dynamic Control Characteristic of a Thyratron.**—R. Dehors & C. Maizières. (*Rev. gén. Élect.*, Sept. 1956, Vol. 65, No. 9, pp. 505–508.) A method is described which enables the characteristic, free from parasitic signals, to be traced rapidly on the screen of a c.r.o.

## MISCELLANEOUS

621.3.002 **1622**

**The Electronic Age.**—R. C. G. Williams. (*Proc. Instn elect. Engrs*, Part B, Jan. 1957, Vol. 104, No. 13, pp. 15–19.) Chairman's address, Radio and Telecommunication Section. The broad field of production, design and technical administration in the radio and electronics industry is considered. Mention is made of the impact of new materials and techniques on a number of applications in radio, television, automation and atomic energy.



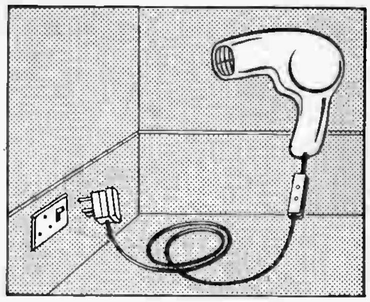


**L1314 FLEX LEAD FILTER, 2 amp.**

*Effective at band I television frequencies.*
Designed for connection in the leads of the appliance, fitted within six inches of the motor. The connections are completely enclosed in the two-piece moulding and the strain of the flex is taken up by cable grips. Two or three core flex may be used, up to $\frac{1}{4}$ in. diameter.

**L1316 FLEX LEAD FILTER, 2 amp.**

*Effective at band I television frequencies.*
This lightweight filter is designed for initial fitting to the appliance by the manufacturer, but is equally suitable for replacing existing cable. The filter is moulded in to a 6 ft. 6 in. length of two core cable.

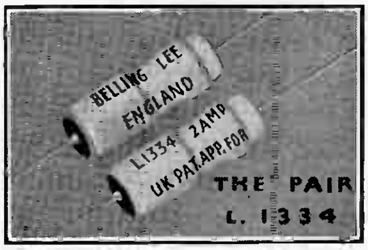


**SPLIT SUPPRESSION**

The most satisfactory way of dealing with troublesome interference on both radio and television frequencies is by "split suppression" — the combined use of two filters with the offending appliance.
Any one of the flex lead filters described on this page may be used in conjunction with the mains filter plug L1308, described below. This technique is becoming general practice, particularly with portable apparatus normally held in the hand, such as hair-dryers, electric razors, drills, etc., having leads not longer than 6 ft.

# "BELLING-LEE" TV Interference Filters

# FOR DOMESTIC APPLIANCES




**L1334 INTERNAL INDUCTOR FILTERS, 2 amp.**

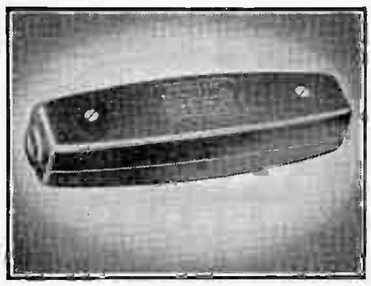
*Effective on bands I and III.*

Owing to the high frequencies involved, any band III filter should be fitted inside the appliance, as an external filter would tend to radiate interference.

These internal inductors must be fitted in pairs inside the casing, in series with the brush leads and as close as possible with the brush terminals. They are hand wound and individually tested for high efficiency.

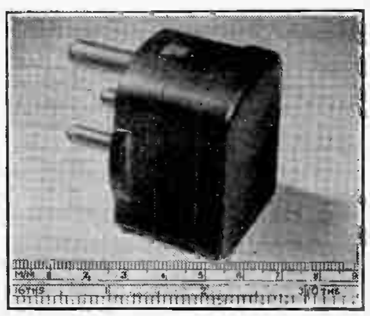
**L799 FLEX LEAD FILTER, 2 amp.**

*Effective at band I television frequencies and short and medium wave bands.*
This filter is similar in design and application to L1314 mentioned above. It is suitable for two or three core flex up to $\frac{3}{8}$ in. diameter.



**L1308 MAINS FILTER PLUG, 5 amp.**

*Effective at radio frequencies, medium and short wave bands.*
This plug is designed for fitting to the end of the flex lead of the appliance, replacing the normal type of 5 amp., 3 pole plug at the mains outlet socket. It is for use with appliances actuated by commutator motors, is supplied with a cable grip and will take two or three core cable up to $\frac{3}{8}$ in. diameter.



