Wireless World

ELECTRONICS, RADIO, TELEVISION

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DECEMBER 1958

In This Issue

VOLUME 64 No. 12

PRICE: TWO SHILLINGS

FORTY-EIGHTH YEAR OF PUBLICATION

Offices: Dorset House, Stamford Street, London, S.E.1

Please address to Editor, Advertisement Manager or Publisher, as appropriate

Telephone: WATerloo 3333 (60 lines)

Telegraphic Address: "Ethaworld, Sedist, London."

PUBLISHED MONTHLY (4th Tuesday of preceding month) by ILIFFE & SONS LTD., Dorset House, Stamford Street, London, S.E.1. *Telephone* Waterloo 3333 (60 lines). *Telegrams:* "Iliffepres Sedist, London." *Annual Subscriptions: Home and Overseas,* £1 15s. 0d. *Canada and U.S.A.* $5.00. Second-class mail privileges authorised at New York, N.Y. BRANCH OFFICES: *BIRMINGHAM:* King Edward House, New Street, 2. *Telephone:* Midland 7191 *COVENTRY:* 8-10, Corporation Street. *Telephone:* Coventry 25210. *GLASGOW:* 26B, Renfield Street, C.2. *Telephone:* Central 1265. *MANCHESTER:* 260, Deansgate, 3. *Telephone:* Blackfriars 4412. NEW YORK OFFICE: *U.S.A.:* 111, Broadway, 6. *Telephone:* Digby 9-1197.

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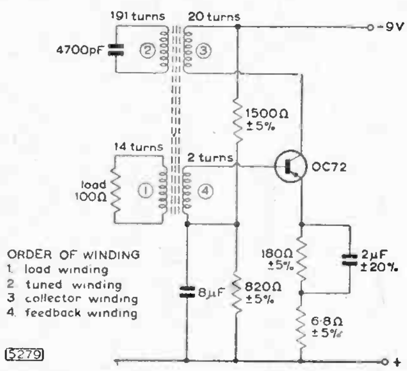
Transistor Bias Oscillator for Speech Recorder

Most magnetic recorders require a built-in oscillator to generate a bias supply. The bias signal restricts the recording action to the linear sections of the magnetisation characteristic of the recording medium, and thus eliminates distortion. The required bias is a symmetrical sine wave with negligible harmonic distortion; any departure from this ideal will tend to introduce noise in the recording and will produce some 'wasted' remanence.

Obviously, the frequency of the bias signal must be outside the audio range. It must also be high enough to avoid any possibility of beat effects, but not sufficiently high to cause demagnetisation. If the recorder is to be used for speech only—as in a dictation machine—an upper recorded frequency of 4kc/s is satisfactory, and the bias frequency can be about 20kc/s. The required power is of the order of 50mW, and the harmonic content should not exceed 5%.

Some very simple transistor oscillators can be built to meet these requirements. They tend, however, to be difficult to start, or to be rather too dependent either on the characteristics of individual transistors or on operating conditions.



PRACTICAL CIRCUIT

A slightly more complex practical circuit, built round the Mullard OC72 transistor, is shown in the diagram. It meets the specified requirements; it is self-starting; and the component values have been chosen to give reliable operation with any OC72. A battery supply of 9V is assumed.

The circuit behaves in a similar way to a valve oscillator, in which cathode, grid, and anode are analogous to emitter, base, and collector respectively. Energy is fed back through the transformer from the collector to the base in such a way as to maintain oscillation.

Automatic bias is applied by using a suitable value of capacitor across the emitter resistor. With the value shown, an OC72 with nominal characteristics will work in class B. A high-gain OC72 will tend towards class C, and a low-gain OC72 towards class A. Thus the circuit reduces the spread of output power which would occur with different samples of OC72, and prevents bottoming of high-gain transistors and consequent clipping of the output voltage waveform. Grounded emitter configuration is used, as this provides the required output power with the minimum of drive power.

TRANSISTOR OPERATING CONDITIONS

The component values and the design of the transformer are arrived at after consideration of the required working Q of the circuit and the collector voltage swing of the transistor. With a 9V supply an average collector-to-emitter voltage of 6V is assumed, leaving 3V emitter-to-ground. The loss of 3V in the emitter resistance is used to give good stabilisation of the d.c. working point and close control of the output power. Bias resistor tolerances, and incomplete bypassing of the emitter resistor, may cause a further loss of 1V. After allowing for transistor spread, a design value of 4.5V for the collector voltage swing is obtained. The load resistance at the collector is then, by calculation, 200Ω. An actual load of some other value (say 100Ω, as shown in the diagram) is accommodated by means of a suitably-designed secondary winding on the transformer.

With this value of load, the following transistor operating conditions are arrived at:

Average collector-emitter voltage	6.0V
Peak collector current	50mA
Mean collector current	15.9mA
Collector dissipation	39.25mW

The required frequency of operation is 20kc/s, and the ambient temperature can be assumed not to exceed 55°C.

The Mullard OC72 is well-suited to these requirements.

COIL DESIGN

The number of turns shown for the collector winding is calculated for a Mullard Ferroxcube pot core type LA1. A capacitance of 0.44μF would be required to tune this coil. Since this is too large and awkward a value, a tuned winding is added so that the more realistic value of 0.0047μF can be used.

For a load of 100Ω the load winding is given by

$$\frac{\text{No. of secondary turns}}{\text{No. of primary turns}} = \sqrt{\frac{100\Omega}{200\Omega}}$$

and similarly for other loads.

Calculation gives 1.6 turns for the feedback winding. The use of a practical 2-turn winding provides a margin for loss of drive voltage in the emitter circuit. The amplitude of the oscillation is determined by the small unbypassed emitter resistor, whose value is chosen to accommodate transistor spread. 30 s.w.g. en. cu. wire is used for all windings.

BIAS SYSTEM

The transistor is biased into a condition where the collector current is the mean current of the oscillator. Oscillation is set up, and the alternating energy fed back to the base is rectified at the base-emitter diode, producing d.c. which charges up the 2μF capacitor so that the mean base-emitter potential tends to zero. Only negative-going pulses at the base cause current to flow at the collector. The capacitor value is large enough to maintain oscillation but not so large that squegging will occur.

No appreciable a.c. potential is developed across the large capacitor in the base circuit. A 3V battery tap could be used, if preferred, in place of the potential divider and the capacitor.

PERFORMANCE

With a range of transistors showing the maximum published spread of current gain, the voltage at the collector in a prototype oscillator remained within ±7.5% of the design value, corresponding to a power output variation from 44.4mW to 59.5mW. The frequency of operation was 19.25kc/s.

Although the design is based on a 9V supply, the oscillator provides a good waveform with the battery voltage as low as 3V and as high as 14.5V. The battery voltage must not, however, exceed 9V where the ambient temperature is greater than 55°C. The output voltage varies linearly with the battery voltage.

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E.R.P.

JOURNALISTS are often chided for their use of clichés, but the automatic and unthinking use of a ready-made phrase or term is as prevalent in engineering circles as it is said to be in Fleet Street. Take e.r.p. (effective radiated power). Nowadays these cryptic letters always accompany the claims of transmitter manufacturers and broadcasting authorities, and there can be no doubt that they enable impressive figures to be presented for the inspection of their clients. But do these figures tell us anything? Only that the 10-kW transmitter with the complicated aerial on yonder hill is sending as strong a signal in our direction as a 100-W transmitter would do if the builders did not know how to make a directional aerial and had been forced to use a simple dipole. We recently saw a similar sort of advertisement for a domestic heating unit with reflector which said "375-W model, as effective as a 1,000-W fire." This does tell us something, because most of us have had experience of and can call to mind the degree of heat coming from an ordinary 1-kW fire element; but how many of us have tuned-in a 100-kW station radiating from a single dipole? Nowadays aerial designers can and do tailor the polar diagram to cover any given service area without waste or unnecessary interference with other stations. The e.r.p. is *still* quoted —not as a unique figure but as a range of values between limits. "You pays your money and you takes your choice."

Faute de mieux we shall no doubt go on quoting e.r.p.s in this journal when these are the only figures available, but whenever possible we shall endeavour to give a field strength map which tells the customer what he really wants to know—the order of field strength to be expected at the point of reception. We say "order of field strength" for, as G. Millington recently pointed out in his chairman's address to the Radio Section of the I.E.E., field contours, due to temporal variations and ground irregularities, can be plotted only on a statistical average basis, and "there will always be the unfortunate people to whom it is small comfort to be told that 99% of the people in their neighbourhood receive an excellent picture." Even so, a field strength map is much more informative than a statement of e.r.p.

The recent scare in the lay press about the possibility of radiation hazards from high-powered forward-scatter radio beams may have had its origins in the too facile acceptance of e.r.p. We were told that a 40-kilowatt transmitter when used in conjunction with a highly directional aerial might produce the equivalent of 40 *megawatts* in the beam. This is enough to frighten anyone—including the Ministry of Power, who might for a fleeting moment have wondered if their programme for building nuclear power stations had not been somewhat premature! In point of fact scatter stations have to use aerials of large aperture in order to produce a narrow beam; 4,000 sq ft would be quite a modest array, so that 40kW would not produce more than 10W/sq ft in the beam. A man standing in the beam might absorb 100 watts which would raise his temperature 0.04°F per minute only in the unlikely event of a breakdown in the normal temperature-regulating processes of his body.

In this instance a closer look at e.r.p. would have saved needless anxiety. There may be other clichés requiring overhaul or eradication before they become too firmly rooted.

Better Batteries

TO radio and electronic engineers who take their power supplies more or less for granted, batteries may seem a dull and messy subject—the province of chemists. But modern chemistry is itself more than half electronic, and the theoretical and technological studies which have contributed to recent improvements in battery performance owe much to the application of electronic methods of measurement and analysis. All the fundamental electrochemical couples used in batteries today were known before the end of the last century and the overall chemical equations had been worked out, but it is now known that these, more often than not, are gross oversimplifications and that the intermediate steps may have an important bearing on battery performance.

The symposium on batteries reported on another page was far from being a dull affair, either technically or socially, and discussion was carried far into the night at the hotels in Bournemouth where the delegates were staying. As Sir Owen Wansbrough-Jones (Chief Scientist, M.o.S.), pointed out in his opening address, a symposium of this kind is one of the quickest and best ways of disseminating the vast accumulation of new knowledge on any subject, particularly when the formal business is extended by "a drinking together" in the original meaning of the word. A passage from Francis Bacon's essay "Of Studies," also quoted by Sir Owen, seemed to us to be particularly appropriate to the occasion: "Reading maketh a full man; conference a ready man; writing an exact man."

Rigidity of Loudspeaker Diaphragms

Advantages of Sandwich Construction

By D. A. BARLOW, M.Sc.

It is well known that the diaphragm of the conventional moving-coil cone loudspeaker is far from rigid under normal conditions of use. The usual theory of the direct-radiator loudspeaker assumes that the cone is a rigid piston; under this condition, the response above the main low-frequency resonance is level (or nearly so) until a certain point, after which output drops off smoothly until it reaches a constant rate of 6 dB/octave (Fig. 1). In contrast, the measured response curve of the best cone speaker resembles the profile of a mountain range. It is known that at low frequencies, above the main resonance, the cone behaves approximately as a rigid piston, but above a few hundred cycles, breakup occurs and the cone resonates in innumerable ways, giving distortion, a ragged response, muddle, and out-of-phase effects. For these reasons, each speaker has its own characteristic tone or colouration. Further, transient response is poor. Shorter's tests[1] show that there is still a considerable sound output even 20 milliseconds after the signal has been cut off, and that in bad cases, at resonant points, the output after first falling may rise,

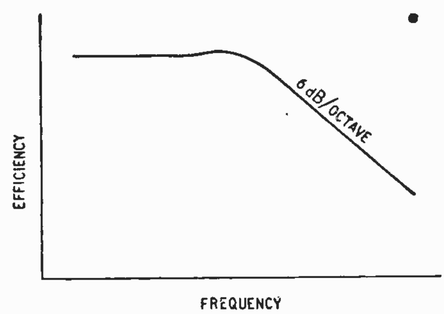

Fig. 1. Efficiency of a moving-coil loudspeaker as a function of frequency.

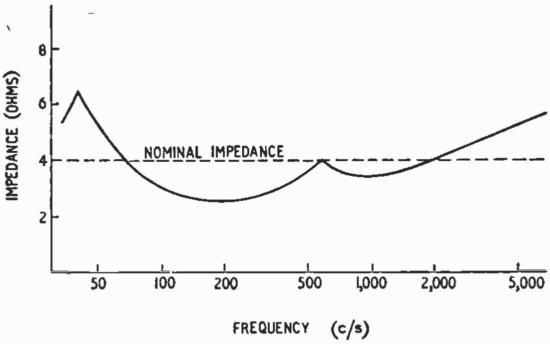

Fig. 2. Impedance curve of a composite cone loudspeaker.

approaching the steady-state output. The cone cannot be stiffened by increasing the weight as this is limited by the efficiency required and by the desired treble response. In an attempt to mitigate the effects of the breakup resonances, various devices, such as felt pads, foam surrounds etc. have been used to damp or spread the worst resonances over a broader range. Other devices include stiffening corrugations; these are often insufficient to prevent the resonances and as they also introduce compliances, they may introduce further resonances, worse than those which it is hoped to suppress. A soft paper cone with high internal friction is usually preferred to hard paper in an attempt to damp out the worst breakup resonances, even if there is some loss of treble response as a result.

Treble Response.—The efficiency of a direct radiator loudspeaker[2], assuming a rigid diaphragm, is given by

$$\mu = \frac{B^2 r_{ma} m_1}{\rho K_r \, (x_{ma}+x_{mc})^2 10^3} \times 100\%$$

where B = gap flux density in gauss

m_1 = voice coil mass in gm.

ρ = density of voice coil material in gm/c.c.

K_r = resistivity of voice coil material in microhms/c.c.

r_{ma} = mechanical resistance due to the air load in mechanical ohms (Values obtainable from ref. 2).

x_{ma} = mechanical reactance due to the air load, in mechanical ohms (Values obtainable from ref. 2).

x_{mc} = mechanical reactance of moving system, in mechanical ohms $= 2\pi m_t f$.

m_t = total moving mass in gm.

f = frequency in c/s.

(This assumes that the mechanical resistance in the diaphragm is small and that r_{ma} is small compared with x_{ma} and x_{mc}).

For a given size of diaphragm the values of r_{ma} and x_{ma} at any frequency are fixed so that the frequency response is then governed only by x_{mc}, i.e. by the total moving mass; the efficiency is fixed by the flux density, voice coil mass and material, and by the total moving mass. For speakers of conventional size and weight, say 8 to 12 in. diameter, the treble response will drop beyond 1 to 2 kc/s, assuming the diaphragm is rigid. In practice, because of cone breakup, the treble response will be much greater than the theoretical, making the commercial speaker with its adequate treble response possible, so that the lack of rigidity is not entirely an ill wind. However, where good quality is required, a speaker might well be judged on its lack of treble, rather than *vice versa!*

It is well known that speakers which are large enough to reproduce the bass frequencies adequately will not reproduce the extreme treble, and various devices are offered to increase the treble. One of the commonest is Voigt's twin cone[3] or variations of it. This consists of a small cone fixed to the centre of the main cone. If the large cone were rigid, it is obvious that the small cone would do nothing except add undesirable weight to the moving parts. However, as the main cone is not rigid or because compliances are deliberately introduced between the main cone and the driving coil, flexing takes place, so that the small cone and voice coil now act as a separate small speaker at high frequencies, moving independently of the main cone. In an alternative design, the small cone is joined at its outer edge to the inner edge of a large one by means of a compliance, forming a composite cone. The complete cone mass plus coil mass with the main suspension compliance will give the main low-frequency resonance, which as usual can be placed low enough to be unobjectionable. However, it is evident that the mass of the small cone plus coil with the suspension and the compliance at the edge of the small cone or with the flexibility of the main cone, will also resonate; this resonance must obviously fall in the audio range if the small cone is to take over from the large one in the audio range. Voigt's twin cone was designed primarily for horn-loaded speakers, where, unlike direct radiators, the resonance would be much less noticeable and perhaps very difficult to detect.

As an example of the resonance of a twin cone speaker, a 10in "high fidelity" speaker of composite cone construction was found to give reasonably satisfactory results on some types of orchestral music, but on piano, an intolerable "ringing" or echo occurred over a very narrow range—two semitones. An impedance curve was taken, using a high-impedance source, giving the result shown in Fig. 2. In use, in spite of a low-output-impedance amplifier, and in spite of alleged magnetic damping, including the use of an aluminium voice coil former, the 600-c/s, resonance was most prominent, as described. With different design, it might have been possible to place the resonance higher up, in the harmonics rather than in the fundamentals, and to provide mechanical damping, but the basic objection remains. Other devices having the same effect and open to the same objection are circumferential corrugations, central domes, etc. This idea may be extended further by means of a compliance on the voice-coil former, generally taking the form of a rubber or other resilient sleeve and an aluminium former, in which the former and coil are decoupled from each other at high frequencies by the sleeve. This device has the same objection of a resonance, even if it is highly damped.

Some manufacturers of high-quality speakers dislike twin cones and prefer to use separate bass and treble speakers with electrical cross-over networks. This method has the advantage that the resonance of the treble speaker (and the middle speaker, if any) can be placed well below its working range, independently of the cross-over frequency. Likewise, the coaxial speaker with electrical cross-over, using either a separate treble cone speaker or a horn loaded speaker, is free from the resonance objection of twin cone speakers.

The unsatisfactory performance of many conventional speakers is emphasised by B.B.C. experience[4]. Various manufacturers were invited to submit high-quality speakers for monitoring purposes. On test all except three models were rejected because of unpleasantness on some types of signal. Two of these were by the same manufacturer and were simple single-cone models of very early make, with limited treble response, the third being a wide-range speaker, this being the first occasion on which a wide-range speaker was found to be tolerable. Many devices used to extend the frequency response are worse than useless, as the distortion which they introduce* more than outweighs the advantage of the increased treble response. It is also apparent from these tests that most devices are better on some types of programme than others, and which device is the best of a more or less bad lot is largely a matter of personal preference.