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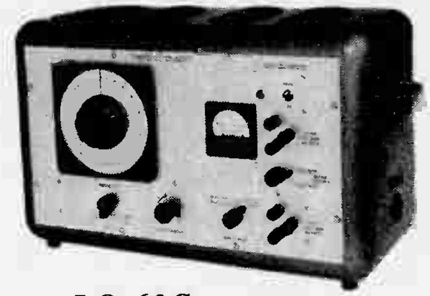

LO 63G

FREQUENCY 10 c.p.s. to 110 Kc/s
OUTPUT 20 volts into 6 000 ohms
DISTORTION less than 1% over 30 c.p.s.
ACCURACY ± 1½% or 0·5 cycle whichever the greater
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RANGE 0 to 100 Kc/s
ACCURACY ± 1%
INPUT VOLTAGE Min. 75 mV
Max. 15 volts
Provision for external recorder.

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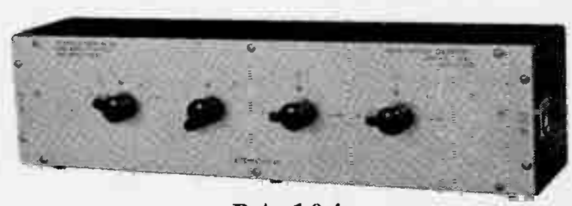

RA 104

ATTENUATION 1dB to 99dB in 1dB steps
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± 5% to 250 Mc/s
INPUT VOLTAGE 3 volts maximum
CHARACTERISTIC IMPEDANCE 75-ohm
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Widespread use has been found for the Carpenter Polarized Relay in Electronic circuits of Industrial and Aircraft equipment.

Its ability to respond to weak, ill-defined, short-duration impulses of varying polarity, and its close operate/release differential has solved many problems of control, amplification, impulse repetition and high-speed switching.

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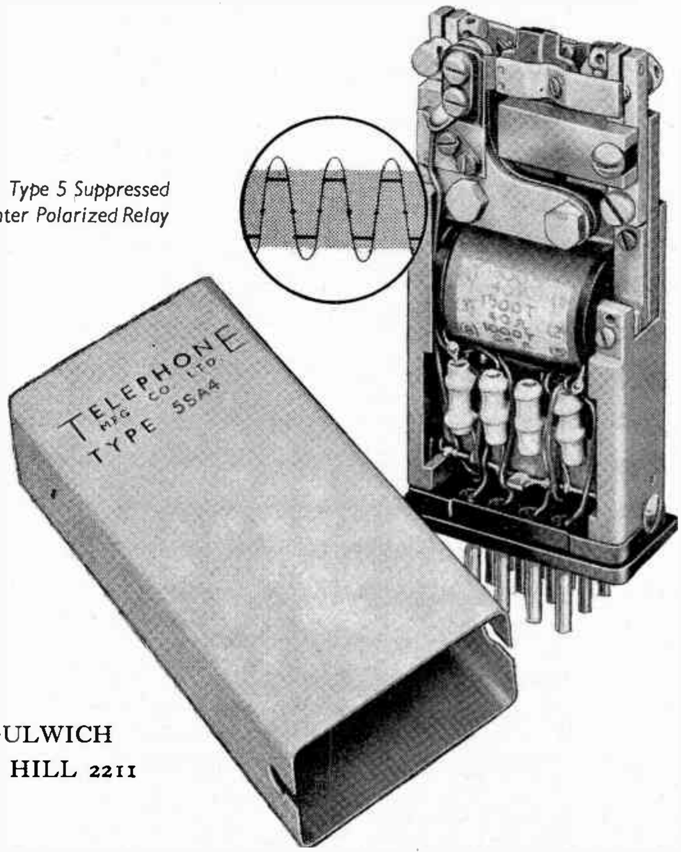


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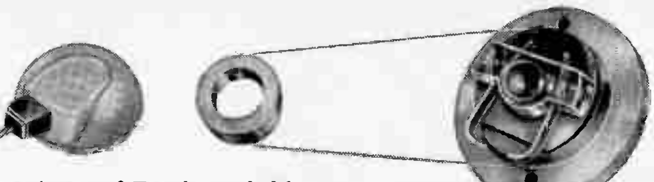
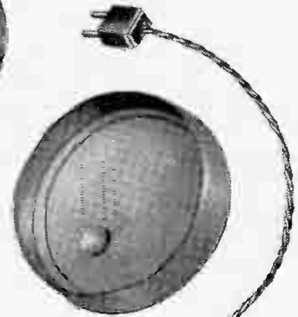
## MURREX SINTERED PERMANENT MAGNETS *are used in this new* AMPLIVOX EARPHONE

*Photographs by courtesy of Amplivox Ltd.*





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Maximum magnetic energy in a small area is essential to ensure the efficiency of this Amplivox receiver, and Murex Sintered Permanent magnets are used to provide these conditions. Efficiency and stability are distinguishing features of Murex Sintered magnets.