The unsatisfactory performance of the direct-radiator moving-coil speaker has recently stimulated interest in other types of transducer, such as the ribbon, electrostatic, Ionophone and corona-wind speakers. In these, the driving force acts over the whole of the diaphragm (whether of metal, plastic, gas molecules or ions), so that diaphragm breakup does not occur. However, if the diaphragm of the moving coil speaker could be made more rigid, its performance might compare with those of other systems.

Diaphragm Stiffness.—The bending deflection of a diaphragm at any point under a given load is proportional to $(1 - \mu^2)/Et^3$ where

μ = Poisson's ratio

E = elastic modulus in bending

t = thickness

This holds for any given shape of diaphragm or condition of edge restraint, with two exceptions not likely to be met in practice. In a very thin diaphragm with clamped edges, deflection is largely governed by the stretching of the centre of the diaphragm, rather than by the bending, and in a very thick diaphragm, the bending deflection becomes small compared with that due to the shear stress. The effect of variation of μ^2 from one material to another

TABLE 1.
Moduli and densities of various materials

Material	Elastic Modulus in bending lb/sq in	Density lb/cu in	Modulus / Density	Modulus / (Density)^3
Steel	30 $\times 10^6$	0.28	107 %10^6	1.37 %10^9
Aluminium ..	10 „	0.096	104 „	11.3 „
Magnesium ..	7 „	0.063	111 „	28 „
Beryllium ..	37 „	0.067	552 „	123 „
Epoxy resin ..	0.5 „	0.045	11.1 „	5.5 „
Polystyrene ..	0.52 „	0.038	16.3 „	11.3 „
Kraft paper-phenol formaldehyde ..	2 „	0.052	38.4 „	14.2 „
Cone paper—hard	0.4 „	0.029	13.8 „	16.4 „
Cone paper—soft	0.15 „	0.015	10 „	44.5 „
Expanded ebonite	1,000*	0.0023	0.44 „	82 „
Expanded polystyrene	500	0.00058	0.86 „	2,560 „

*Surface skin from moulding removed.

*Or reveal?—Ed.

is small, so that this can be ignored and we may say that the rigidity of a diaphragm of given size, shape and edge condition is proportional to Et^3, and different materials may be compared on this basis. If the weight of the diaphragm is fixed, as it is by other considerations, the thickness will be proportional to 1/density, i.e. stiffness $\propto$ bending modulus/(density)^3. As no values were available for the paper used for cones, two samples were taken, one from a small speaker used in a portable radio, the other from the aforementioned "high fidelity" speaker. The densities were measured, and the bending moduli obtained from cantilever loading tests. Table 1 gives values of modulus and density for a variety of materials. It will be seen that for a given weight, the soft paper is considerably more rigid than the hard paper, so that there is no point in fitting hard paper cones, quite apart from any other disadvantages which they may possess. Further the plastic-impregnated paper, which is harder still, is even less rigid (for a given weight). There is still less advantage in using plastics or metals, except for beryllium. The best materials are those of very low density, is spite of their very low moduli. (The moduli of the expanded ebonite and expanded polystyrene were determined from cantilever loading tests.) The expanded ebonite, which is nearly twice as rigid as the soft paper cone of the same weight, has been on the market for 20 years, but the expanded polystyrene of density only 0.016 gm/c.c. = 1 lb/cu ft is a more recent product, used primarily for thermal insulation and is reasonably cheap. Both these expanded materials have a fine structure of non-connected pores, so that moisture absorption is small. The expanded polystyrene is naturally rather weak and has a compressive strength of only 10 lb/sq in, but this is quite sufficient with careful handling, as is necessary with any diaphragm. This material is nearly 60 times stiffer than the paper cone. Expanded phenolics are produced to a density as low as 1/3 lb/cu ft but this material does not appear to be available in this country at present; such a material is several times stiffer than the expanded polystyrene. However, there is a method of still further increasing the flexural stiffness.

Sandwich Construction.—In bending, the maximum stress occurs at the surfaces, so that by concentrating a stiff heavy material at the surfaces,

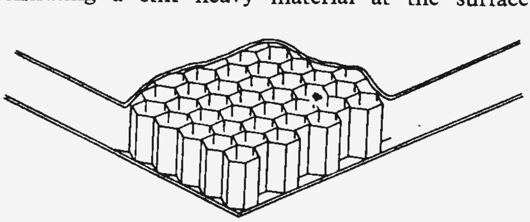

Fig. 3. Sandwich construction with a high stiffness/weight ratio

and using a lighter, weaker material for the core, a great increase in strength and stiffness can be obtained, the sandwich being far stiffer than the same total weight of either material used separately. This form of construction is increasingly used in aircraft, where it usually takes the form of sheet metal skins supported by a metal or plastic-impregnated paper honeycomb (Fig. 3). The honeycomb has the desired properties of high stiffness/weight ratio, with high compressive strength in the direction in which it is required, and is lighter than expanded plastics with the required strength. In a loudspeaker, honeycomb would be difficult to construct in the small sizes required, and as the maximum stiffness is required rather than maximum strength, the expanded polystyrene is the most suitable core material at present available. For the skins, the best material is that with the highest modulus/density ratio (unlike a solid material in bending), so that, as will be seen from Table 1, aluminium would be a convenient skin material. (Beryllium and also molybdenum, ruthenium, and rhodium have higher modulus/density ratios, but are hardly practical.)

The proportions of the sandwich are important, as there is an optimum ratio of skin thickness to core thickness for the maximum stiffness for a given weight. The equations for the bending stiffness of a sandwich have been put in convenient form by de Bruyne[5]:—

$$\text{Flexural stiffness of 1in wide strip of sandwich} = \frac{E_s}{12}\left[(2s+a)^3 - \frac{(E_s - E_a)\,a^3}{E_s}\right]$$

$$s_{opt} = w\left[\frac{\sqrt{g}-1}{2k+2e(\sqrt{g}-1)}\right] \qquad a_{opt} = \frac{w-2es_{opt}}{k}$$

$$\frac{a_{opt}}{s_{opt}} = \frac{2}{\sqrt{g}-1} \qquad g = \frac{1-E_a/E_s}{1-k/e} \qquad w = 2es + ka$$

$$\text{Flexural stiffness of 1in wide solid material} = \frac{Et^3}{12}$$

where a = core thickness, in.
s = skin thickness, in.
E_a = core modulus, lb/sq in.
E_s = skin modulus, lb/sq in.
t = thickness of solid material, in.
E = modulus of solid material, lb/sq in.
w = weight of 1 sq in of sandwich, lb.
k = weight of 1 cu in of core, lb.
e = weight of 1 cu in of skin, lb.

Compared with a 10-gm, 8in diameter 95° soft paper cone 0.022in thick, a cone consisting of an expanded polystyrene core 0.37in thick, clad with 0.00054in thick aluminium skins would be almost 3,000 times as stiff; if the wonder metal beryllium were available as 0.0008in thick skins on a core of expanded phenolic (1/3 lb/cu ft) 1.13in thick, the stiffness would be 150,000 times as great as the paper!

The stiffness of the sandwich is so great that it might well be made in the form of a flat disc for simplicity in construction and to give a plane wave front. With paper, on the other hand, a cone shape is necessary to give enough rigidity to make a speaker at all practical. The deflection of a cone under load is difficult to calculate, but from loading tests on a 95° paper cone (representing the most acute and therefore most rigid cone likely to be used in practice), it is thought that the average stiffness of the cone is about 140 times that of a flat disc of the same diameter and thickness. As the cone has a greater surface area, the disc can be made 1136 times the cone thickness, and the cone is then only $140/1.36^3 = 56$ times stiffer than the flat disc. A 10-gm disc of 0.50in thick core with 0.00073in thick aluminium skins would still be 53 times stiffer than the best 10-gm paper cone. This means that the amplitude of any breakup would be 34 dB below that of the conventional speaker. If poor transient response is due entirely to cone breakup, the output after cut-off of the transient test signal would be about 15 dB better than the electrostatic speaker; for a sandwich cone (in aluminium and expanded polystyrene), the hangover level would be 30 dB below that of the electrostatic speaker![6] However, in practice, the improvement will be considerable but not as large as this, as the resonances in the normal cone are already damped to some extent (i.e. the amplitude of movement is reduced) by the air.

Redesign for Maximum Rigidity.—Further improvement in diaphragm rigidity could be made by redesign. Thus in the conventional speaker, the cone is driven near its apex, so that the outer part of the cone is free to flap (Fig. 4(a)). If the driving force, i.e. the voice coil, were applied near the centre of the annular area constituting the cone, the reduced overhang of the free cone would give less flapping (probably only $\frac{1}{8}$), (Fig. 4(b)). Pursuing this to its extreme, the most rigid diaphragm would be a very narrow annulus of very large diameter (Fig. 4(c)). Narrow annular diaphragms have been used in horn loaded speakers, but the reason for this is to avoid phase differences in the throat chamber, rather than to increase the diaphragm rigidity. There is a limit to how far the voice coil diameter can be increased in a woofer speaker, as it makes less economical use of the magnetic gap. Thus to reproduce the bass, the amplitude is large and the voice coil must usually be much longer axially than the gap; as this length is therefore fixed, increasing the voice coil diameter must be accompanied by a reduction in the number of layers on the coil or the gauge of the wire. There is a practical minimum clearance in the gap, so that a single layer coil consisting of say 0.01in clearance + 0.01in former + 0.01in wire + 0.01in clearance uses only 25% of the gap flux; a small-diameter coil of say three layers of 0.01in wire uses 50% of the gap flux. Furthermore, it is doubtless more difficult to make a large-diameter voice coil than a small one to the required dimensional tolerances, thus increasing the minimum necessary clearances. Nevertheless, there are speakers with voice coils up to about 4in diameter, including one American design which uses an annular magnet to suit (Fig. 4(d)).

A further possible means of improving the rigidity would be to vary the thickness of the sandwich according to the stress distribution, so that the best use is made of the weight of material available. The bending moment is a maximum adjacent to the voice coil, so that the sandwich might be made thicker at this point, tapering to the rim. However, the rim tends to buckle, so that it needs to be thick, and there are also other stresses present. It would be a rather nice mathematical exercise to calculate the optimum profile, but it would probably approximate to uniform thickness.

Another way of increasing rigidity in the case of thin materials is by "rigidizing", i.e. the impressing of a dimpled pattern on a flat sheet—an extension of the idea of corrugation. It is well known that corrugation gives an increase in flexural rigidity in the longitudinal direction at the expense of the rigidity in the transverse direction. A dimpled pattern, rather like that of a papier maché egg container, is a sort of two-dimensional corrugation and gives an overall increase in flexural stiffness. With simply rolled designs in sheet metal, the stiffness can be doubled; where a deeper pattern can be used e.g. on moulded paper cones, a much greater increase of stiffness will be obtained. A dimpled cone in paper would not be nearly as stiff as a sandwich, but it would be a useful improvement and could be very easily done.

The stiffness of a sandwich diaphragm is so great

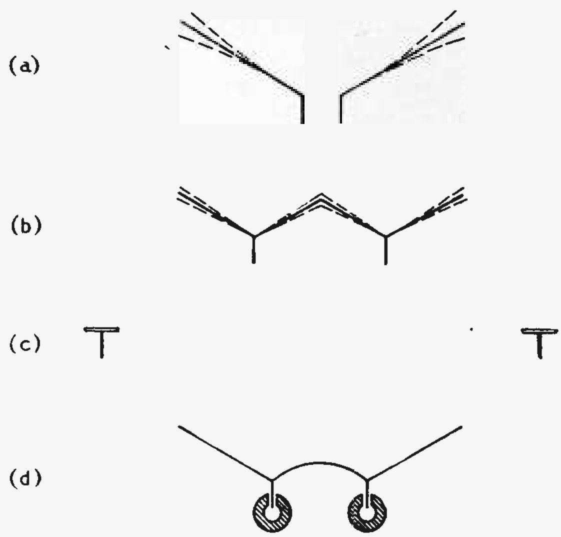

Fig. 4. Alternative diaphragm forms discussed in the text

that if full advantage is to be taken of it, the stiffness of the voice coil former may have to be improved. The coil former should obviously be as short as possible and for the smaller diameters, any part of the former above the magnetic gap could be plugged with expanded polystyrene, to reduce the tendency to buckle; the additional weight would be small. Clearance holes would have to be left in the plug to allow for the insertion of feelers when centring. Any increase in thickness of the voice coil former in the gap would of course increase the size of magnet required. Perhaps the best way to increase the stiffness without increasing the thickness would be to wind a tube from copper (or aluminium) foil, bonded and insulated with epoxy resin. This would form a combined voice coil and former and would be stiffer and stronger than one made from edge-wound ribbon or square wire. The diaphragm could be cemented directly to the foil coil. The impedance of the foil coil would be low and might need an additional transformer for matching. The portions of the foil coil outside the gap would presumably act as shunt resistors, in contrast to the usual long wire coil, where the unused portions act as series resistors. The effect of a shunt resistance is increasingly to short-circuit the active portion of the coil as the frequency is raised, due to the rise in impedance of the active portion; this might not be serious in a woofer, and must occur to a lesser extent in those speakers with metal voice-coil formers or a shorting ring on the pole piece—in fact the reduced rise in impedance claimed for

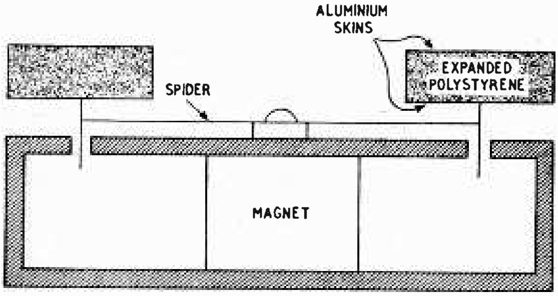

Fig. 5. Proposed design for a low-frequency "woofer" loudspeaker.

these speakers must be due to just this shunting of the voice coil.

Proposed Design of Sandwich Speaker System.—We have seen that the response of a rigid diaphragm woofer of say 8-12in diameter will start to fall beyond 1-2 kc/s. To handle power down to 1 kc/s, a 2in diameter speaker is about the smallest practicable size, and this will start to drop off around 7 kc/s; the extreme treble to 15 kc/s could be provided by a 1in diameter tweeter.

The woofer (shown diagrammatically in Fig. 5) would have a flat 8in diameter annular diaphragm consisting of 0.001in thick aluminium foil skins glued with epoxy resin to the 0.67in thick expanded polystyrene core. The voice coil would be 2 gm of copper wire, and could be 6in diameter (or smaller if necessary). The diaphragm would be supported entirely by a suitable spider glued to the voice coil former—no edge compliance would be required, nor plastic foam "to provide matching acoustic terminating impedances," etc. If necessary, a loose cloth surround could be fitted to reduce air leakage. As there is no edge restraint, a front spider of identical characteristics to the rear spider would be desirable, fixed to the voice coil to avoid stressing the diaphragm; without the front spider, the diaphragm will tend to droop under its own weight when used in the vertical position (as it usually is); a front spider might be avoided if the rear one could be placed at the centre of gravity of the moving parts. It might be necessary to shape the pole pieces to avoid trapped air and "boxiness". With a flux density of 10,000 gauss, and a total mass of say 16 gm, the efficiency would be about 2% and would be 3 dB down at 1.5 kc/s.

There is no way of appreciably increasing the treble response of this speaker. Thus if aluminium is substituted for a copper voice coil, weight for weight, ρK_r is halved and the efficiency doubled but the response is unaltered. The volume of the aluminium will be about 3 times that of the copper, and will therefore require 3 times the size of magnet to maintain the same flux density; in most cases it would be better to use any extra magnet to increase the flux density and retain the copper voice coil. If alternatively, aluminium is substituted volume for volume, the coil mass is now about 1/3 and ρK_r is $\frac{1}{2}$, so that the efficiency is only 2/3 of that with a copper voice coil and the same size magnet; the treble response is very slightly improved due to the slight reduction in the total moving mass. There is no advantage therefore in using an aluminium voice coil with a rigid diaphragm bass speaker. The reason that the use of an aluminium voice coil extends the treble response in a conventional speaker is because the treble is radiated largely by the apex of the cone; the voice coil is thus relatively heavy compared with the effective moving cone mass (at high frequencies). Any reduction in the mass of the voice coil will therefore appreciably reduce the total effective moving mass at these frequencies, so that treble cut off is delayed. This also applies to small speakers, where the voice coil mass is usually a large proportion of the total moving mass.

The skins of the proposed woofer sandwich weigh about 3.5 gm, the core weighing 6.5 gm. As the skins are so thin, the weight of the glue layer will be appreciable, and will also add to the stiffness. Somewhat thinner skins might thus be used, with the thinnest possible glue layer. However, if the full calculated modulus is to be obtained, there must be complete adhesion over the whole area of foil and core; a test on a sandwich with a very thin glue layer, giving incomplete adhesion, showed a modulus of only $\frac{1}{4}$ of the calculated value, although the sandwich was still 750 times stiffer than cone paper of the same weight. The aluminium skins could be omitted, the core being given a thick lacquer coating, 0.002in. or solid skins of polystyrene formed on the foam during moulding—indeed the expanded ebonite normally has such a solid skin as a result of the method of manufacture; unfortunately as the modulus/density ratios of plastics are low, the stiffness would be only about $\frac{1}{8}$ of that of the aluminium skin sandwich. A possible means of avoiding the weight of the glue layer would be to expand the polystyrene directly on to the metal foils; polystyrene does not adhere very well to metals, but as the stresses involved are small, a good enough bond for this purpose might be obtained. Alternatively, epoxy resin, which gives an excellent bond, could be expanded directly on to the foils; the minimum density so far obtained with epoxy resins is about 3 lb /cu ft, and at this density, the material is extremely weak, but with further work, lower densities with higher strength could almost certainly be obtained. Other methods of avoiding the weight of the glue layer would be by electroplating (on to a chemically silvered surface). However, the desired metals are not readily plated or are expensive, and the surface of the polystyrene would have to be fairly smooth. Vacuum vapour deposition of aluminium would be preferable, but again a smooth surface would be required.