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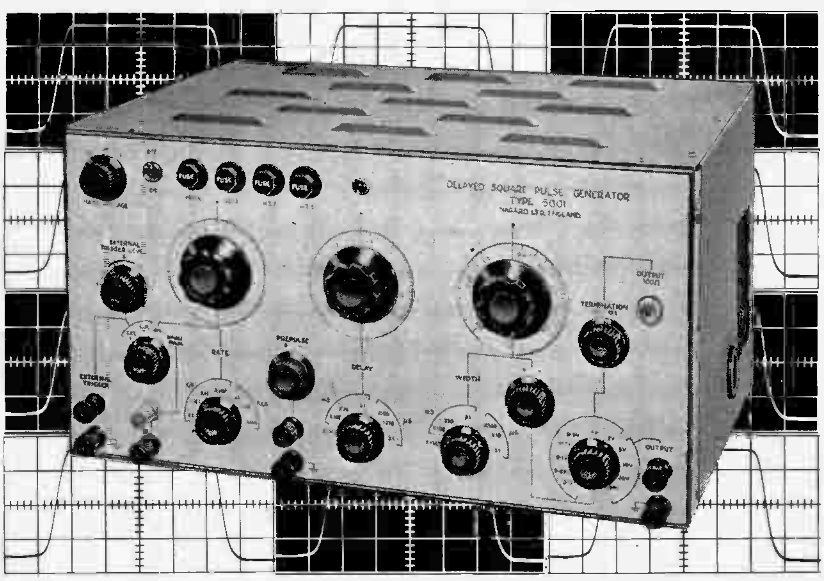


*WITH ACCURATE TIME & VOLTAGE CALIBRATIONS*

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Waveforms show 0·2 μsec pulse on 25 cm/μsec sweep
10 million to 1 range of pulse rate, width and delay calibrated by direct reading dials within 5%