The 2in middle speaker, taking over above 1 or 1.5 kc/s would ideally consist of an expanded polystyrene disc 0.17in whick with aluminium skins 0.00024in thick. The weight of the diaphragm would be 0.16 gm, with a 0.1-gm copper voice coil, and allowing 0.14 gm for former etc., the efficiency would be about 2% at 14,000 gauss; the treble response would be 3 dB down at 5.5 kc/s. The 1in diameter tweeter, taking over above 5 kc/s, requires a coil weight of only 5 mgm aluminium and a diaphragm + former etc. weight of only 25 mgm with a flux density of 14,000 gauss. The sandwich would ideally consist of a disc 0.05in thick with aluminium skins only 0.00007in thick, giving a weight of 13 mg. The efficiency would be about 2% (at 5 kc/s) and would be 3 dB, down at 13 kc/s and 5 dB down at 15 kc/s.

The sandwiches required for the middle and treble speakers would be difficult to make, especially as the expanded polystyrene, as at present produced, is not too homogeneous. As it is made by the expansion of granules, the density of each granule varies and there are voids between granules. Doubtless a more suitable structure could be obtained and the easiest way of making diaphragms for treble speakers might be to mould the material to give thin solid skins, like the expanded ebonite.

Use of Rigid Foam Plastic.—DeMars[7] has used a square of rigid foam plastic fixed in front of a normal cone speaker. There is an American "Racon" speaker in which radial strips of rigid foam are fixed to the back of the cone to reduce breakup. The German "Zellaton"[8] speaker has a metal foil cone, backed with foam plastic, followed by varnish; whether the plastic is rigid or flexible is uncertain. With this possible exception, there appears to be no commercial speaker in which full use has been made of sandwich construction and the materials available.

Other Applications for Sandwich Construction.—In addition to increasing the stiffness of the diaphragm without increasing the weight, sandwich construction could be used for reducing the diaphragm weight without reducing the stiffness. In this way, a thin sandwich diaphragm could be made of the same stiffness as a conventional cone, but a fraction of the weight. The total moving mass would then be less than half the normal, increasing the extreme treble output by 4 times and the bass by 2½ times. The advantages of increased efficiency of commercial speakers without deterioration of quality are obvious.

A flat sandwich diaphragm would be useful where the speaker must be compact and shallow, as in some television sets and small radios.

Sandwich construction could also be used to advantage in horn-loaded speakers. The diaphragms of horn speakers are often smaller and more rigid than those of direct radiators and the resonances are more heavily damped; this is one of the reasons for the superiority of horn speakers. A further increase in diaphragm stiffness would still be very desirable.

The diaphragms of microphones, earphones and soundboxes would likewise benefit from sandwich construction. In this case, the optimum sandwich would be impractical, but a useful increase in stiffness and/or reduction in weight would be possible.

Horns, baffles and cabinets, particularly those which are required to be portable, could with advantage be made in sandwich form. In the case of cabinets, if the core material has inter-connected pores, giving good sound absorption, the inner skin could be perforated, the sandwich thus providing its own sound absorbent lining.

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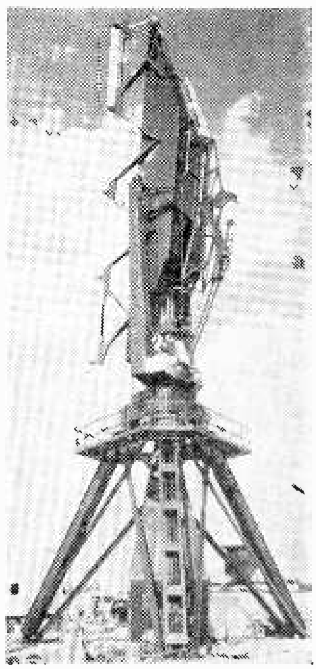
NEW RADAR AERIAL

EASILY ERECTED SELF-ALIGNING HEIGHT-FINDER

ONE of the radars shown at a recent "open day" held by Marconi's W/T Co., Ltd., at Rivenhall aerodrome uses the imposing aerial shown in the accompanying photograph. It is designed for extreme ease of erection, the only "machinery" needed being three hand-winches and a pole long enough and stout enough to support the turning gear and the reflector assembly. This 49-ft high aerial belongs to the S244 long-range S-band height-finder, which can use the SR1000 3-MW transmitter/receiver shown at the SBAC exhibition in 1957. In designing the aerial and its support Marconi engineers came up against the old radar height-finder bugbear—accuracy. They point out that 2000 ft at 200 nautical miles corresponds to an angle of only 6 minutes. This would be the error caused by a 0.2-in deflection in a 10-ft high supporting structure and to overcome this source of inaccuracy, to which other system errors might add, a ridiculously strong and heavy support is required. The solution adopted for the S244 aerial is to design the supporting members for normal mechanical considerations and carry "level ground" up to the elevation-angle measuring device by a pair of light rods so that their points of attachment to the ground and to the elevation-angle sensor form a parallelogram. With this construction, deflection of the aerial-support members cannot cause errors in height measurement.

The aerial can slew through 180° and come to rest in 3 seconds and it nods at one up-and-down cycle per 1¼ seconds. The nodding angle is adjusted automatically by the range of the p.p.i. echo so that the aerial does not nod over an unnecessarily wide angle. The nodding rate, however, is kept constant so that a greater number of radar hits per second is achieved on distant targets. With its companion display unit (type SD1050) there is no difficulty in taking fifteen height readings per minute. The aerial can be used for volumetric scanning.

The overall, absolute height accuracy of the S244 is better than ±1,700 ft at 150 nautical miles and the equipment meets the requirements of the appropriate British Inter-Service Specifications.



SA113 aerial for new Marconi S244 height-finding radar.

Developments in Batteries

TOPICS DISCUSSED AT THE RECENT S.R.D.E. SYMPOSIUM

A SYMPOSIUM on batteries, sponsored by the Interdepartmental Committee on Batteries of the Ministry of Supply and held at the Signals Research and Development Establishment in October, was the first of its kind to be held in Europe. It was attended by well over 100 representatives of Government departments, universities, and battery manufacturers, including delegates from the U.S.A., Canada, Australia, Germany, Italy and Norway.

Most of the 30 papers read during the three days of discussion were concerned with practical aspects of the development and utilization of batteries, but pure research was not neglected. The application of modern electronic techniques in electrochemical research is significant. A typical example is the use by Drs. M. Fleischmann and H. R. Thirsk (University of Durham) of wide-band high-gain feedback amplifiers to stabilize the electrode potential difference when studying the rate and nature of phase changes at electrode surfaces. By recording and analysing the current transient under constant potential conditions they have been able to differentiate between the processes of nucleation and growth in the deposition of metals and oxides or insoluble salts on a reacting metal anode and to study phase changes involving electron transfer within the deposit.

Technological advances in the manufacture of batteries are continually being made as a result of applied research, and the various items of interest brought out in the discussions are perhaps best collected under the headings relating to the principal battery types now in use.

Primary Batteries: *Leclanché "Dry" Cells.* The normal average shelf life of these batteries is about nine months and much work has been done to extend this period. D. H. Collins (Admiralty Engineering Lab.) described tests with thin polythene cases which pass hydrogen but stop water vapour. These gave much longer storage life and showed that loss of water is a prime cause of deterioration; spontaneous erosion of the zinc also uses up cell water. Experiments with cold storage had confirmed the results obtained by Hellfritsch (U.S. Naval Ordnance Laboratory) and batteries which had been kept at 0°C for three years gave unimpaired performance when discharged at normal temperature. The equivalent of cathodic protection to inhibit zinc corrosion had also been tried by applying a counter e.m.f. during storage, giving currents of 1 to 5μA in h.t. batteries and 30μA in U6 cells. The results in the case of h.t. batteries were inconclusive, but there was definite deterioration in the U6 cells under charge, and greater than normal deterioration when the cells were kept for a further period without charging. The work of Kobe and Graham (1938) on the use of Leclanché cells as secondary cells has been repeated and extended and it was found that a U2 cell had a capacity of 0.1 Ahr with a charge-discharge rate of 0.1A and a life of 4 to 10 cycles. It was confirmed that there was a liberation of chlorine during this process which combined with the manganese in the "dolly" and represented an irreversible self-discharge reaction limiting the life of the cell.

The composition of the zinc used in Leclanché cells is important. Zinc of high purity was first used for extruded cans on account of its greater ductility, but gave the worst results from the point of view of perforation in storage. F. Aufenast (Ever Ready) reported investigations leading to the choice of 1% lead, 0.05% cadmium alloy. This alloy produces a small metallic grain size which prevents deep penetration of the mercury during amalgamation and gives a high surface concentration.

The origin of the manganese dioxide used as a depolarizer is also important, and F. M. Booth (S.R.D.E.) showed that electrolytic MnO_2 gave a discharge life more than twice that of natural ore, due partly to the maintenance of a higher terminal voltage on load. The cost of pure MnO_2 is, however, about four times that of the natural product.

Storage life of so-called "inert" cells is related to the residual moisture before sealing and Dr. R. E. Bauer (Australian Defence Standards Laboratory) described the "Tarana" multi-cell battery in which a shelf life of at least ten years has been achieved by vacuum drying at 50°C and pressures down to 1 mm Hg.

Magnesium cells. These are of similar construction to Leclanché cells but the consumable energy-producing electrode is of magnesium instead of zinc. W. A. Nattrass (Burndept, Ltd.) pointed out that for a given energy output the weight and cost of magnesium metal were approximately $\frac{1}{5}$ and $\frac{1}{4}$ those of zinc. The magnesium cell gives a higher terminal voltage (1.8), a flatter discharge curve than the zinc cell, and has a longer storage life and better low-temperature performance. The high chemical activity of magnesium presents corrosion problems and the surface is passivated by a film of magnesium bromide during storage. This results in a voltage delay when the outer circuit is closed while the film is being temporarily dispersed. Other electrolytes have been tried including nitrates, other halides and alkaline earth salts, but none has so far proved to be better than magnesium bromide.

Mercury Cells. These consist of a zinc anode (negative pole) and a mercuric oxide cathode (positive pole) in an electrolyte of potassium hydroxide, and the energy is derived from simultaneous oxidation of the zinc and reduction of the mercuric oxide. The theoretical capacity is related to the weight of zinc and is 820 mAhr per gramme; in practice the efficiency approaches 100%. In the RM cell described by R. R. Clune and N. Naylor (Mallory Batteries) the cathode is an inner cylinder of pressed amalgamated zinc powder spirally wrapped by a cellulosic material impregnated with potassium hydroxide saturated with zinc oxide. An outer cover of micro-porous synthetic film prevents migration of mercury from the cathode compartment. The cathode-depolarizer element is an intimate mixture of HgO and graphite and is above the equivalent weight for total anode consumption to ensure that there is no significant gassing. In the "Kalium" version described by G. Matthews (Burndept) the outer electrode is the anode and consists of granulated zinc supported on layers of Whatman filter paper. The electrolyte is potassium hydroxide with the addition of potassium zincate to reduce anode attack. The cathode consists of a carbon-mercuric oxide mix, pressed into pellets and housed in a porous wrap with a central carbon current collector. An important advantage of the mercury cell is its low internal resistance, which is of particular advantage in transistor circuits. The Mallory RM625, for instance, has an impedance of less than 2 ohms at 1kc/s at the 5mA discharge rate.

Water-activated Cells. These can be stored indefinitely and consist of a magnesium anode and a silver chloride or cuprous chloride cathode in intimate contact with the base metal. When activated by sea water or any suitable aqueous electrolyte the chloride is reduced and the magnesium goes into solution as chloride. M. J. H. Lemmon and W. E. Casson (McMurdo Instruments) described a wide range of batteries of this type for use on lifebuoys, emergency flare path markers, and igniters for underwater weapons. They pointed out that where expense is not the first consideration, silver chloride is preferable as it is ductile and easily handled; it also delivers its maximum voltage without a time delay. Current densities of well over 150A/sq ft are possible with silver chloride even in freezing water, but cuprous chloride is limited to only about a third of this. K. Jones (Burndept) reported developments in h.t. batteries of the cuprous chloride water-activated type in which a stacked construction of copper cups is used. A cuprous chloride-graphite mixture is pressed into each cup and a magnesium disc, copper plated on one side, is soldered to the outside. The battery gives 80mA at 150V for two hours with a flat discharge curve. The graphite is added to give increased conductivity and in l.t. cells has been found to give a higher starting e.m.f., probably because of adsorbed oxygen.

Lead Peroxide Cells. These are "single-shot" primary batteries which in some ways resemble accumulators not only because of the lead peroxide cathode, but because they often use sulphuric acid as the electrolyte. The anode is of zinc or cadmium instead of lead and their virtue is that they are instantly available when the electrolyte is added. An alternative version uses a magnesium anode in a neutral salt solution and is virtually a water-activated type. H. P. Rain (Chloride Electrical Storage) described S.D.R. (short duration reserve) batteries for guided missile test vehicles using cadmium anodes designed to function when spinning at up to 1,000 r.p.m. and with accelerations up to 100g. The performance is actually better when spinning as the gas is pushed away from the plates. Currents of 0.6 to 0.9A/sq in and capacities of 17Whr/lb are realizable.

Secondary Batteries: *Lead Acid.* Dr. M. Barak (Chloride Electrical Storage) in a masterly and comprehensive survey of fundamental problems in the development of storage batteries showed how the lead acid accumulator still holds a unique position in fulfilling the basic requirements of (a) high free energy content, (b) high cell voltage, (c) highly ionized electrolyte, (d) open-circuit stability, (e) high degree of reversibility (large number of charge-discharge cycles), (f) cheap and easily fabricated materials. Among recent advances the use of micro-porous p.v.c. or rubber separators instead of wood is one of the most important as it not only gives greater mechanical and chemical stability, but a better volumetric efficiency (the acid plays an active part in the fundamental chemical reactions).

Much attention has also been given to the effect of migration of the antimony which is usually alloyed with the lead plate grids to give rigidity. This tends to plate out on the negative electrode and causes corrosion. It may also combine with the nascent hydrogen during excessive gassing with a high cell voltage to form the poisonous gas stibene, but investigations by Dr. R. Holland (Admiralty Engineering Laboratory) indicate that if normal ventilation precautions are taken to prevent the accumulation of explosive quantities of hydrogen the stibene hazard is unlikely to be serious. Work on alternative alloying materials reported by N. L. Parr, A. Muscott and A. J. Carter (Admiralty Materials Laboratory) points to a 3% tin, 0.1% barium alloy as giving the best combination of stiffness, creep strength, resistance to stress corrosion and good casting properties. Plastic grids are also being developed and tests by F. M. Booth (S.R.D.E.) point to the form in which a polystyrene grid is threaded by lead "spines" connected to a top bar as being a satisfactory type.

Problems of charging batteries under arctic conditions were discussed by R. T. Foster (Joseph Lucas Research Labs.). Due to the high viscosity of the acid at low temperatures, gas cannot readily escape and frothing forces the electrolyte out of the cell. To heat the electrolyte without causing gassing, a.c. currents of the order of 30 amps can be passed through pairs of batteries with positives connected to the outer ends of a centre-tapped transformer secondary. The normal d.c. charging current is then applied through the centre tap to both batteries. In aircraft the problem is to keep the temperature down and to prevent "run away" boiling of the electrolyte at the top of the charge. G. A. Earwicker (R.A.E.) has made a special study of this problem and has shown that in lead acid batteries the heating is mainly due to electrolysis of water and that the cell "over-voltage" at which this starts can be raised by eliminating antimony from the grid alloy.

Alkaline Batteries. Considerable interest has been shown recently in hermetically sealed accumulators of the nickel-cadmium type. Normally both oxygen and hydrogen are evolved from these cells, but H. Bode, K. Dehmelt and H. von Döhren (Accumulatoren-Fabrik A.G.) showed that, by precise proportioning of the active electrode masses, cells can be formulated to meet conditions of over-charging only or both over-charging and over-discharging. Briefly, free oxygen evolved at the cathode is caused to migrate to the anode, where it recombines with hydrogen by any of three known chemical or electrochemical processes. Provided that there is an excess of chargeable active material, $Cd(OH_2)$, at the anode an equilibrium between the formation and removal of oxygen is established and the evolution of hydrogen is completely suppressed.

Silver-Zinc. Although more expensive than other types, this accumulator is coming very much to the fore in military and other applications where high power/weight and power/volume ratios are the first consideration. More accurately, it is an alkaline silver oxide-zinc cell in which there is simultaneous reduction of the positive plate and oxidation of the zinc negative on discharge. C. L. Chapman (Venner Accumulators) discussed the problems of plate design and the necessity of using compressed or sintered forms for both positive and negative to increase surface area. The separator is of vital importance and must prevent penetration of zinc through minor imperfections in the separator, leading to reduction of silver oxides and hard growths of a solid solution of zinc and silver on the positive plate surface. I. A. Dennison and R. B. Goodrich (Diamond Ordnance Fuze Laboratory, U.S.A.) described special silver-zinc primary batteries with auxiliary heating for use at low temperatures. They pointed out that the intrinsic low temperature performance could also be improved by meticulous removal of all traces of zinc oxide film from the negative plate before the addition of electrolyte.

Special Systems: *Radiation Cells.* Dr. A. M. MacSwan (Plessey) discussed the theory of semiconductor junctions irradiated by light which pointed to gallium-arsenide and cadmium-telluride as cell materials having the best theoretical performance. The importance of keeping the junction close (0·0001 in) to the cell surface was emphasized. Efficiency could be increased by using a coating with a refractive index intermediate between that of the cell material and free space, to reduce reflection loss. Dr. E. J. Casey (Defence Research Laboratory, Ottawa) reported studies of the possibility of direct conversion of radiation energy into electricity by splitting water into H and OH ions and utilizing their reducing and oxidizing energies in suitable electrodes. The equivalent redox (reduction-oxidation) potential under gamma and high X-radiation had been measured and found to be of the order of $0{\cdot}85 \pm 0{\cdot}03$ volt.

Fuel Cells. The oxidising and reducing processes which bind and free electrons and give rise to currents in ordinary wet batteries can operate also in the gaseous state and are present when fuels are "burnt" under controlled conditions. C. G. Conway (Ministry of Power) and Dr. H. H. Chambers (Sondes Place Research Institute) read a paper on a cell designed to use a variety of fuels (e.g., hydrogen, carbon monoxide, methane and paraffin vapour). The cell consists of a porous solid electrolyte (mixture of sodium and lithium carbonates) with porous silverized zinc oxide electrodes. The gas is fed to one electrode, and air to the other with a proportion of CO_2 to maintain the carbonate. At temperatures of the order of 500°C there is ionic migration in the electrolyte giving a cell voltage of between 0·2 and 1·3 and current densities up to 150A/sq ft. A 64-cell generator with a nominal output of 2½kW has already been built with a thermal efficiency of 70%.