**INTERNAL MULTIVIBRATOR** of new type gives highly stable frequencies continuously variable from 0·1 c/s to 1 Mc/s

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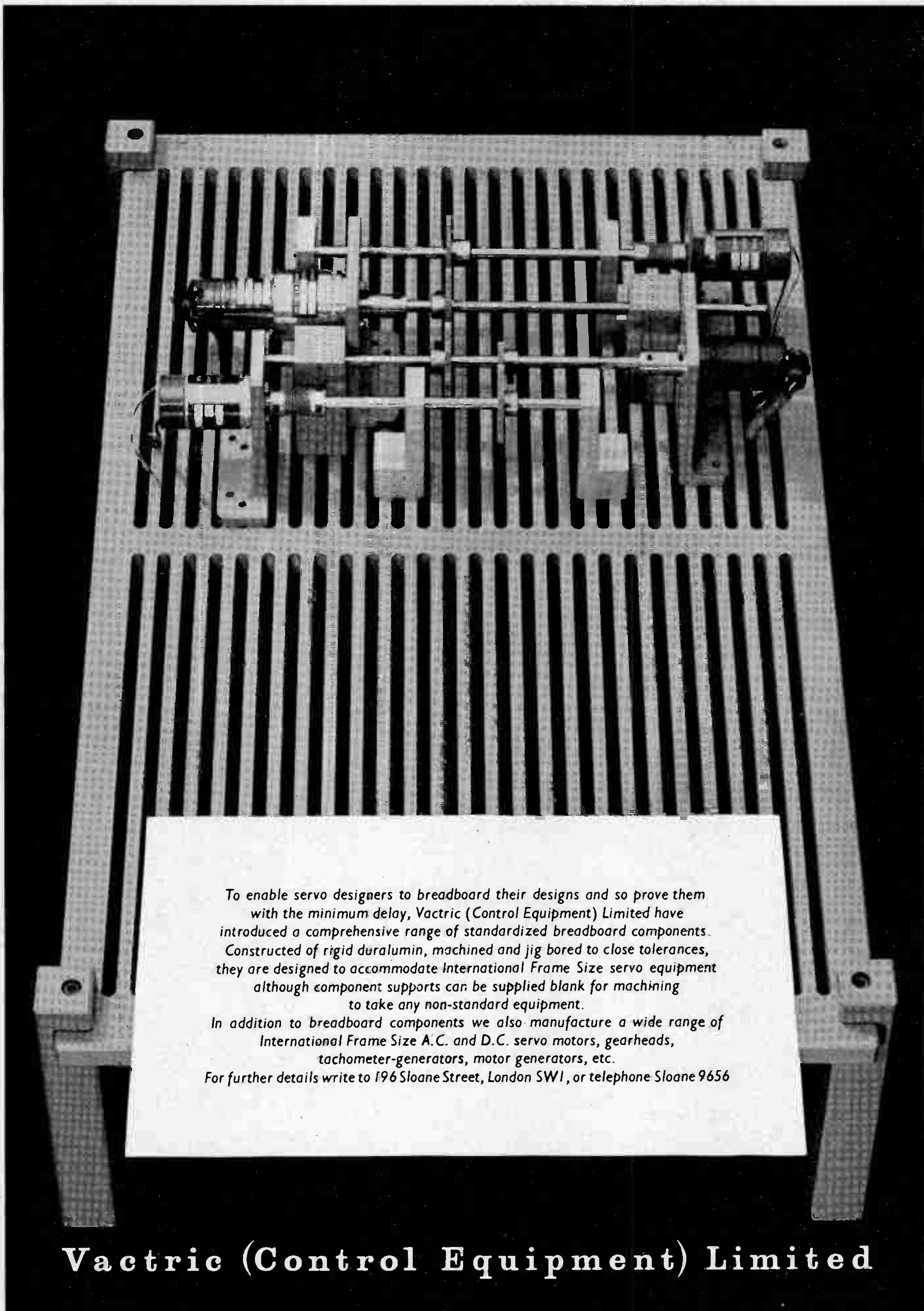
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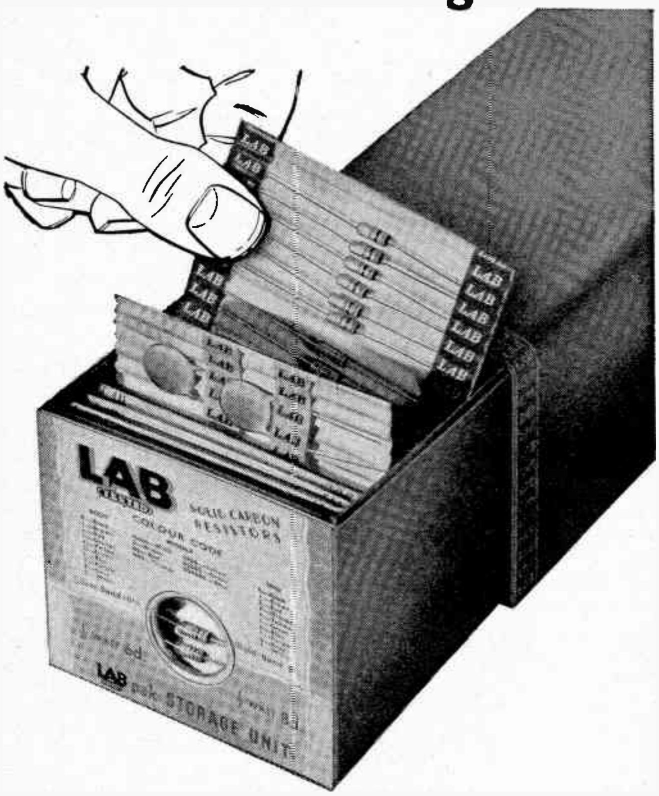


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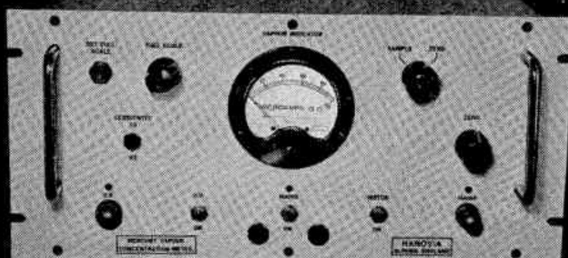
Hg vapour in concentrations as small as 75 μg in 1 $m^3$ of air in a confined space can be a hazard, and traces may also interfere with work such as semi-conductor research.

**Toxic Hg Concentrations in air can occur**

Near the mercury cells for Chlorine production
In ill-ventilated laboratories
In production, or repairs of rectifiers, fluorescent lamps, or near Hg vacuum pumps in preparation of mercury, and its compounds
In atomic heat transfer work



## Detection with Hanovia U.V. equipment

Employing the principle of the absorption of ultra-violet rays by Mercury Vapour the Meter measures concentrations between 0-700 MG. Hg/$m^3$. By connecting a chart recorder to the instrument, continuous records are available

## Improved performance

The instrument now includes many new features for increased accuracy, and has been officially calibrated by the Medical Research Council.