Transistor Tape Pre-Amplifier

Use of Head Inductance in a Feedback Circuit

By P. F. RIDLER, B.E., A.M.I.E.E.*

THE magnetic tape reproducing head is essentially a voltage generator producing an electromotive force which is proportional to the rate of change of magnetic flux in its core. As the maximum flux is controlled by the saturation density of the tape material ($\hat{B}$) and is thus a constant, the head output is proportional to frequency, rising at the rate of 6 dB per octave up to a point where other factors,

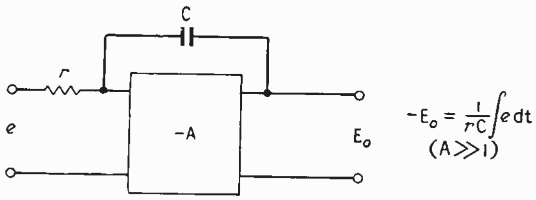


Fig. 1. Resistance-capacitance feedback integrating circuit.

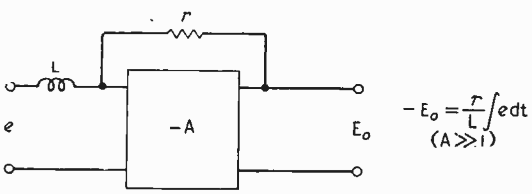


Fig. 2. Inductance-resistance dual of the circuit of Fig. 1.

such as self-demagnetization of the tape and core and gap losses in the head, become important.[1]

The normal type of pre-amplifier requires a high input impedance so as to measure the true e.m.f. induced in the head, and must also provide some form of equalization to transform the rising output characteristic into one which is flat with frequency. These two requirements are both inimical to a high signal to noise ratio; the high input impedance tending to give high thermal agitation noise and electrostatic pick-up of mains hum, while the greater gain required at low frequencies for equalization emphasizes any mains hum which is picked up.

The signal recorded on a tape under constant current conditions is

$$B = \hat{B} \sin \omega t \qquad \ldots \quad (1)$$

and the reproduced signal at the head terminals must therefore be

$$-e = k\frac{dB}{dt} = k\hat{B}\cos \omega t \qquad \ldots \quad (2)$$

where k is a constant depending on the head construction.

If, however, the signal from the head is integrated, the output of the integrator will be

$$-\int e\,dt = k\hat{B} \qquad \ldots \quad (3)$$

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i.e. the original signal multiplied by a constant (k).

There are two well known integrating circuits, one of which, the resistance capacitance feedback amplifier (Fig. 1), is a high-impedance, voltage-operated device, while the other, the inductance resistance dual (Fig. 2) is low impedance and current-operated.[2] The latter is the obvious choice, as with a low-impedance circuit it is easier to obtain a high signal to noise ratio, and the inductor necessary is already provided by the head itself. As this form of integrator is current-operated, transistors are ideal for its active elements and they have the added advantages of negligible microphony and hum.

An analysis of the integrator of Fig. 3 produces the result.

$$-E_o = e\,\frac{rR_m}{rz + j\omega L\,(R_m + r + z)} \qquad \ldots \quad (4)$$

and if $rz \ll \omega L\,(R_m + r + z)$,

$$-E_o = e\,\frac{rR_m}{j\omega L\,(R_m + r + z)}$$

$$= \frac{rR_m}{(R_m + r + z)} \cdot \frac{e}{j\omega L}$$

$$= \frac{rR_m}{L(R_m + r + z)} \cdot \int e\,dt \qquad \ldots \quad (5)$$

where R_m is the transfer resistance of the amplifier
z is the input resistance of the amplifier
r is the feedback resistance
L is the inductance of the tape head.

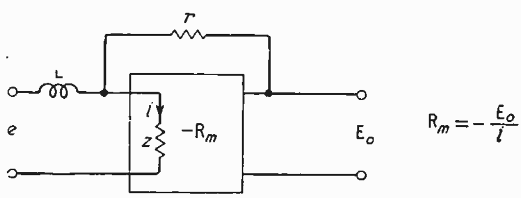


Fig. 3. Another version of the circuit of Fig. 2.

The circuit of Fig. 4 shows a two-stage direct-coupled amplifier in which the feedback path from the second emitter to the first base is direct coupled, enabling the d.c. working point of the first stage to be stabilized against temperature changes at the same time as the signal feedback path is provided.[3]

Using general-purpose a.f. transistors having a β of 30 and an α cut-off frequency of 500 kc/s, the transfer resistance was $4 \times 10^5\,\Omega$ and the input resistance without feedback $1 \times 10^3\,\Omega$, so that with a head inductance of 0.5 H, the approximation in equation (5), is satisfactory to a frequency well below the point where the coupling capacitor causes low-frequency attenuation. The output is taken from the collector load for the sake of the additional voltage-

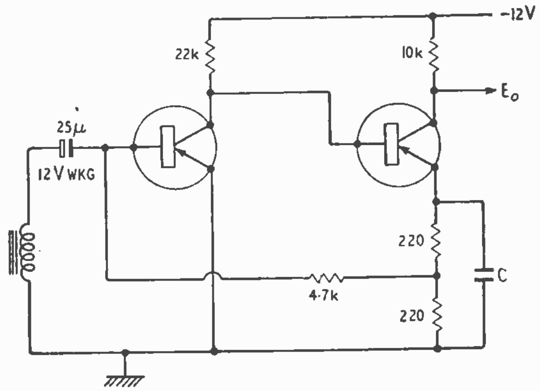


Fig. 4. *Practical transistor temperature-stabilized amplifier corresponding to Fig. 3.*

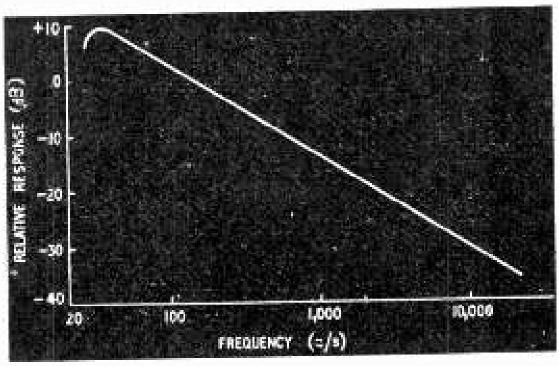


Fig. 5. *Frequency response of the amplifier of Fig. 4 with capacitance C zero.*

gain available. The curve of Fig. 5 shows the overall response, which was obtained by feeding a constant 25mV from a 10Ω source in series with the head.

The C.C.I.R. standard playback curve for a tape speed of 7½in/sec provides for a bass boost of 100μsec time constant, and this can easily be built into the circuit by connecting a capacitor (C) across the feedback source to decrease the loop gain above 1600c/s. The curve of Fig. 6 shows the response with a capacitance of 0.25 μF connected between the top of the emitter resistor in the second stage and earth. The regenerative peak at 15 kc/s is due to phase shift in the transistors and can be eliminated, as

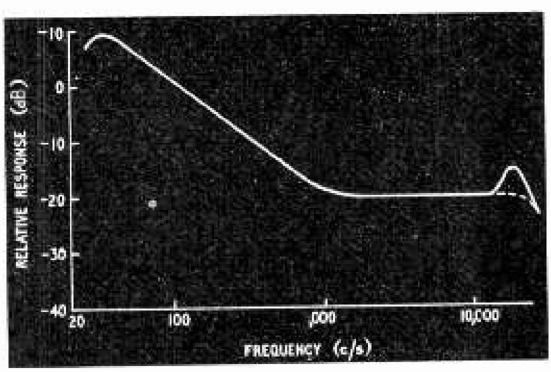


Fig. 6. *Frequency response of the amplifier of Fig. 4 with capacitance C equal to 0.25 μF.*

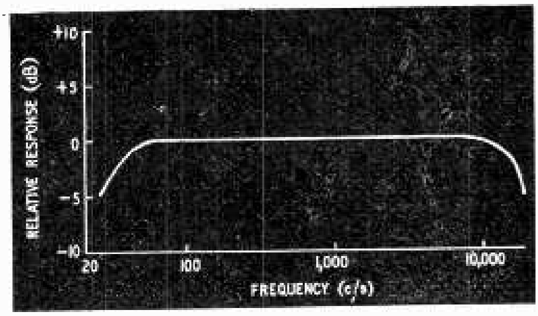


Fig. 7. *Frequency response from a standard test tape using the amplifier of Fig. 4.*

shown in the dotted curve, either by using transistors with a higher cut-off frequency, or by connecting a small resistance in series with the capacitor. On the other hand it may be desirable to use this peak to compensate for the high frequency gap and core losses of the head, and in the writer's case a series resistance of 33 Ω gave a peak of 5 dB at 15 kc/s which compensated for the head losses exactly.

The response to a test tape recorded to C.C.I.R. standards is shown in Fig. 7, and is flat from 50 c/s to 15 kc/s within ± 2 dB. The signal to noise ratio was greater than 70 dB at maximum signal even without choosing the transistors for low noise level.

REFERENCES

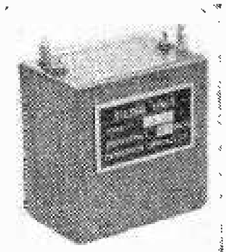
[1] Daniel E. and Axon P. *Proc. I.E.E.*, 1953, Vol. 100, Part III, p. 157-165.
[2] Chance *et al.*, "Waveforms," M.I.T. Radiation Laboratory Series (McGraw-Hill), Vol. 19, p. 648.
[3] Murray J. S., *Electronic and Radio Engineer*, Vol. 34, May 1957, p. 161.

Miniature I.F. Crystal Filters

SHARP cut-off crystal filters primarily for use in the i.f. amplifiers of fixed and mobile radiotelephone sets have been introduced by Cathodeon Crystals. They have a low insertion loss and enable high adjacent-channel selectivity to be obtained without recourse to double-frequency changing and the customary chain of i.f. transformers. Amplifiers following a single frequency changer and crystal i.f. unit can be broadband and, as filters of 7.5kc/s, 12.5kc/s and 25kc/s bandwidth, measured between −6dB points, are available, receivers can be aligned for different channel spacing merely by changing the crystal filter unit. At −60dB points the bandwidths of the above three filters are, <15kc/s, <25kc/s and <50kc/s respectively.

Rugged miniature quartz crystals are employed which, together with printed circuit board and the appropriate components, are housed in an hermetically-sealed case measuring 2in × 1⅝in × 2in high.

The centre-frequency stability is said to be 0.0012% and while the terminating impedances are normally 1,600Ω filters with input and output impedances to suit transistor circuits are also available. The makers are Cathodeon Crystals, Ltd., Linton, Cambridge.



Cathodeon miniature i.f. crystal bandpass filter unit.

WORLD OF WIRELESS

Transistor Convention

IT has been found necessary to change the date of the International Convention on Transistors being organized by the Radio and Telecommunication Section of the I.E.E. for next year. The new dates are May 21st to 27th.

The Convention and associated International Technical Exhibition will be held at Earls Court, London. Particulars of the Convention, at the opening session of which Dr. W. B. Shockley, Professor J. Bardeen and Dr. W. H. Brattain, the originators of the transistor, will speak, are obtainable from the I.E.E., Savoy Place, London, W.C.2.

The Exhibition is being arranged on behalf of the Institution by Industrial and Trade Fairs, Ltd., Drury House, Russell Street, London, W.C.2.

Technological Awards

THE National Council for Technological Awards has set up a new institution to be known as the College of Technologists. It will not be a teaching body but will, through a board representative of the universities, technical colleges and industry, supervise the administration of a scheme for a higher award than the Dip. Tech. introduced by the N.C.T.A. two years ago.

Students possessing the Dip. Tech. or "others who are deemed to have acquired equivalent qualification" will be able to undertake a programme of further study at a technical college for the award, which will be known as the M.C.T. (Member of the College of Technologists). Lord Hives, chairman of the Council, has stated that although the M.C.T. will rank with a Ph.D. degree, students will not undertake purely academic work, but will maintain their industrial link during their post-diploma studies.

There are at present 1,786 students taking courses leading to the Dip. Tech.; nearly twice as many as a year ago. Of this total 1,645 are taking sandwich courses.

Canadian Broadcasting Board

SOME time ago a Royal Commission was set up in Canada to go into the whole question of broadcasting in the Dominion. Its report, published last year, recommended that a board, independent of the Canadian Broadcasting Corporation, should be set up to direct and supervise broadcasting. In the past the C.B.C. has been both judge and advocate in its own cause, for it has not only conducted a sound and television broadcasting service but has had regulatory powers over the allocation of licences and frequencies to private broadcasting stations.

The constitution of a Board of Broadcasting Governors has been announced. It will be responsible to the Government for the direction and supervision of the Dominion's sound and television broadcasting services, authorizing the licensing of all stations and the allocation of wavelengths, etc. The Board consists of 15 members drawn from various walks of life.

Physical Society Exhibition

THE forty-third Exhibition of Scientific Instruments and Apparatus organized by the Physical Society will be held at the Royal Horticultural Society's Halls, London, S.W.1, from January 19th to 22nd. Admission on the first day is restricted to members of the Society and the press until 2.0, but on the other three days the exhibition opens at 10.0. The closing times on the four successive days are 7.0, 9.0, 7.0 and 4.30. Admission tickets are obtainable from exhibitors or from the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

The Exhibition Handbook, which forms a valuable book of reference to scientific instruments and apparatus, will be available from the Society in December price 6s (postage 1s 8d). There will be some 150 exhibitors. Firms in the radio and electronics field include:—

A.E.I.
Airmec
Avo
B.T.H.
Baird & Tatlock
Baldwin Instrument Co.
British Physical Labs.
Burndept
Cambridge Instrument Co.
Cawkell Research & Electronics
Cinema-Television
Claude Lyons
Cossor Instruments
Croydon Precision Inst. Co.
Dawe Instruments
Dobbie McInnes
Doran Instrument Co.
Dynatron Radio
Edwards High Vacuum
Ekco Electronics
Electro-Methods
E.M.I. Electronics
Electronic Instruments
Electronic Tubes
Elliott Brothers
Engelhard Industries
English Electric Valve Co.
Ericsson Telephones
Evans Electroselenium
Fairey Aviation
Ferranti
Flann Microwave Instruments
Furzehill Laboratories
G.E.C.
General Radiological
Hatfield Instruments
Hilger & Watts
Hivolt
Isotope Developments
Johnson, Matthey
Kelvin & Hughes
Labgear
Lintronic
Megatron
Mervyn Instruments
Metro-Vick
Muirhead
Mullard
Murex
Nagard
Nash & Thompson
New Electronic Products
Panax Equipment
Planer, G. V.
Plessey
Pullin & Co., R. B.
Pye, W. G.
Racal Engineering
Royston Instruments
S.T.C.
Salford Electrical Instruments
Sanders, W. H.
Sangamo Weston
Servomex Controls
Siemens Edison Swan
Solartron
Solus-Schall
Sunvic Controls
Sylvania-Thorn
Telegraph Construction & Maintenance Co.
Thompson, J. Langham
Tinsley, H.
Twentieth Century Electronics
Ultrasonoscope Co.
Venner
Wayne Kerr Laboratories

As in the past, the emphasis is on new developments in instruments and research techniques rather than on standard instruments and equipment.

"B.C.A.C. Bulletin" is being issued bi-monthly by the British Conference on Automation and Computation. This consortium of some 40 institutions was set up about a year ago to provide liaison between interested organizations. Its three groups cover: (A) engineering applications of automation; (B) computation and automatic control and programming techniques; and (C) sociological and economic aspects.

Automation and Navigation.—In its annual report the Institute of Navigation announces that arrangements have been made with the Francais Institut de Navigation and the Ausschuss für Funkortung of Germany to hold a joint meeting in Paris next May to discuss the place of automation in navigational methods.

Stereo Broadcasting.—A survey by the American Institute of High Fidelity Manufacturers, quoted by our New York contemporary *Radio-Electronics*, shows that at least 50 stations were broadcasting f.m.-a.m. stereo last summer. A questionnaire answered by 319 f.m. stations showed that 24% of the 215 which had affiliated a.m. stations were broadcasting f.m.-a.m. stereo. Of stations not affiliated with a.m. stations, six said they are now transmitting multiplexed f.m. stereo, and some 30 more stations said they plan to begin multiplex operations in the near future.

Hire Purchase.—With the revocation of the Board of Trade Orders controlling hire purchase and credit sales and rental transactions, the initial down payment and the period covered by the hire purchase agreement for domestic sound and television receivers are now unrestricted. The Orders lifting the restrictions are S.I.1958/1771 and 1772. The revocation of these orders does not affect the protection accorded to hirers under the Hire Purchase Acts.

Audio Fair.—Next year's London Audio Fair will be held from April 2nd to 5th at the Russell Hotel, Russell Square, W.C.1. The members of the Council of Audio Fairs, Ltd., of 42, Manchester Street, London, W.1, the non-profit making organization set up to sponsor these exhibitions, are G. E. Spark (chairman), M. L. Berry (vice-chairman), L. H. Brooks (secretary), D. A. Lyons, J. W. Maunder, H. V. Slade, T. R. B. Threlfall, and V. G. P. Weake.

Paris Components Show.—The second international components show (Salon International de la Pièce Détachée Electronique) to be organized in Paris, will be held from March 19th to 24th. The organizers are Syndicats Nationale des Industries Radioélectriques et Electroniques, 23 rue de Lubeck, Paris XVI.

Receiving Licences.—During September the number of combined television and sound licences in the U.K. increased by 78,863 bringing the total to 8,423,512. Sound only licences totalled 6,276,984, including 357,080 for car radio, making a total of 14,700,496.

New TV Standards Converter developed by Granada Television (the I.T.A. Northern programme contractors) is basically an improved version of the orthodox system using a camera "looking" at a monitor c.r. tube. On the occasion of the Pope's coronation the equipment was used at Manchester to convert the pictures from Rome to the 525-line American standard. The 525-line video signal was then recorded magnetically on an Ampex recorder and the tape was flown to America for re-transmission on the C.B.S. network.

I.T.A. in Northern Ireland.—A group under the chairmanship of the Earl of Antrim has been appointed by the Independent Television Authority to provide the programmes for its Northern Ireland transmitter. The station, to be built at Black Mountain, near Belfast, is planned to open at the end of 1959.

Rugby Repairs.—The extensive work of aerial maintenance at the Post Office station at Rugby, which has taken nearly two years, is now complete. The standard frequency transmissions (MSF) on 60 kc/s are again being radiated daily from Rugby from 14.29 to 15.30 G.M.T. The high-power telegraphy transmitter GBR (16 kc/s) has also resumed operations.

Communal television aerials are to be erected experimentally in a housing area in Edinburgh. Tenants will be compensated for the dismantling of their existing aerials and will pay a rent for linking to the communal system. It is proposed to erect communal aerials in future housing estates to be built by the city corporation.

"Bluebird," the boat with which Donald Campbell set up a new world water speed record on Coniston Water on November 10th, was fitted with Marconi v.h.f. radio. Throughout the trials and the record-breaking runs Mr. Campbell and his chief mechanic in the control boat maintained two-way communication.

Tube Rebuilders.—With the object of establishing standards for rebuilding cathode-ray tubes and to promote and protect the interests of member firms, the Association of Tube Rebuilders has been formed with offices at 21 Devonshire Street, London, W.1. The president is A. R. Cundell, managing director of the British Neon Manufacturing and Installation Co. A list of member firms is not being issued until the outstanding applications for membership have been approved.

Relay Subscribers.—The report of the Relay Services Association of Great Britain, presented at the annual general meeting on November 11th, records that although television subscribers increased from 28,000 at the end of 1955 to 108,000 at the end of last year, the overall total of subscribers (sound and television) decreased during this period from 1,077,000 to 1,024,000. It is understood that the number of television subscribers had risen to 160,000 by the end of October this year.

Apprentice Awards.—For the second year the Telecommunication Engineering and Manufacturing Association have held a competition for the best final-year apprentice of their member-firms in the three categories of graduate in training, student apprentice and technician apprentice. The £25 awards were presented to A. Proudman (graduate with S.T.C.), R. Hartshorn (student with A. T. & E.) and R. M. Lane (technician with S.T.C.), at the annual dinner of the Association on November 12th.

I.E.E. Research Scholarships.—The Institution has awarded the Ferranti Scholarship (£500 p.a. for 2 years) to J. C. Vickery (honorary award) for research at Imperial College on the switching applications of transistors, and to T. Williams for electronic engineering research at Queen's University, Belfast. The I.M.E.A. Scholarship (£420 for one year) goes to W. A. Charleson to continue research at the Heriot-Watt College, Edinburgh, on the study of dislocations in semiconductor crystals. The Oliver Lodge Scholarship (£420 for one year) is awarded to S. C. Choo to study the fundamental properties of semiconductors at Imperial College.

C. & G. New H.Q.—On December 1st the City and Guilds of London Institute will move to its new headquarters at 76, Portland Place, London, W.1 (Tel.: Langham 3050). During December certain administrative changes will be made and only matters of extreme urgency will be dealt with during the month.

Computer Training Courses.—E.M.I. Electronics have organized a series of training courses at Hayes, Middx, for computer programmers. Each course lasts three weeks and at present the number of students is limited to about 15. The next course starts on January 12th.

Transistor Lectures.—A course of 20 lectures on the theory and applications of transistors is being given at the S.E. Essex Technical College, Longbridge Road, Dagenham, on Thursday evenings at 7.0 from November 13th (fee £2 1s).

I.A.L. Air Traffic Control School, at Hayes Road, Southall, Middx., was opened on October 29th. Although primarily for training the staff of International Aeradio, Ltd., a few places may be available on some courses for private students.

Nigeria.—The first of several new medium-wave broadcast transmitters in Northern Nigeria was recently brought into service at Kano. Medium-wave stations are being used in the more densely populated areas to supplement the existing short-wave service provided by the Nigerian Broadcasting Corporation.

India's Institution of Telecommunication Engineers is holding its second Technical Convention in New Delhi on December 27th and 28th. The subjects being covered will include radio propagation, broadcasting and telecommunications in India, semiconductors, and navigational aids.

Personalities

Captain F. J. Wylie, R.N. (retd.), this year's president of the Institute of Navigation, has been director of the Radio Advisory Service since its formation ten years ago by the Chamber of Shipping and the Liverpool Steam Ship Owners' Association. Throughout the major part of his naval career (1909-1947) Captain Wylie was closely associated with wireless. He was at one time officer-in-charge of the wireless experimental department of H.M. Signal School, and was successively Deputy Director, Signal Department, Admiralty ('41/'43), and Director, Radio Equipment, Admiralty ('44/'46). Captain Wylie, who edited "The Use of Radar at Sea," published by the Institute of Navigation, received the Thurlow Navigation Award of the American Institute of Navigation for his "outstanding contribution to the science of navigation" in 1953. He is a member of the P.M.G.'s Frequency Advisory Committee.

A. T. Starr, M.A., Ph.D., M.I.E.E., was recently appointed Chief of Research and Development with Rank Precision Industries in succession to **Dr. N. Levin** (see September, p. 409). Dr. Starr was a lecturer at Faraday House from 1931-8, and was seconded to the Ministry of Aircraft Production in 1940. He worked at T.R.E. from 1940 to 1945 on microwave radar, and then joined Standard Telecommunication Laboratories, where he was responsible for the design of the microwave link between Manchester and the Kirk o' Shotts television station, and the portable equipment used for the first cross-Channel television link. In the past few years he has worked on digital techniques in computers and telecommunications. In his present position he is concerned with the development and applications of xerography, computer printers and automation. Dr. Starr is th author of a number of books including "Electric Circuits and Wave Filters" and "Radio and Radar Technique."

Professor A. C. B. Lovell, O.B.E., F.R.S., who is giving this year's Reith Lectures in the B.B.C. Home Service on six successive Sunday evenings (November 9th to December 14th) has occupied the Chair of Radio Astronomy at the University of Manchester since 1951 and is well known as the director of the Joddrell Bank experimental station of the University. For three years before the war Dr. Lovell was assistant lecturer in physics at the University to which he returned in 1945 after spending the war years at the Telecommunications Research Establishment, Malvern.

Air Comdre A. C. P. Brightmore, the new Director of Electronics Research and Development (Air) in the Ministry of Supply in succession to **Air Comdre. C. A. Bell**, is a signals specialist and held a number of signals appointments during the war. He commanded No. 3 Radio School at Compton Bassett, Wilts., for some time, and since 1956 has been chief signals officer of the 2nd Tactical Air Force.

G. J. S. Little, C.B.E., G.M., B.Sc.(Eng.), M.I.E.E., Director of Research at the Post Office for the past four years, has retired. He joined the Post Office Research Branch in 1922. In 1945 he became staff engineer in the Radio Maintenance Branch and two years later was promoted to assistant engineer-in-chief.

R. J. Halsey, C.M.G., B.Sc.(Eng.), F.C.G.I., D.I.C., M.I.E.E., succeeds Mr. Little as Director of Research at the Post Office, which he joined in 1927. For the major part of his service he has been in the Research Branch, but for the past five years he has been assistant engineer-in-chief responsible for submarine cable systems and in particular for the British contribution to the transatlantic telephone cable. In his new post he will be concerned with research and development in the many fields relevant to telecommunications, including, as the result of recent reorganization, radio experimental work.

Basil A. Turner, B.Sc.(Eng.), A.M.I.E.E., has joined Cosmocord Limited as chief engineer. An honours graduate of London University, he was a major in Royal Signals during the war and was for some time afterward in the G.E.C. Applied Electronics Laboratory, where he led a group in the development of guided weapons systems. More recently he was chief engineer of Penco Research and Development, Ltd.

W. J. Bray, M.Sc.(Eng.), A.C.G.I., D.I.C., M.I.E.E., who joined the Post Office in 1934 and since 1954 has been in charge of the Headquarters section planning radio-relay systems for television and multi-channel telephony, has been appointed to lead the newly formed Inland Radio Planning and Provision Branch. For nearly 20 years he was in the Radio Laboratories at Dollis Hill. In 1955 he was awarded a Commonwealth Fund Fellowship for Advanced Studies and Travel and spent a year in the U.S.A.

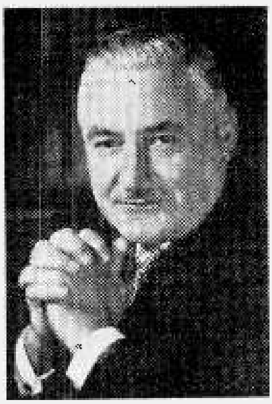
C. A. Quarrington, A.M.Brit.I.R.E., publicity manager of Ultra Electric from 1946 to 1957, has joined Roles and Parker, the press and public relations organization, as group executive. During the war he was closely associated with the development of radar and was the first to hold the R.A.F. appointment of Chief Radar Officer, H.Q., Bomber Command. For nine years before the war Mr. Quarrington was with Cossor, first as technical publicity manager and later as publicity manager.

Capt. F. J. WYLIE.

Dr. A. T. STARR.

R. J. HALSEY.

B. A. TURNER.



F. N. Sutherland

F. N. Sutherland, C.B.E., M.A., M.I.E.E., for eleven years general manager of Marconi's Wireless Telegraph Company, has been elected to the Board of Directors and appointed managing director—a newly created post. He has also been elected a director of Marconi Instruments. Marconi's also announce the election of **Paul de Laszlo,** O.B.E., as a director of the two companies. Mr. Sutherland joined Marconi's in 1947 from English Electric, the parent company, with which he had been associated since 1922.

Air Comdre. C. M. Stewart, C.B.E., Air Officer Commanding No. 27 Group, Technical Training Command, R.A.F., becomes Chief Electronics Officer, Fighter Command, on December 1st, in succession to **Air Comdre. M. D. K. Porter,** C.B.E. A signals specialist since 1936, Air Comdre. Stewart was chairman of the Communications Electronics Committee of the N.A.T.O. Standing Group, Washington, from 1955 to 1957.

J. N. Toothill, C.B.E., Comp.I.E.E., Comp.Brit.I.R.E., F.R.S.E., general manager of Ferranti's Edinburgh factory since 1942, has been made a director of the company, which he joined in 1935. He is a member of the Council of the Electronic Engineering Association and is also a governor of the College of Aeronautics at Cranfield.

G. F. W. Adler, B.Sc.(Eng.), D.I.C., A.M.I.Mech.E., has been appointed chief mechanical engineer and a member of the Directorate of Engineering of Marconi's W.T. Co., with responsibility for all mechanical engineering design aspects, both of Marconi's and their associated company, Scanners, Ltd. He joins Marconi's from The English Electric Company, where he was chief development engineer.

Bowman Scott, M.B.E., B.Sc.(Eng.), A.C.G.I., A.M.I.E.E., director of the Solartron Electronic Group and managing director of its subsidiary Solartron Electronic Business Machines, has returned from a seven weeks' visit to North America. He was accompanied during part of his tour by **Peter Curry,** M.A., B.Sc.(Oxon.), sales manager, who delivered a paper on the Solartron Electronic Reading Automaton at the convention of the Society of Motion Picture and Television Engineers in Detroit on October 20th.

M. M. Macqueen, who joined the General Electric Co. 35 years ago and has been manager of the radio and television department since 1930, becomes general manager of the Radio Division under a recent reorganization of the company's General Products Group. Mr. Macqueen was chairman of the Council of the British Radio Equipment Manufacturers' Association for several years until 1957 and is on the Council of the Electronic Engineering Association.

Aubrey Harris, A.M.I.E.E., A.M.Brit.I.R.E., who left Marconi's last year to go to Bermuda on a twelve months' contract as chief engineer to the television station ZBM/TV, has now joined the Ampex Corporation, of Redwood City, California. He will be working on the design and development of vision tape recording equipment. For just over five years before going abroad Mr. Harris, who is 29, was in Marconi's research and development divisions, where he worked on colour television cameras and associated equipment.

The Fellowship of the Television Society has been awarded to the following:—**Dr. A. J. Biggs** of the G.E.C. Research Laboratories, which he joined in 1935, who is also chairman of the technical committee of B.R.E.M.A.; **Dr. Rolf Möller,** technical vice-manager of Fernseh-A.G. and first chairman of the German television society (Fernseh-Technische Gesellschaft); **Bryan Overton,** head of the television division of Mullard Laboratories, which he joined in 1947; and **Dr. G. N. Patchett,** head of the electrical engineering department of Bradford Technical College where he has held various appointments since 1940.

Dr. Albert Rose, senior member of the technical staff of R.C.A. Laboratories, Princeton, N.J., has been awarded this year's David Sarnoff Gold Medal by the Society of Motion Picture and Television Engineers, for "basic contribution to the development of the Orthicon, Image Orthicon and Vidicon television pick-up tubes." Since obtaining his Ph.D. at Cornell University in 1935 he has been on the staff of R.C.A. Laboratories both in the U.S.A. and in Europe. Dr. Rose was associate editor of the *Physical Review* of the American Physical Society from 1955 until earlier this year.

W. F. Smith, B.Sc.(Eng.), A.C.G.I., M.I.E.E., has retired from the Post Office Engineering Department which he joined in 1924. For a considerable part of his service he has been in the Radio Branch and for three years was in charge of radio maintenance. Since 1953 he has been in the External Telecommunications Executive which was formed when the Post Office took over a number of radio stations from Cable & Wireless.

OUR AUTHORS

D. J. Spooner, contributor of the article on page 594, is in charge of the development liaison section of the Wandsworth works of Redifon, Ltd. He joined the company in 1946 and was senior design engineer engaged mainly on medium-power transmitters until the beginning of last year. For five years prior to joining Redifon he was on the staff of the Inter-Services Research Bureau, having previously been with Marconi's and Marconi-Ekco Instruments.

James P. Grant, Assoc.Brit.I.R.E., who in this issue contributes to the discussion on the Plymouth Effect, was a radar instructor in fire control in coastal artillery in the early part of the war and also worked on the development of radar trainers. Since 1946 he has been engaged in the retail radio trade. He drew the attention of the B.B.C. to the peculiar type of television interference known colloquially as the Plymouth Effect in 1954.

OBITUARY

Georges Conus, vice-president and former president of the European Broadcasting Union, died suddenly on July 22nd, aged 63. His technical career in his native Switzerland started in the radio section of the P.T.T. Administration, which he subsequently represented at numerous international radio and telecommunications conferences. He was closely associated with the formation of the E.B.U. in 1950 and the work of its predecessor, the International Broadcasting Union. Since January 1950 he had been deputy to the director-general of the Swiss broadcasting organization Société Suisse de Radiodiffusion.

Arthur Gray, founder of Arthur's, the well-known London retailers, died on October 26th aged 68. He founded the business in 1919 in Charing Cross Road, where it remained until May this year when it was transferred to the present address, 125, Tottenham Court Road.

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News from the Industry

Associated-Rediffusion, the weekday programme contractors of the London I.T.A. station, earned a trading profit before taxation of over £5M during the year ended last April—its third year of operation. In the previous year there was a loss of £626,000. The two principal shareholders in the company, which is a private concern, are British Electric Traction and Rediffusion.

Lord Rank, in his statement on the affairs of the Rank Organization, said that on the manufacturing side the profits for the year ended last June of both the Rank Precision Industries Group and the Rank Cintel Group (which includes Bush Radio) were less than in the previous year. The figures are: R.P.I. £321,764 compared with £485,989; R.C.G. £777,816 compared with £976,191.

Thompson, Diamond & Butcher, the well-known wholesalers and manufacturers of 5-9 University Street, London, W.C.1, have been acquired by Rank Records, Ltd., a member of the Rank Organization.

E.M.I.—The consolidated trading profit for the E.M.I. Group for the year ended last June was £5.322M compared with £4.732M the previous year. U.K. and overseas taxation absorbed over £2.5M from each of these figures. The sum retained by the subsidiaries totalled £1.462M last year, and after certain other deductions the profit for the parent company was reduced to £694,000.

G.P.C.—The annual report for the year ended last June of the Gas Purification and Chemical Co., shows a deficit of nearly £0.5M. Among the company's 16 subsidiaries are A.B. Metal Products, Grundig, Wolesey and E.A.R.

Pena Aftermath.—When Pena Industries went into liquidation the subsidiaries, including Thermionic Products and Peto Scott, were put into the hands of receivers. Both of these companies have survived the crash and are being reconstituted. Thermionic Products (Electronics) Ltd., of Hythe, Southampton, has been formed to take over the goodwill and to market the products of the original company. The directors are D. D. Prenn, Col. D. A. Zinovieff and J. S. W. James. The business of Peto Scott is being purchased as a going concern and a new company is being formed. The name of the purchasing company has not been divulged.

Tectonic Industrial Printers, Ltd., of Denmark Street, Wokingham, Berks. (Tel.: Wokingham 1150), are now licencees for the manufacture of printed circuits under British and world patents held by Technograph Printed Circuits, Ltd. The company, which operates a 24-hour prototype service and has facilities for design, drawing and production, is associated with Instrumentation, Ltd., electro-mechanical research and development engineers.

Leevers-Rich Equipment, Ltd., of 80-82, Wardour Street, London, W.1, have been appointed distributors to the film industry of Emifilm 16- and 35-mm magnetic recording film. The company is already distributing Emitape.

E.M.I. Electronics are to supply a specially designed underwater industrial television camera for observation inside the Merlin water-moderated nuclear research reactor at Aldermaston. The camera is 30in long and 3½in in diameter.

Trix Statement.—In view of certain press reports, the Trix Electrical Co. wish to make it clear, in order to avoid any confusion, that they are in no way connected with, nor have they ever had the remotest association with, any other company of a similar name.

Multimusic, Ltd., manufacturers of Reflectograph tape recorders, are bringing into operation a new guarantee scheme under which all their models used in the U.K. will be guaranteed for one year from the date of purchase. During this period no charge for parts, valves or labour will be made unless the receiver has been misused or neglected. The servicing is being carried out on behalf of Multimusic by an E.M.I. company, Home Maintenance, Ltd., who have depots throughout the U.K. After the first year they will be prepared to offer a comprehensive maintenance contract (including valves) for 3 gns a year for each recorder.