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**Hanovia**

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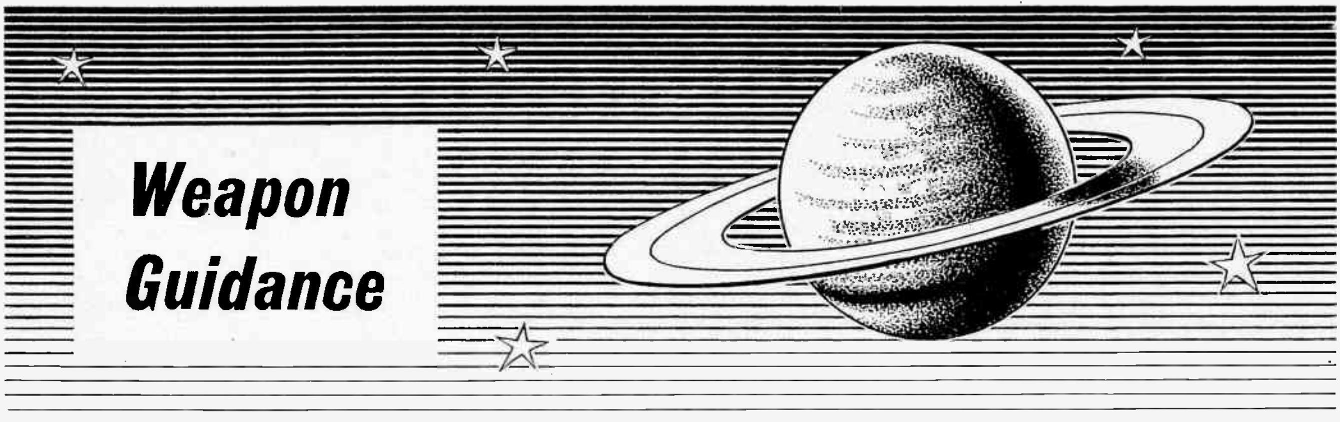
*Specialists in ultra-violet ray equipment for all applications*

TGA T92




An expanding programme of development has created a number of

**Interesting and Progressive Vacancies in**

**The Weapon Guidance Development Laboratories of**

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**SENIOR ENGINEER**

or Physicist with a good academic background and considerable experience of electronics and/or electromechanical instruments is required at our London office for interesting and important work on a major G.W. project. The work will include design studies and liaison within the company and with specialist sub-contractors.

**SENIOR ENGINEER**

required with experience of electronic and/or electromechanical devices. Following a period of familiarisation with complex equipment, the successful applicant will be responsible for the testing of this equipment and for the maintenance of laboratory test gear and facilities. This is a responsible position involving contact with outside contractors. A sound technical or academic background is essential together with considerable practical experience.

**SENIOR RADAR ENGINEER**

to supervise a team preparing equipment for weapon firings. The applicant should be familiar with centimetre-wave techniques and have had some experience in the testing and preparation of equipment. Previous missile experience would be a great advantage. This is a position of considerable responsibility and the ability to make decisions under conditions of stress is essential. A good academic background plus considerable practical experience is essential.

**COMMUNICATIONS ENGINEER**

required to control a small staff engaged on the design, installation and maintenance of varied forms of line and telecommunication equipment. The applicant will be required to take up permanent residence near the development site situated in an outlying district. This vacancy should be of interest to a man who has had experience in a wide variety of communication systems and possesses a good technical background.

**SENIOR COMPUTER ENGINEER**

required for an expanding and vital project involving the adaptation of electronic digital computer techniques to specific problems. A widening field of opportunity is open to a man with the right "feel" for the capabilities of digital computers, with some experience of adapting the form of a problem and of detailed programming. The work is centred in London but will involve the responsibility for a computing team to be set up elsewhere. A sound academic or technical background together with several years' practical experience is essential.

**SITE MANAGER**

required for a radar development project involving the responsibility for the building up and operation of a development site situated in an outlying district. The applicant must be capable of the administration of technical and non-technical personnel and possess a leading personality. Experience of the repair and maintenance of ground radar equipment is essential and a good academic or technical background is very desirable. An ex-serving officer possessing the right qualifications and prepared to be permanently resident near the site would possibly be suitable.

**V.H.F. ENGINEERS**

Two vacancies exist for engineers to supervise teams preparing equipment, one in the U.K. and one overseas. A good academic or technical background together with a number of years' practical experience is essential. Applicants should be familiar with V.H.F. techniques and preferably have had some field experience.

**ELECTRONIC ENGINEER**

required to develop equipment associated with flight measurements. Experience in the development of magnetic recording, pulse forming and counting circuits would be an advantage. A good academic or technical background together with four to five years' practical experience is desirable.

**ELECTRONIC ENGINEER**

required to develop a system for aircraft flight measurements. Experience in the development and use of magnetic recording, pulse forming and counting circuits would be an advantage. Applicants will be required to carry out field trials and in consequence should be prepared to live away from home for reasonable periods mainly in U.K. A good academic or technical background together with four to five years' practical experience is desirable.

**MECHANICAL ENGINEER**

required to assist in the design and production of breadboard and prototype V.H.F. equipment. Ability to interpret laboratory sketches is essential and experience in the design of V.H.F. systems would be an advantage. A good technical background plus four to five years' practical experience is desirable.