Solartron have concluded selling and manufacturing licensing agreements for the "Kintel" range of electronic products of Cohu Electronics, Inc., of San Diego, California, U.S.A., covering the eastern hemisphere with the exception of Sweden.

Lasky's Radio have opened a new audio demonstration room at their Tottenham Court Road, London, W.1, shop with facilities for stereo and single-channel listening.

Gresham Developments Ltd., the research and development company of the Gresham Transformer Group, has moved to Thurlestane House, Uxbridge Road, Hampton Hill, Middlesex. (Tel.: Molesey 4540.)

Pye.—All correspondence relating to the company's sound reproducing equipment should now be sent to the Hi-Fi Division at 65 Fairview Road, London, S.W.16. (Tel.: Pollard 9441.)

EXPORTS

Export Department of Marconi's W.T. Co., has been transferred from the company's London office to Chelmsford. W. J. Richards has relinquished his position as export manager to become assistant to the general manager on export matters. A. E. Shepherd is appointed manager of the export department and will also have overall responsibility for the policy decisions of the associated companies division; I. O. Mortada becomes export sales manager; and B. T. Turner assistant manager, export department.

Radiotelephone equipment to the value of about £80,000 has been ordered from Pye by the Hong Kong government for the colony's police force. The installations include fixed and mobile f.m. Ranger transmitter-receivers.

Portable television receivers made by Ekco for operation from a 12-volt battery have been fitted in two new buses put into service on the Berlin-Frankfurt route.

Radio Compasses.—A Yugoslavian firm, Jugoimport, have been licensed by Marconi's to manufacture their sub-miniature airborne automatic direction finder, AD722, from parts supplied from this country.

Scandinavia.—An overseas subsidiary company of the Solartron Electronic Group, Ltd., is being formed in Stockholm, Sweden. Incidentally, address of the German subsidiary—Solartron G.m.b.H.—is now Bayerstrasse 13, Munich.

Australia.—Scope Laboratories, mechanical, electrical and electronic engineers, of 421 Keilor Road, Niddrie, Victoria, are anxious to manufacture suitable products under licence in Australia. Their present activities include the manufacture of soldering irons, electronic sequence timers, and plastics goods ranging from TV tube escutcheons to refrigerator liners.

"No Hands" Blind Landing

COMBINED RADIO AND INDUCTIVE SYSTEMS

MOST blind-landing systems developed in the past have provided reliable information only up to a point where visual contact with the ground could be expected under average conditions. In other words, they gave guidance to a point above the end of the runway, and that was all. Even ILS (Instrument Landing System)—the latest in a long family of odd names (e.g. BABS)—is allowed, in the International Committee of Air Navigation's specification, too great a tolerance to permit safe landing, as distinct from approach-for-landing. Obviously a system which can give full information right up to and even past the point of touch-down is desirable and, in the not-too-far-distant future, it may well become a necessity, not only for service aircraft but for civilian airlines as well.

In modern high-speed aircraft the delay involved in the pilot transposing an indicator reading to a movement of the controls may be undesirably long.

A new system, devised by the Blind Landing Experimental Unit of the Royal Aircraft Establishment, takes information from several sources and feeds it into the aircraft's autopilot, so that the aircraft is landed without any human intervention at all. The various stages in the landing cycle together with the source of guidance information are shown in the accompanying table.

Approximate height (ft)	Stage of Landing	Source of guidance	
		Azimuth	Elevation
Circuit to 300	Runway approach	Radio beams (ILS)	
300 to 150	Accurate approach	Leader cable	ILS glide path
150 to 60	Constant altitude	Leader cable	Autopilot
60 to 20	Controlled altitude	Leader cable	Radio altimeter
20 to 0	Touch-down	Compass	Radio altimeter
Ground level	Ground run	Leader cable	—

ILS is used to define the glide path and runway-centre line down to about 300 ft. At this height the centre-line guidance signal could become too inaccurate for landing, so azimuth guidance is switched, automatically, to another system. This, developed by Murphy Radio, consists of two cables running about 250 ft away from, and parallel to, the runway, one on either side. These cables extend from about 5,000 ft beyond the undershoot area at the end of the runway to the point on the runway where azimuth control is no longer required. Into each cable an alternator feeds a constant current signal; but a different frequency is used for each cable. A small rotating loop in the aircraft picks up signals from the magnetic fields caused by the cables and these are compared in a simple receiver, two frequencies being used to avoid ambiguity. This gives centre-line guidance, with an accuracy of ±5 feet.

The ILS glide-path signal may not be reliable below about 150 ft, so at this height the radio altimeter causes the ILS signal to be switched out and the autopilot maintains the aircraft's altitude constant down to about 60 ft, where the radio altimeter takes over control of height. The radio altimeter is not used in the 150- to 60-ft stage because there is a likelihood that the aircraft will not have reached the level ground of the undershoot area or runway until its height has dropped to about 60 ft on an ILS approach.

Removing Drift Correction

Crosswinds on the runway may have caused the aircraft to be "pointing" along a line at an angle to the runway, so the aircraft would land crabwise. As this is not good for aircraft or their passengers and crew any drift correction on the aircraft is removed at 20 ft by the altimeter. This gives the aircraft time to respond to the autopilot system to correct the alignment of the aircraft with the runway. At the same time the wings are levelled and azimuth guidance is transferred to the gyro compass on which the pilot has set up the true bearing of the runway before landing starts.

As soon as the aircraft has touched down the pilot disconnects the automatic control and then he can steer the aircraft manually by watching an indicator operated by the magnetic leader cable system.

The radio altimeter used is a version of the Standard Telephones and Cables S.T.R.30 (mentioned in our recent review of the S.B.A.C. exhibition at Farnborough). This altimeter is extremely accurate and provides not only a height-analogue output but also a rate-of-change of height analogue. For the descent from about 60 ft this latter output is used to control the pitch attitude of the aircraft so that the rate of descent is proportional to the height: this ensures a very smooth touch-down. Also the throttles are controlled automatically so that the speed is held at the optimum for each phase of the landing.

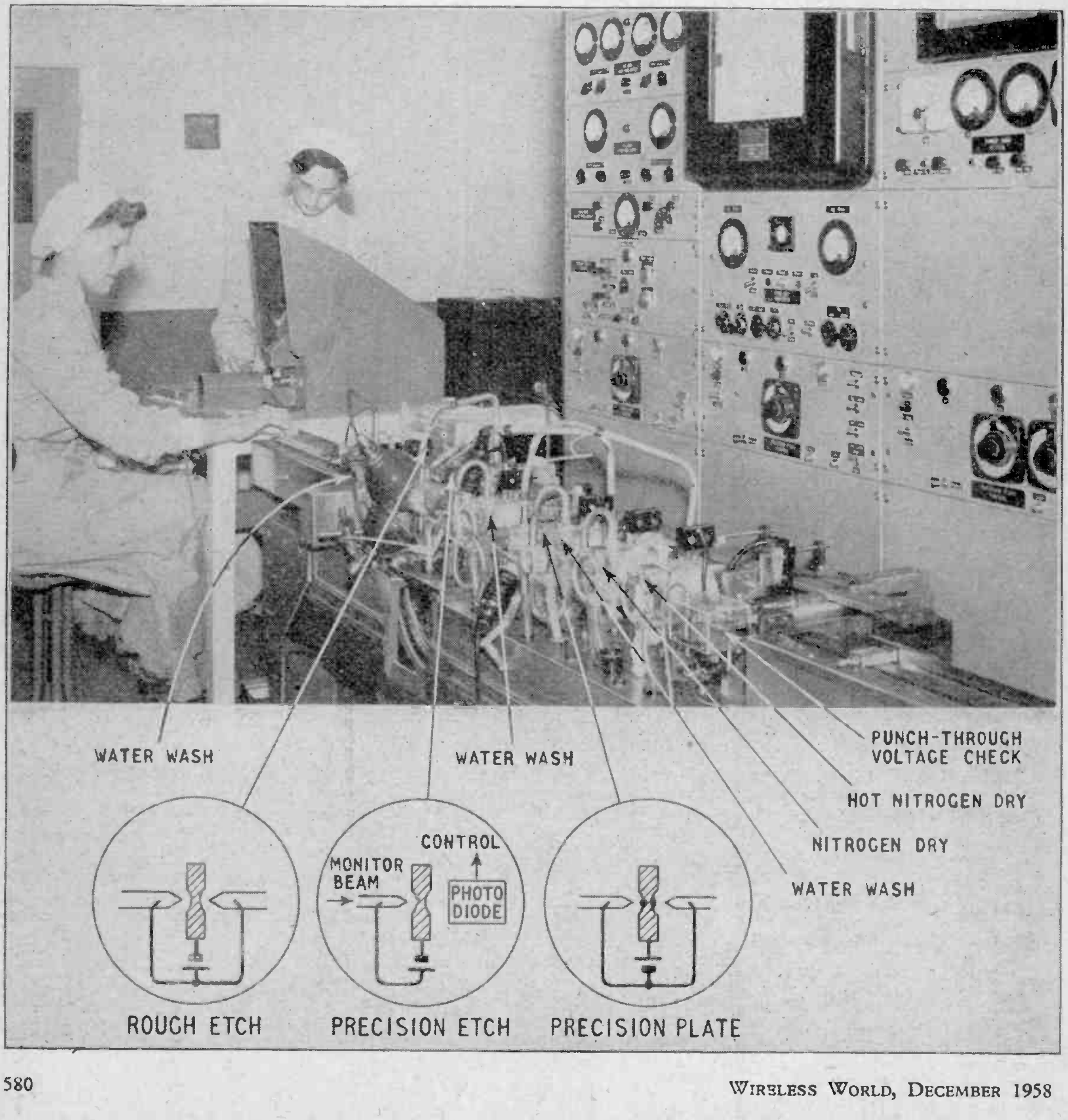
An important feature of the system is that monitoring signals are displayed on the normal flight instruments throughout the landing; only one additional instrument to the standard Smith's Flight System is used: this indicates the source of guidance during each stage of the controlled landing.

Automation in Transistor Production

THREE key operations in the manufacture of surface-barrier transistors at the new Swindon factory of Semiconductors, Ltd., are performed without human intervention on the automatic transfer machine shown below. As is well known, surface-barrier transistors have the ability to work at high radio frequencies (alpha cut-off frequencies of 30Mc/s or above) because of their very thin base regions, which are achieved by electrolytic etching of the semiconductor material. The emitter and collector electrodes are not alloyed to the base region but plated on to the semiconductor surface in the etched pits.

After preparation of the germanium semiconductor blanks they are mounted on the usual transistor stems and passed in work carriers or jigs to the transfer machine. Here they move along a conveyor system (seen emerging on the right) which automatically inserts them into the successive work stations and withdraws them again after each process is performed.

The first stage is a preliminary wash in high-purity water, after which the mounted semiconductor is passed to a "rough etch" position where two jets of electrolyte impinge on opposite sides of the germanium wafer and produce concentric pits. Next follows the "precision etch" position, which has a single jet carrying an infra-red monitoring beam. Since the intensity of the infra-red transmission through the semiconductor is determined by the thickness of germanium at the bottom of the pit, a



photoelectric detector on the other side can feed a "thickness" signal to a servo system which stops the etching process when the required thickness is reached. The large pen-recorder (top centre in the picture) allows the progress of each etching cycle to be observed.

Another washing process follows, and the mounted semiconductor is then fed to the "precision plate" position. Two jets of electrolyte are used, the electrical polarization and electrolyte composition causing indium electrodes of the required diameter to be plated into the etch pits. After washing and drying with nitrogen, the transistors next go to a position where contact is made to the indium electrodes and a check of punch-through voltage is made. This measurement is also recorded on a chart (edge of the recorder top right in the picture).

When the transistors emerge from the transfer machine (bottom right) they go to another automatic machine for attaching thin wires to the indium electrodes, then on to the final cleaning, washing, baking (to remove moisture) and hermetic sealing processes. The completed transistors undergo comprehensive checking of electrical characteristics, of course, and artificial "life" tests are performed on a proportion of each batch—the results of which determine whether that batch is suitable for sale or not.

Apart from the automatization of many of the processes, the factory has an ultra-modern, almost "science fiction" atmosphere about it, resulting from its being designed as a hygienic sealed box, without windows, immune from all outside influences. A large air-conditioning plant in the basement controls the ambient temperature to 2°F, the humidity to ±5% and, by electrostatic and mechanical filtration, keeps the ambient dust to less than one cubic micron per centimetre of air. All internal surfaces are p.v.c. coated to be smooth and non-dust-catching, water and gas supplies are purified, and the operatives, wearing nylon overalls and rubber gloves, are continually being "de-dusted" by air blasts when they pass through doors. Even the effluents from the factory are neutralized before being disposed of. One emerges slightly grateful for the dirt, discomfort and inclemency of the outside world—but impressed by what is being done for the transistors. No wonder the products of the factory are confidently estimated to have a life of 1,000,000 hours!

Books Received

Loudspeakers by G. A. Briggs. Revised and enlarged fifth edition reveals many aspects of sound reproduction, but chiefly the principles and practice of moving-coil loudspeaker design, construction and mounting. The narrative follows the course of the author's experience since 1932 as a loudspeaker manufacturer, book publisher and lecturer. Pp. 332; Figs. 230. Price 19s 6d. Wharfedale Wireless Works, Ltd., Idle, Bradford, Yorks.

B.B.C. Television. A survey of the television engineering services of the British Broadcasting Corporation. Descriptions of types of transmitters and studio equipment, map of service areas, "Eurovision" networks and a list of important dates in the development of television in the U.K. Pp. 64; Figs. 41. Price 2s 6d. B.B.C. Publications, 35 Marylebone High Street, London, W.1.

The B.B.C.'s Mark II Mobile Studio and Control Room for the Sound Broadcasting Service by L. E. H. O'Neill. Engineering Division Monograph No. 20 Pp. 23; Figs. 15. Price 5s. B.B.C. Publications, 35 Marylebone High Street, London, W.1.

Selected Abstracts from the Journal of the Brit.I.R.E. New edition covering the period 1946-1958 (December) and contains 529 main references classified under 9 headings, together with an authors index. Pp. 72. Price 3s 6d. The British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1.

NEL Reliability Bibliography, Supplement I. Contains 576 additional references numbered for inter-filing with the pages of the basic bibliography published by the U.S. Naval Electronics Laboratory in May 1956. Price of supplement $3. Office of Technical Services, Department of Commerce, Washington 25, D.C.

Radio Engineering and Electronics, Vol. 2, No. 2 1957. English translation of the U.S.S.R. Academy of Sciences publication. Pp. 183. Annual subscription £16 (2.500 pages p.a.).

Telecommunications, No. 1. English translation of U.S.S.R. Ministry of Communications journal. Pp. 94. Annual subscription £10 14s (1,000 pages p.a.). The above are published on the initiative of the Massachusetts Institute of Technology and the Pergamon Institute and are obtainable from the Pergamon Press, Ltd., 4 and 5 Fitzroy Square, London, W.1.

Bibliography on Medical Electronics. Prepared by the Medical Electronics Centre of the Rockefeller Institute. Gives 2,200 references to papers up to June 1958 with subject and authors index. Pp. 91. Price $2.50. Published by the Professional Group on Medical Electronics, Institute of Radio Engineers, 1 East 79th Street, New York, 21, N.Y.

Single Sideband for the Radio Amateur (Second Edition). Digest of upwards of 50 articles in *Q.S.T.* on the theory and practice of single sideband communication. Pp. 210 with numerous illustrations. Price $1.75. American Radio Relay League, West Hartford 7, Connecticut, U.S.A.

The All-in-One Tape Recorder Book by Joseph M. Lloyd. Popular introduction to magnetic tape recording; possible uses, types of machine, microphone techniques, maintenance, etc Pp. 210, numerous illustrations. Price 12s 6d. Focal Press, Ltd., 31 Fitzroy Square, London, W.1.

The Grundig Book by Frederick Purves. A manual of tape recording, similar in scope to the above, but with special reference to the use of the Grundig range of instruments. Pp. 184 + XVI, with numerous illustrations. Price 12s 6d Focal Press, Ltd., 31 Fitzroy Square, London, W 1.

Oscilloscope Techniques by Alfred Haas. Description of basic cathode-ray oscilloscope circuitry and its application in testing and measurement. Profusely illustrated by photographs of typical trace patterns. Pp. 224; Figs. 1023. Price $2.90. Gernsback Library Inc., 154 West 14th Street, New York 11, N.Y.

TV and Radio Tube Troubles by Sol Heller. Description with illustrations of the effects of faults arising in valves and cathode-ray tubes themselves, with hints and tips for cure where possible. Pp. 224; Figs. 901. Price $2.90. Gernsback Library Inc., 154 West 14th Street, New York 11, N.Y.

How to Read Schematic Diagrams by David Mark. Beginners' guide to the correlation of circuit symbols with practical components and their arrangement in typical circuits. Pp. 147; Figs. 89. Price $3.50. John F. Rider Publisher Inc., 116 West 14th Street, New York 11, N.Y.

Simplified Mains Transformer

Guide to Choice of Core Size and Windings for Any Particular Requirement

THERE are few radio engineers who, at some time in their careers, have not been required to design mains transformers. A new transformer may be required for mass production to be incorporated in a radio receiver or other equipment, or may be a "special" involving perhaps only one or two for some specialized apparatus. Also, the enthusiastic amateur often wishes to wind a mains transformer for requirements not fulfilled by the commercially available ranges of transformers, and it is surprising that, so far as the author is aware, all published information on mains transformer design appears to give least assistance where it is needed most, particularly by the tyro. This is at the point where the size and stack of lamination are to be selected, where one often gets the impression that some degree of inspired guesswork is essential to success. The principles of transformer design are well known and are treated in many standard textbooks. The reader will probably be familiar with the usual treatment.

The output voltage and current requirements are stated, a probable efficiency assumed and the total wattage evaluated. Next, a suitable lamination and stack are chosen, which subsequently turn out to be a correct choice, the windings occupying the window area with a satisfactory margin for insulation, etc.

The designer will indeed be fortunate if his first choice of lamination size and stack proves to be correct; all too often when selected arbitrarily it turns out to have insufficient winding area and major revision of the design is necessary. The degree of success usually depends on the extent of previous experience, and the engineer who only occasionally requires to design a transformer is obviously at a disadvantage. The author, having met this problem a number of times, has calculated tables of the power handling capabilities of various laminations, which can be used as a guide to the selection of a suitable lamination for any particular power requirement.

The theoretical considerations on which the tables are based are given in the Appendix, where it is shown that the VA rating of a given stack of laminations can be expressed by:-

$$\text{VA Rating} = 36.9 \times T^2 \times L \times H \times r$$

where T = tongue width in inches
L = window length in inches
H = window height in inches
r = ratio of stack/tongue

The expression has been used to evaluate Tables I and II for a unity stack/tongue ratio (r) taking the frequency as 50 c/s, the peak flux density as 10k gauss and the current density in the windings as 2,000 amps/sq in. The VA rating for any value of r other than unity is obtained by direct proportion.

The VA ratings in the tables refer only to open type transformers operating in normal ambient temperatures, using cheap commercial insulation materials (e.g. paper, Presspahn adhesive paper tape, etc.). Special transformers calling for unusual construction or winding techniques (e.g. high-temperature operation, low capacitance or e.h.t. types, etc.) may have considerably different space factors to those assumed in the Appendix, and consequently different power handling capabilities to the values in the tables. Also, if a transformer is to be mass produced, the most economical design is usually sought, and this can only be obtained by considering the maximum permissible temperature rise in conjunction with the other factors. Nevertheless, it has been found that the values given in the table form a useful starting point in these cases. For many purposes, and particularly when a "one

TABLE I

E. and I. Laminations.

Tongue width (inches)	M.E.A.	Scotts	R. T. & B.	Sankey	R.C.S.C. RCL. 191	VA Rating for unity stack/tongue ratio (r)
½	228	143	404	237		2.35
½	70		433	470	470	5.14
9/16†	18	212	339	219		2.78
⅝†	145	145	392	222		4.23
⅝	71	187	243			5.08
⅝	84	243	333	212		22.0
11/16	72	176		156		7.30
11/16†	74	130	386	74	474	6.19
¾†	35	120	217	70	417	8.75
13/16†	182		347			12.1
13/16	125	228	344	8		12.0
⅞†	147	279		223		16.2
1.0†	29	43	430	111	429	27.6
1.0	159			220		64.6
1 1/16		232	354	131		47.5
1⅛†		280		214		44.2
1¼†	78	174	420	133		67.7
1⅜†	152	246	362	225		99
1½†	120	173	311	217		105
1½	88			174		498
1¾†	220A	248		235		260
2.0	87	276				1000
2½	117					1900
3.0	122			167		4650

† Indicates "no waste" type.
Laminations by different manufacturers, shown in the above table as having the same power handling capabilities, have not necessarily all dimensions identical.
In many cases the lamination type numbers used by M.E.A. Ltd. apply to laminations manufactured by Linton and Hirst Ltd.

*Mains Radio Gramophones Ltd.

Design

*By H. D. KITCHEN**

off" is required, a transformer can be designed using the tables without any of the trial and error procedures which characterize most other methods. The designer can proceed along the well-established paths with a reasonable degree of confidence in the windings all being ultimately accommodated in the available winding space.

The range of the tables can be extended to cover other frequencies, flux densities and current densities if it is remembered that the VA rating is directly proportional, over a limited range, to:—

(1) The frequency.
(2) The current density in the windings.
(3) The flux density (13,000 gauss is the normal limit with 4% silicon iron stampings).

Some further points worth noting are:—

(4) The ratings in the tables are based on a winding length of 0.85 of the window length. Coils to be wound on a multiple machine may require this factor reducing, and if we assume a value of 0.7 the ratings in the table are reduced by a factor of 0.825.

(5) It is common practice on the smaller sizes to use random windings on a bobbin which improves the space factor and increases the rating by a factor of about 1.25.

(6) As the transformer size increases it is necessary to reduce the current density in the windings, due to the radiating area per unit volume decreasing with increasing physical size. The value of 2,000 amp/sq in assumed in evaluating the tables will generally give a satisfactory temperature rise in normal ambient temperatures for transformers handling up to about 100VA. Above this, it is desirable to reduce the current density in the windings and the following values are suggested:—

1,500 amp/sq in for 100 to 300VA
1,000 amp/sq in for 300 to 1,000VA

These current densities will, of course, reduce the VA ratings of the tables by factors of 0.67 and 0.5 respectively.

(7) As the transformer size increases the inevitable variations in the tightness of the windings, wire diameter and paper thickness become a smaller proportion of the available winding height and the allowances made in the Appendix for winding insulation become more than adequate. Consequently it will usually be found that for transformers of over 200W, based on the tables, the windings can be accommodated easily. At the other end of the scale, very small transformers (below 20VA) will be found to be rather tight when based on the tables, unless great care is taken with winding tension and other practical constructional points.

(8) The expression for the VA rating derived in the Appendix assumes that the terminal voltage is dependent only on the flux in the core and the number of turns. In practice the secondary terminal voltage will be less and the impressed primary voltage more than this, due to IR drop in the windings. In order to realize the required voltage output for a given input under load conditions, it is necessary to use different values of the turns per volt for the primary and the secondary. The required relationship is obtained from the voltage efficiency which must be in the first instance assumed‡.

TABLE II

T. and U. Laminations

Tongue width (inches)	M.E.A.	Scotts	R. T. & B.	Sankey	R.C.S.C. RCL. 191	VA Rating for unity stack/tongue ratio (r)
½	102			210		9.06
9/16	47	97	5	47		4.93
9/32	68	108		68		8.4
⅝	175		81	55	455	10.1
⅝	100	102	3	100		7.75
⅝	12A	104A	14	102A	403A	10.2
⅝	15	15A	17	15	415A	16.2
23/32	26	153		199		10.3
¾	135	154	27	64		8.76
¾	101	116A	51	60A	401A	17.5
¾	110		25	213A		30.3
⅞	59		29	40		34.5
⅞	59A	84A	91	40A	440A	34.5
15/16	82	247A	105	82		20.6
15/16	130A	34A	9A	30A		32
15/16	24	42A		221	442A	46.1
15/16	4A	4A	88	4A	404A	66
1.0	75A	26A	34	75A	475A	88
1.0	157A	124A	116	39A		130
1⅛	46	165A	35	164A		63
1.22	28A	25A	55	28A	428A	208
1¼	60A	60A	57	33A	460A	159
1.26	98	127	74	200		73
1½	136A	76A	80	36A		230
1½	235A	45A	54	35A	435A	506
1¾	137A	78A	117	37A	437A	918
2.0			99	179		1330
2½	41A	213A	109	41A	441A	1920

Laminations by different manufacturers, shown in the above table as having the same power handling capabilities, have not necessarily identical dimensions.
In many cases the lamination type numbers used by M.E.A. Ltd. apply to laminations manufactured by Linton and Hirst Ltd.

Example Showing the Use of the Tables.—To design a mains transformer having the following specification:—

Frequency = 50 c/s.
Input 10-0-200-220-240 volts.
Output; h.t. to give 325 volts d.c. at 100mA d.c. when full-wave rectified using an EZ81 valve.
L.T.1; 6.3V at 1A; L.T.2; 6.3V at 3A.

The first step is to assess the total power handled

‡It is possible to derive an expression for the voltage and power efficiency due to winding and core losses in a similar manner to that used in the Appendix for the VA rating. To be of much value it would require to be tabulated for each lamination size and stack and would greatly increase the complexity of the tables.

by the transformer. The total heater supply power is $6.3 \times 1 + 6.3 \times 3 = 25.2$VA.

The calculation of the h.t. secondary power is rather more complicated due to there being no simple relationship between the d.c. output current of the rectifier and the r.m.s. secondary current, but as the heating effect of the secondary current is dependent on the r.m.s. value of the secondary current it is essential that this should be used in assessing the secondary power. Probably the simplest way of arriving at the value of the r.m.s. secondary current is by use of the graphs given in chapter 30 of ref. 2, and the procedure will now be illustrated in application to the present example.

From the published EZ81 data; at 100mA d.c., 322 volts d.c. is obtained with an a.c. input of 300 volts r.m.s. per anode with a series resistance of 200 ohms per anode, using a 50-μF reservoir capacitor.

$$\therefore \frac{E_{dc}}{E_{pk}} = \frac{322}{300 \times \sqrt{2}} = 0.759$$

E_{dc} being the d.c. output voltage and
E_{pk} the peak a.c. input voltage.
Also the effective load resistance R_L is

$$\frac{322}{0.1} = 3.22\text{kohm}$$

and with the 50-μF reservoir capacitor the product ωCR_L is, therefore,

$$314 \times 40 \times 10^{-6} \times 3.22 \times 10^3 = 50.6$$

From Fig. 30.6 on page 1,173 of ref. 2, we obtain the total effective diode conduction and source resistance $\bar{R}_s$ as:—

$$\frac{\bar{R}_s}{R_L} = 0.1$$

From Fig. 30.8, p. 1,175 of ref. 2 the ratio of r.m.s. anode current to direct anode current per anode is 2.15 approximately for this value of $\bar{R}_s/R_L$.

The direct current per anode is obviously 50mA, therefore the r.m.s. current per anode is $50 \times 2.15 = 107.5$mA.

The r.m.s. secondary voltage is 300-0-300, i.e. 600 volts, resulting in an h.t. secondary power of $600 \times 107.5 \times 10^{-3} = 64.4$VA.

The total power thus becomes $64.4 + 25.2 = 89.6$VA.

Assuming a transformer power efficiency of 90% the transformer handling power required is $89.6/0.9 \simeq 100$ watts.

For this size of transformer 2,000 amp/sq in can be used for the current density and hence the ratings in the table can be taken directly.

From Table I a suitable E & I lamination would be one with a 1¼in tongue width and of the "no waste" type. (This type is indicated in the tables by †.)

The VA rating of this lamination is 67.6 watts when $r = 1$, therefore the stack required would be one with $r = \frac{100}{67.7} = 1.5$, i.e. 1⅞-in stack. Also from the tables we see that this laminaticn is listed by most manufacturers and could be, for example, Scotts No 174.

From Table II a suitable T and U lamination type would be Scotts No 4A having a 15/16in tongue width and stacked to give $r = 1.5$ (i.e.1 13/32in stack) or alternatively Scotts Type 222 having a 1in tongue width and stacked to give $r = 1.25$ (i.e. 1¼in stack).

There are, of course, many other sizes of lamination which would be suitable with the appropriate stack but the above have been selected as being common sizes and having proportions convenient for construction.

The completion of the design is straightforward and the case using a 1⅞in stack of the 1¼in tongue width "no waste" lamination (Scotts No 174) has been chosen as an illustration of the procedure. The build up of the windings will be calculated as the design progresses and show that the windings can be accommodated in the winding area available.

The secondary turns per volt are:—

$$\frac{7.78}{T \times S} = \frac{7.78}{1.25 \times 1.875} = 3.3$$

The winding length will be $0.85 \times 1.875 = 1.59$in if the transformer is to be individually wound.

Primary.—If the power efficiency is 90% the voltage efficiency will be in the region of 95% and the primary turns per volt will be therefore $0.95 \times 3.3 = 3.15$. Thus the primary turns required are 789 tapped at 32, 662 and 725. If the primary wire current density is not to exceed 2,000 amp/sq in on any voltage tap, the primary wire gauge must be such as to carry on the lowest tap $\frac{100}{200} = 0.50$ amp.

At 2,000 amp/sq in a suitable wire gauge is 26 s.w.g.

Over a winding length of 1.59in we may wind 73 turns of normal enamel wire, and we will require, therefore, $789/73 = 11$ layers.

If we use 0.003in interleaving paper the build up will be $0.0224 \times 11 = 0.247$in.

H.T. Secondary.—The r.m.s. voltage is to be 600 centre tapped so that the turns required at $600 \times 3.3 = 1{,}980$ tapped at 990.

For an r.m.s. current of 107.5mA a suitable wire gauge will be 36 s.w.g. at approx 2,000 amp/sq in.

Using normal enamel covering we can wind 171 turns in the width available and the number of layers required is $1{,}980/171 = 12$. Using 0.002in interleaving paper, the build up will be $0.0103\text{in} \times 12 = 0.124$in.

L.T. Secondary.—Each winding will require $6.3 \times 3.3 = 21$ turns, say 22 to allow for the extra drop due to the higher resistance when wound on last. Suitable gauges of wire, at 2,000 amp/sq in, are:—

L.T.1 = 22 s.w.g.; L.T.2 = 18 s.w.g.

We may wind 28 turns of 18 s.w.g. in the width available so that the 22 turns required will go on nicely in one layer. Using a 0.010-in paper, the height occupied will be 0.061in.

The L.T.2 winding will go on last and only occupy part of a layer. The height occupied will be 0.040in if we allow 0.010in insulation to finish.

The total height occupied by the windings is:—
0.247in + 0.124in + 0.061in + 0.040in = 0.478in. The window height is 0.625in, therefore 0.147in is left for the bobbin and the insulation between windings.

This space could be distributed as follows:—

(i) Bobbin 1/16in = 0.063in.

(ii) Primary to h.t. secondary insulation, including one incomplete turn of copper foil for electrostatic screen = 0.030in.

(iii) H.T. secondary to L.T.2 winding = 0.020in.
Total = 0.113in.

APPENDIX

If we have a stack of laminations, with the dimensions in Fig. 1, of thickness S, then the cross-section of the core will be $S \times T$, and the window area $L \times H$.

The fundamental transformer equation is[1]:—

$$E = 4.44 \times f \times N \times A_c \times B_{max} \times 10^{-8}$$

where E = R.M.S. voltage across winding,
f = frequency in c/s,
N = number of turns in winding,
A_c = effective cross-section of iron core in sq cms,
B_{max} = peak flux density in gauss.

If we take B_{max} as 10k gauss, a normal value for the usual grades of silicon steel, f as 50c/s and allow 10% of the stack thickness for insulation of the laminations, we obtain, after substitution in the above equation and conversion to inches:

$$\text{turns/volt} = \frac{N}{E} = \frac{7.78}{T \times S}$$

We will assume the winding to be layer wound and interleaved, and make the following estimates; referring to Figs. 1 and 2.

(a) Winding length $L' = 0.85L$.
(This is possible with individually wound coils, but requires reducing if the coils are to be wound on a multiple machine. See note (4) of main text.)

(b) Linear winding factor $\frac{\text{(Practical t.p.i.)}}{\text{(Theoretical t.p.i.)}} = \frac{d'}{q} = 0.9$

(c) Paper interleaving thickness $t = 0.35 \times$ overall wire diam. $= 0.35d'$.

This is a reasonable approximation to the thickness usually employed and is equivalent to the use of interleaving paper of thickness:—

0.001in for wire gauges up to 0.004in diam (42s.w.g.),

0.0015in for wire gauges of 0.004in diam (42s.w.g.) to 0.0048in diam (40s.w.g.),

0.002in for wire gauges of 0.0052in diam (39s.w.g.) to 0.0068in diam (37s.w.g.),

0.003in for wire gauges of 0.0076in diam (36s.w.g.) to 0.0124in diam (30s.w.g.),

0.005in for wire gauges of 0.0136in diam (29s.w.g.) to 0.028in diam (22s.w.g.),

0.010in for wire gauges of 0.032in diam (21s.w.g.) and above.

(d) Available winding height = 0.80 of window height = 0.80H. (Thus allowing 0.20H for the bobbin, insulation between windings and outside insulation.)

On the basis of the above estimates we may calculate the fraction of the winding area occupied by copper. Referring to Fig. 2, the ratio of d to q with a 90% linear space factor, varies from 0.81 for 0.004in (42s.w.g.) to 0.85 for 0.0036in (20s.w.g.) wire with normal enamel covering. Also, the ratio of copper diameter d to overall diameter d' varies from 0.9 to 0.935 for the same range of wire sizes (from the wire tables of ref 2). If we take the lower value in each case, each turn of wire will occupy a rectangle of $d/0.9$ high by d 0.81 wide, i.e. $1.11d \times 1.24d$. From section C above, the paper thickness t is assumed to be 0.35 of the overall wire diameter, whence $t = 0.35d' = 0.35 \times d\ 0.9 = 0.389d$.

Thus the total height of each layer is $1.11d + 0.389d = 1.5d$, and each turn, including paper, occupies a rectangle of $1.5d$ high by $1.24d$ wide, an area of $1.86d^2$.

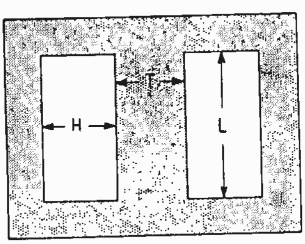


Fig. 1. Type of lamination discussed in the article. Cross-sectional area of magnetic path assumed constant and equal to cross-sectional area of centre link.

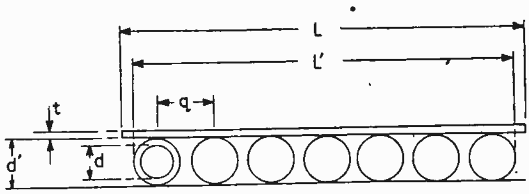


Fig. 2. Single layer of winding illustrating factors involved in calculating space occupied by the copper conductor; t = thickness of inter-layer insulation, d = diameter of copper conductor, d = overall diameter of wire, q = space between adjacent turns, L = window length and L' = winding length.

The cross-sectional copper area of each turn is $\pi d^2/4$. Therefore, the ratio of (copper area)/(area occupied) per turn is:—

$$\frac{\pi d^2}{4 \times 1.86 \times d^2} = 0.422$$

From section (a) above, the windings only occupy 0.85 of the window length.

Therefore the ratio:

$$\frac{\text{copper area/layer}}{\text{window area/layer}} = 0.85 \times 0.422 = 0.358$$

Also, from section (d) above, the windings only occupy 0.80 of the winding height.

Therefore the ratio:

$$\frac{\text{total copper area}}{\text{window area}} = 0.358 \times 0.80 = 0.286$$

If the transformer is to be double wound the most efficient design will be when the primary and secondary each occupy approximately half the available winding area.

Therefore, the available copper area for primary and secondary each will be:—

$$0.5 \times 0.286 \times \text{window area} = 0.143 \times L \times H$$

The power handled by the transformer is independent of the manner in which the available copper area is divided up, providing that the total copper cross-sectional area remains constant, so that for the purpose of evaluating the power handling capabilities we will postulate a single turn of cross section equal to the available copper area.