**HOUSING ACCOMMODATION**

will be considered in appropriate cases.

*Qualified persons are invited to apply in writing to the Personnel Manager (quoting Ref. GD.1), de Havilland Propellers, Limited, Stevenage, stating age, education and experience, and indicating the appropriate vacancy.*

# Electronics for ambitious young scientists

A few special openings for able young men are now available in Hollerith electronics research. Candidates may be . . .

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(b) Postgraduates with degrees in physics or engineering.

(c) Electronics technicians with laboratory experience.

Senior men will operate as group leaders; postgraduates and electronics technicians as group members. The groups are small and the research, in really well-equipped laboratories, is highly specialised.

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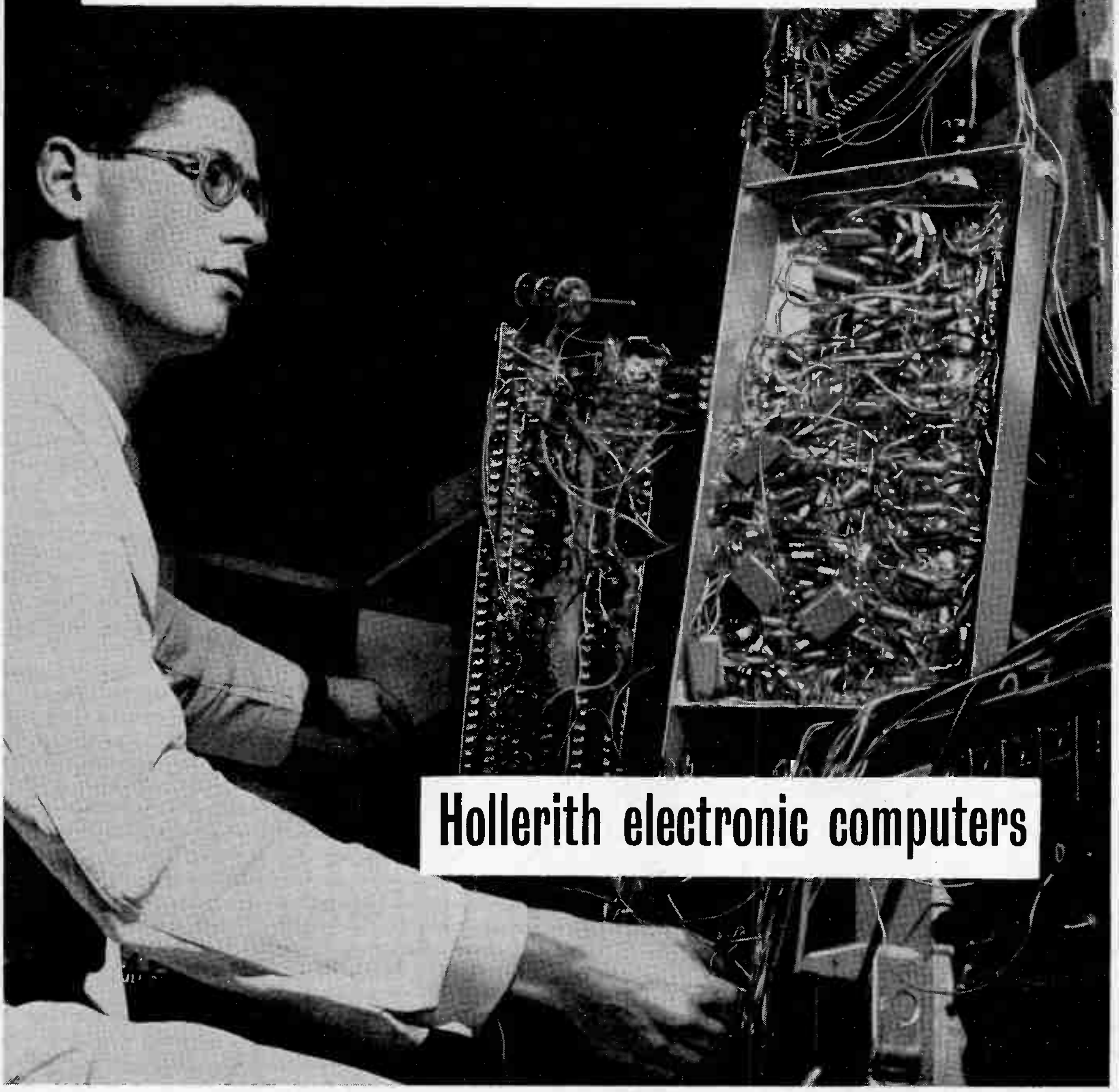

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## and Physicists

There are opportunities for Engineers and Physicists in the Research Department and Scientific Apparatus Department of the Company.

An important field of interest is that in which electrons or ions are produced and utilised in vacuum. Specific applications are found in particle accelerators, high power radio valves, electron microscopes, mass spectrometers, etc. Work, of a fundamental and developmental nature, is in progress, and there are openings for men with either academic or practical interests.

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Application should, in the first instance, be made to:

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**Research Department**

**Metropolitan-Vickers Electrical Co. Ltd.**
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## Invitation to GOOD★ Electronics Engineers

*★GOOD—meaning, for our purposes, able and ambitious Electronics Engineers and Physicists, fully qualified, but not necessarily experienced in our sort of business. YOU?*

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**Gunnels Wood Road, Stevenage, Herts.**

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(*Affiliated to the University of Glasgow*)

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**Press date for the June 1957 issue is first post Friday, 24th May 1957**

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**TO** undertake the official scientific, technical and legal work in connexion with Patent applications.

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**CANDIDATES** must have (or obtain in 1957) 1st or 2nd class honours in Physics, Organic or Inorganic Chemistry, Mechanical or Electrical Engineering or in Mathematics, or an equivalent qualification, or have achieved a professional qualification, e.g. A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E., A.R.I.C. For a limited number of vacancies candidates with 1st or 2nd class honours degrees in other subjects—scientific or otherwise—will be considered. Exceptional candidates otherwise qualified by high professional attainments will be considered.

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**INTERVIEW** Boards will sit at intervals, as required. Early application is advised. [1058

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**ELECTRONIC ENGINEERS**

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**WE** are looking for circuit engineers to design and develop test equipment for all types of cathode ray tube and allied devices. Experience in pulse, radar or television techniques would be an advantage, but it is not essential in the case of applicants with the right aptitude.

**WE** offer absorbing work in an expanding well-equipped department of the Cathode Ray Tube Division. The company has a progressive salary policy, good holidays, and provides facilities for further study.

**IF** this looks attractive to you and you are a graduate of a university or a professional institute or have a H.N.C. with suitable background apply in writing to The Mullard Radio Valve Co., Ltd., New Road, Mitcham Junction, Surrey, quoting reference JFG/E. [1059

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**BRITISH OVERSEAS AIRWAYS CORPORATION** have vacancies for Radio Instructors for the instruction of all grades of staff on the maintenance and overhaul of current radio, radar and allied equipment and in preparation for the Aircraft Radio Engineers Licences class "A" and "B" with radar ratings. Duties will include the preparation of technical manuals which will involve liaison with manufacturers' design staff at the prototype or production stage of the equipment. Applicants should have City and Guilds Final Certificate in Telecommunications or equivalent qualifications; real ability to express themselves clearly on technical subjects, with previous experience as lecturer on technical subjects; experience of the operation, maintenance and overhaul of radio, radar and electronic systems, preferably on aircraft equipment. The salary for these posts will be in the scale £920–£1,190 per annum. In the event of an applicant not having the full qualifications required but who is otherwise suitable, appointment initially in the scale £852 10s.–£1,032 10s. per annum may be considered. Generous Staff Pension and Insurance and leave schemes. Write, giving details of experience to Assistant Staff Manager (Appointments), Recruitment Centre, B.O.A.C., London Airport. [1060

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**APPLICATIONS** are invited for appointment as Lecturer or Assistant Lecturer in Electronic Computing. The salary scales are at present under review. It is expected that the Lecturer scale will be £900 × £50–£1,350/ × £75–£1,650 and the Assistant Lecturer scale £700 × £50–£850. Applications (three copies) stating date of birth, qualifications and experience, together with the names of three referees, should reach the Registrar, The University, Leeds, 2 (from whom further particulars may be obtained) not later than 30th June, 1957. [1064

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**D.S.I.R.** require Experimental Officers and Assistant Experimental Officers at Radio Research Station, Datchet, Berks, to (*i*) assist in radio research and (*ii*) prepare abstracts of scientific and technical articles on radio research and development. Qualifications in Physics or Electrical Engineering, minimum G.C.E. (advanced level) in two scientific subjects or equivalent. Over 22 pass degree, H.N.C. or equivalent generally expected. Experience in radio research or development, or communications an advantage. For posts (*ii*) ability to read technical French and German an advantage. Posts (*i*) offer opportunities for service abroad. Special short-term appointments are also available at home and abroad for assistance in observations and reduction of results during the International Geophysical Year (1957–58). Salary within ranges: E.O. £875–£1,075, A.E.O. £350 (age 18)–£755. Slightly less for women but subject to improvement under Equal Pay Scheme. Five-day week. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.111/7A. [1062

**JUNIOR** Electronic Engineers required to assist in the development of electronic equipment associated with Railway Traffic Control Systems. Together with two or three years' electronic development experience applicants should possess C. and G. Telecommunication Certificates to Intermediate or Final level. This latter requirement may be waived for applicants with more than five years' experience, and who are capable of developing outline circuitry to its final state with a minimum of supervision. Some experience of transistor circuitry is desirable, but not essential. Pension Scheme and five-day week. Write giving full particulars of age, qualifications and experience, to The Personnel Superintendent, Westinghouse Brake & Signal Co., Ltd., Chippenham, Wilts, quoting reference no. EQUIP/N/W. [1053

**PLESSEY NUCLEONICS, LTD.,** have vacancies for Electronic Engineers to work on the design of reactor instruments, pulse circuits, and other applications of electronics to nuclear problems. Both Senior and Junior posts are offered. All applicants should possess a thorough knowledge of basic electronic theory, a degree in science or electrical engineering, H.N.C., or appropriate equivalent standards of technical education for the two grades. Previous experience in nucleonics advantageous but not essential. The other important qualifications are enthusiasm and initiative to progress in this new and expanding field. These posts will carry attractive salaries commensurate with qualifications and experience. Apply in writing to Chief Engineer, Plessey Nucleonics, Ltd., Weedon Road, Northampton. [1052

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(1) Test gear (Radio and TV) designer.
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**ELECTRONIC** Engineers and Physicists required by Ministry of Supply Research and Development Establishments chiefly at Malvern, Worcs, Farnborough, Hants, Sevenoaks, Kent. Candidates should have or be obtaining 1st or 2nd class honours degree or equivalent with experience or interest in radio, radar and communications; instrumentation for telemetry and other measurements; electronic devices; application of advanced techniques to other fields, e.g. armament. Appointments initially in grade of Scientific Officer (minimum age 21) with salary according to research experience, etc., in range £565–£995 p.a. (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D/514/6A. [1044

**PHYSICIST** or Electrical Engineer required by Ministry of Supply at R.A.E., Bedford, for design of precision electrical and electronic instruments for use in wind tunnel operation and for measurement of physical quantities in wind tunnels. 1st or 2nd class hons. degree or equivalent in Physics or Electrical Engineering, with at least three years post-graduate research experience. Appointment as Senior Scientific Officer (minimum age 26) with salary in range £1,075–£1,265 (superannuable). Forms from N.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A117/7A. Closing date 24th June, 1957. [1065

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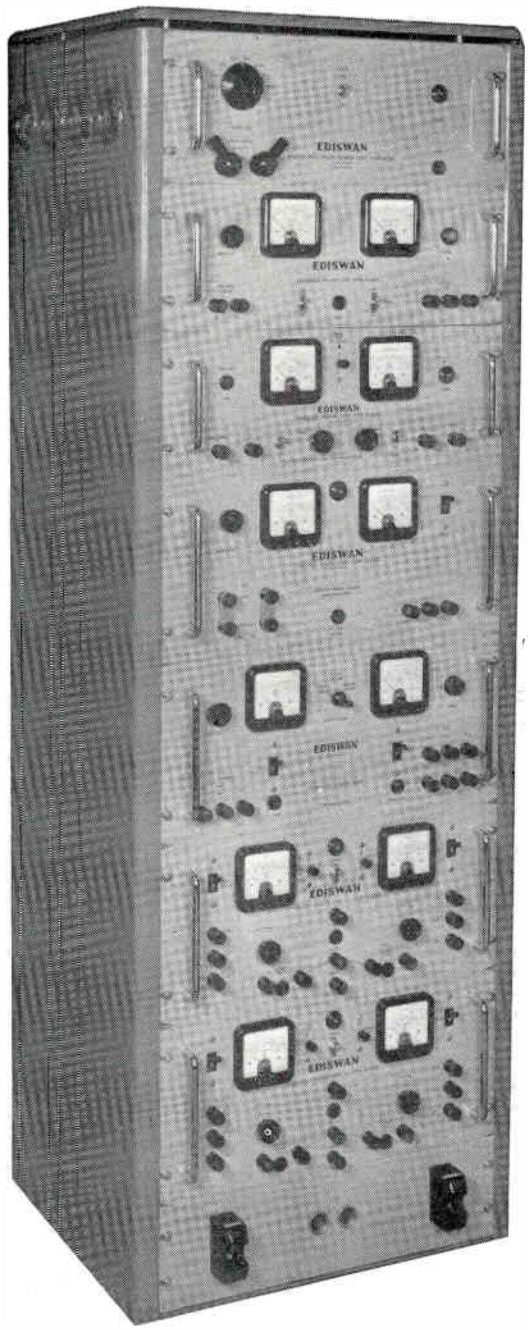


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