If we assume a current density of 2,000A/sq in the current capacity of the single turn will be $2{,}000 \times 0.143 \times L \times H = 286 \times L \times H$ amperes: and the voltage developed across the ends of the turn will be:—1/t.p.v. $= T \times S/7.78$.

Therefore, the volt/amperes (VA) of the winding are equal to:—

$$\frac{T \times S}{7.78} \times 286 \times L \times H$$
$$= 36.9 \times T \times S \times L \times H.$$

Putting $S = r \times T$ where r is the stack-to-tongue ratio, this expression becomes:—

$$VA = 36.9 \times T^2 \times L \times H \times r.$$

If laminations with a known relationship between T, L and H are to be used, the expression may be simplified further, e.g., for "no waste" laminations the following proportions hold:—

$$H = 0.5T \text{ and } L = 1.5T.$$

Therefore, in this particular case $VA = 36.9 \times T^2 \times r \times 0.75T^2 = 27.9 \times r \times T^4$

If $r = 1$ (square core cross-section) then:—

$$\text{Cross-section of core } T^2 = \frac{\sqrt{VA}}{5.3}$$

This is similar to the relation quoted by Langford-Smith[2] and Terman[3] and it should be noted that it holds only for a square stack of "no waste" laminations having the proportions stated above.

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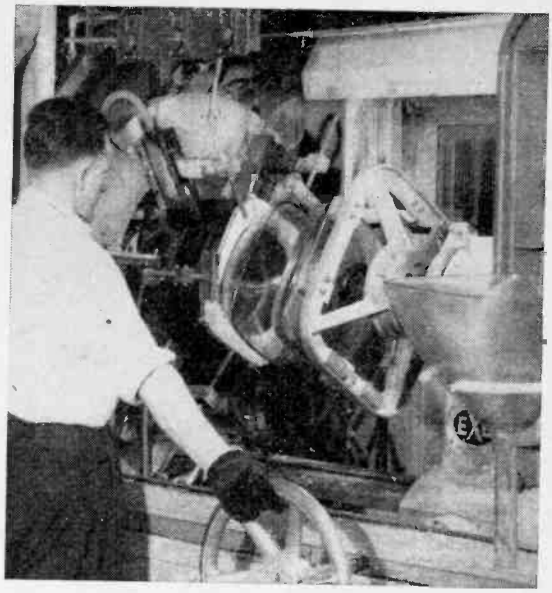
1 "Magnetic Circuits and Transformers," M.I.T. Staff, Chapman and Hall, p. 168.
2 "Radio Designers Handbook," F. Langford-Smith, Iliffe, 4th Ed. p. 235.
3 "Radio Engineers Handbook," F. E. Terman, McGraw-Hill, 1st Ed, p. 105.

Modern C.R.T. Production

ELECTRIC WELDING OF GLASS



Faceplate and cone in glassworking lathe. Two electrodes can be seen—one just above operator's wrist, the other in line with his chin.

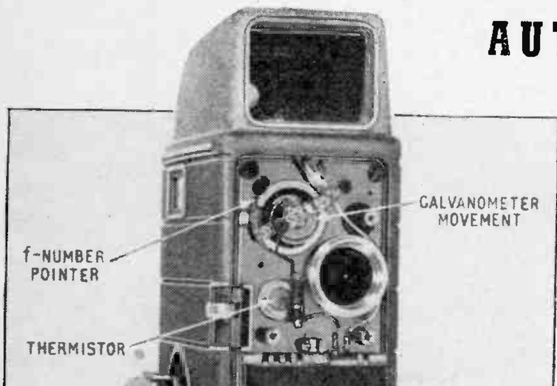
ABOUT 12,000 tubes are made each week at the Sunderland factory of Siemens Edison Swan Limited and production has totalled about 1 million tubes since the plant started operating about two years ago.

Many automatic processes are used, the tubes being carried throughout manufacture on overhead conveyors altogether nearly two miles long. Possibly the most interesting process demonstrated was the welding of the tube faceplate to the cone, using electric arcs. The cone-and-neck assemblies and the faceplates converge on a group of glass-working lathes on which they are joined. Closing the door of the cage round the lathe initiates an automatic cycle of events which starts with the "ware" being preheated by gas flames. As the "ware" rotates the distance of the burners from the glass is kept constant by attaching them to followers running on a cam with the same profile as the tube. When the edges of faceplate and cone have been raised to the correct temperature the power is switched on to the arc.

The welding process employed looks like normal arc welding; but, in fact, it is resistance welding. A typical glass has a resistivity 10^{14} less at its melting point than that at room temperature, so current can flow through almost-molten glass quite easily. Oxy-coal-gas flames are used as the electrodes, three being employed on a three-phase system as this was found to give a better current waveform and, consequently, a more regular weld and less radiated interference. About 11kV is used to start the discharge; but only about 1kV (1.7kV between electrodes) is required to maintain it. To achieve this characteristic a leaky-flux transformer with a series resistor is used, fed from the 50c/s, three-phase mains supply. The current flowing through the glass is in the region of 3A and total power dissipation is about 9kW.

The use of this process, in which the heat for the actual joining operation is developed inside the glass itself and not applied externally from gas flames is claimed to provide a very regular weld with a very small proportion of rejects.

AUTOMATIC IRIS CONTROL



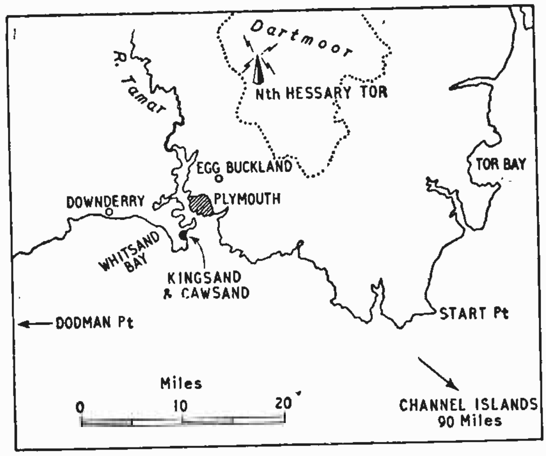
Components of the automatic control system mounted in the "Autoset". An insulating cover for the circuitry has been removed, as well as the metal cover.

ELECTRONIC techniques occasionally surprise us by their simplicity. A good example of what can be achieved with extreme economy of means is the automatic iris control system in the G.B-Bell and Howell "Autoset" 8-mm cine camera, made by Rank Precision Industries. In this a photocell is used to adjust automatically the aperture of the iris according to the amount of light on the scene being filmed. The output from a barrier-layer photo-voltaic cell directly operates a galvanometer movement which drives two lightweight, jewel-mounted toothed wheels in opposite directions. Each wheel has a specially shaped hole cut in it, and where the two holes coincide the effect of a varying aperture is achieved when the galvo rotates the wheels. At the same time a pointer on the galvo movement indicates *f* numbers on a scale incorporated in the metal cover (removed in the illustration).

A thermistor and shunt resistor are wired in series with the photocell and galvo to compensate for temperature variations. The photocell has a yellow correction filter in front of it and also a mask in the form of a grid to give an acceptance angle approximately the same as that of the lens. A knob on the metal cover allows the automatic system to be changed over to manual aperture control if desired.

COMMENTS ON PERTURBATIONS IN NORTH HESSARY TOR TELEVISION TRANSMISSIONS

By JAMES P. GRANT, Assoc. Brit. I.R.E.



MORE ON THE "PLYMOUTH EFFECT"

SINCE I first wrote of the interference in the television transmission from North Hessary Tor in the March 1957 issue of this journal*, there have been a number of comments on the phenomenon and suggested explanations as to the cause. It has also been the subject of an I.E.E. paper†. Unfortunately most of the workers have been unable to spend much time in the locality, while some correspondents have presumably not even seen this unique effect.

In view of the complex and very unusual form of interference—the full significance of which can only be appreciated after long observation—it is necessary to check the distortion of the picture, in its various forms, against the theories which have been advanced. It is the purpose of this article to compare the observed effect with the suggested cause.

Most of the theories deal to some extent with the fluctuations in brilliance, but do not entirely explain the selective line pulling and variations in the strength of the interfering signal similar to that associated with anomalous propagation—both of which are equally characteristic features. Bunches of lines are displaced in synchronism, usually to the left but sometimes to the right. Quite often there are 10 to 15 lines in a bunch, displaced at about quarter, half, and three-quarters of the way down the picture. The movement usually coincides with the maximum increase in brightness, and occurs when the brightness fluctuations are fairly severe. On other occasions the displacement moves successively from top to bottom, in steps of about 10 to 20 lines at each surge. If flywheel sync is used, then the whole picture sways to one side and the verticals are bowed.

Thus it should be understood that reference to "beating" includes the characteristic line displacement—which is the more annoying to the viewer—as well as the brilliance fluctuations. It has also been observed that when the general level of beating is only moderate, groups occur of two or three consecutive beats of very much increased intensity at about thirty seconds intervals. On other occasions, the basic beat is quite slight, and there is marked increase in intensity for about one minute every three or four minutes.

From the foregoing it will be appreciated that the variation in the effect produced on the television screen is such that a different combination occurs at almost every observation, some of which agree, but more often disagree, with the arguments which have been used to explain the phenomenon.

Back-scatter From the Sea?

There is general agreement that the interference is due to the reflection of the North Hessary Tor transmission by a surface which is in motion and situated to seawards of Plymouth. The obvious choice is the surface of the sea itself. It is said such reflection could only take place as back-scatter from the wave fronts of advancing sea waves. Radar experience would not suggest this as being significant at metre wavelengths, and even so it would be liable to variation in amplitude, depending on the force of wind and consequent height of sea waves, but not seriously affected by other atmospheric conditions. No correlation between wind direction and force and the strength of beat has been found. Also at Downderry, owing to the shadow of the intervening cliff the sea is not irradiated by North Hessary Tor for the first five miles from the shore, and a receiving aerial at 25ft above sea level has a horizon of six and a half miles. Thus for the interference to be due to back-scatter from the sea at Downderry, it would have to come from an area of water only one and a half miles in depth, five miles from the shore and 25 miles from the transmitter.

It is interesting to note that the beating effect is present on horizontally polarized transmissions on Band II from the same transmitter, and allowing for limiting in the receiver appears to be the same as on Band I.

One of the earliest comments suggested that optimum scatter from sea waves in the Plymouth area would only occur when they were travelling to or from the S.S.W., while other opinions later favoured

* "Television Interference Problem." *Wireless World*, March, 1957.

† "Phase-Coherent Back-Scatter of Radio Waves at the Surface of the Sea" by E. Sofaer. *Proc. I.E.E.*, Vol. 105, Part B, No. 22, July, 1958.

sea waves travelling to or from the S.E. Allowing latitude of a few degrees either side, there is not much of the 360° where interference should not occur, yet many observations have been made when the wind has not been from the specified directions and severe beating was experienced. While it has been said that any scatter effect would be likely to occur in Torbay as well as in the Plymouth area, it has been conversely argued that it could not occur in Torbay, which in fact it does not. One point of view favours a relatively small scatter area well inside Plymouth Sound, rather than back-scatter from the English Channel.

While quasi-specular reflection from the advancing wave fronts in Plymouth Sound may be deemed to affect Kingsand and Cawsand, it could not possibly affect Whitsand Bay and Downderry. Although the Kingsand area is most affected the falling off in intensity at either side is quite gradual, such that Whitsand Bay is only a little less affected and is sheltered from Plymouth Sound and North Hessary Tor by Rame Head and a ridge of high ground about 350ft above sea level.

There is also no correlation between the speed of beat and the state of tide, as one writer suggested. See Table I below.

TABLE I

Date	Time	High Water	Speed of beat
4-6-57	10-05	10-58	38
	12-35		34
	17-00		40
5-6-57	10-10	11-51	40
	12-40		42
	17-05		42
6-6-57	10-15	12-55	36
	12-40		40
	17-15		34

(Many similar examples could be quoted.)

The multiple ghosting is present whenever the beat is severe. The number of ghosts increases with the severity of the beat and is not dependent on the state of the sea. Drawings which have been produced showing the distortion of the line sync pulse were presumably derived from observations of oscillograms which only showed the average picture of a large number of pulses. In view of the selective line pulling it would appear that only some pulses are so distorted, while others are reasonably normal. It is doubtful if much can be learned from the synchronising pulses unless apparatus is available to enable observation of individual line pulses.

Owing to the difficulty of manœuvring a highly directional aerial, there has been some difference of opinion as to the bearing of the source of maximum interference. Locally 140° is favoured, as opposed to the suggested 100°, but there is little doubt that, on certain sites at least, the reflection does appear to be stronger from one direction. The suggestion that the lowering and shielding of aerials might give some relief is not borne out in practice. For example, at Kingsand, one three-element aerial is about 45ft above ground, 150ft above sea level and open to a wide area of Cawsand Bay, yet only slight interference is experienced. Another four-element aerial 25ft above ground, 75ft above sea level and screened from the sea by houses suffers badly from beat interference.

Since writing the original article, a site has been discovered about a mile inland to the north of Kingsand, 300ft above sea level, almost visual to North Hessary Tor and obscured by a 400ft hill from all but the very smallest glimpse of the western corner of Cawsand Bay. When beating is severe down in the village a definite brilliance fluctuation of the characteristic type can be detected on this site, although it is completely screened from the part of Cawsand Bay to which sea scatter reflection is attributed. Also, in the centre of Plymouth in a radio service department with an aerial 80 to 100ft above ground, slight brilliance fluctuations have been noticed without causing any undue concern, but there is no doubt that this interference is of the same type experienced at Kingsand. It has the same characteristic rhythm and is nearly always present. The sea is not visible even from this height due to the intervening Plymouth Hoe.

It is said that the offending "isostematic"‡ reflections occur when the wind direction falls between 105° and 160° and between 285° and 340°, and are more pronounced when the barometer is unsteady and the wind velocity low. This assertion is not supported by prolonged observation, and on the 18th November, 1957, an experienced independent observer reported that at Kingsand the beat was as severe as he had ever seen it. Observations were made on several commercial receivers and a reliable field-strength meter between 1630 and 1715 G.M.T. Local met. reports show that the wind direction was 180° force 15 knots, barometer steady. The barometer fell slowly from 1100 to 1500 hrs, and then remained steady at 1019.6 mbs, for 1600 and 1700 hrs G.M.T. Thus the wind direction was 20° outside that predicted, the barometer was steady when it would have been expected to be unsteady, and even though the wind force was recorded in a rather sheltered position, it was stronger than predicted. Similar examples could be quoted.

It has been said that back-scatter from the sea is likely to occur when a television transmitter is sited high and near the sea. Broadly these conditions are met at Wenvoe, Blaen Plwy, and Sandale Fell transmitters, one of which has a much higher e.r.p. than North Hessary Tor. As far as I am aware, no similar effect is experienced in these areas.

Unlikely Case

All the theories so far considered favour back-scatter from the surface of the sea, but they differ widely on the conditions necessary to cause it, and there is an even deeper gulf between suggested cause and observed effect. In the case of Downderry, for example, it is presumed that an area of sea 25 miles from the transmitter, only 1½ miles in depth and 5 miles from the receiver could, from calm water, reflect back sufficient signal that interference could be caused. While I do not dispute that it is possible, it does not seem very probable; nevertheless this idea has considerable theoretical support if little practical corroboration. On the same basis it seems only reasonable to consider another possibility which,

‡ In the I.E.E. paper this word is defined as "characterized by similar intervals."

while being equally improbable, does more nearly explain the observed effects.

The idea that North Hessary Tor signals could be reflected from the Channel Islands appears at first sight to be fantastic but there is on Guernsey, on high ground near the sea, an unusually large array of long sloping wire receiving aerials, with their top ends 90ft above ground and beamed on North Hessary Tor. Such an array offers an ideal reflecting surface of considerable size, and the aerials on both sides of the Channel have an uninterrupted view of the horizon. Since the long sloping wire aerials are non-resonant at these frequencies, then the Band II transmissions could be equally effected, the receiving aerials acting as a very large reflector. The distance from North Hessary Tor to the Channel Islands is about 95 miles, the return distance to Kingsand being slightly less. The horizon from the transmitter aerials is about 57 miles, and that from Guernsey about 28 miles (assuming an aerial height of 500ft); thus there is a gap of some 10 miles where refraction and *forward* scatter from the sea would influence the signal.

Coastal Limits

Since the Guernsey aerials are very directional, a slight and possible error in siting could result in the reflected beam being centred on Kingsand, with a steady falling-off to each side, with Dodman Point and Start Point as the outer limits (these have been observed). This would explain the freedom of Torbay from interference and the reduced effect either side of Kingsand. Such a reflection would be subject to atmospheric conditions and the general variations associated with anomalous propagation. The illumination of the land promontories to the east of Plymouth by the Channel Islands reflection when it was strong would, depending on phase, reduce or enhance the direct-ray reflections from these points and account for the multiple ghosting under severe beating conditions. Although the leading edge of the line sync pulse has shown to be distorted sufficiently to lead to irregular firing of the line timebase, it is not sufficient to account for several consecutive lines starting very early and yet remaining synchronised in the new position. If however the reflected signal was delayed several lines, then it would be possible for short bursts of sync pulses to prematurely trigger the line timebase. The absence of a vertical ghost is not surprising, as the reflected signal would not be sufficiently well defined to show a separate picture, but would only affect the general brightness level. The *forward* scatter from the sea, both on the outward and return journeys, would account for the pulsing brilliance, but as it would take place at a considerable distance from the Devon shore, local tides, land recorded wind force and direction and other meteorological data would be of little use for predicting the severity of the beat.

The less frequent sudden bursts of two or three greatly increased beats are more reminiscent of ionospheric scatter, but it seems even more unlikely that the outward or return path could be via this medium. The similarity in effect, however, is remarkable. During investigations of ionospheric scatter at v.h.f. carried out in this country by the G.P.O. and D.S.I.R. covering frequencies of 25, 41 and 89 Mc/s, variations in the background signal of some 70dB were recorded. It was also observed that peaks of as much as 40dB or more above background, lasting for a second or up to half a minute were received and at times signals of up to 60 to 100dB above background.

I doubt if such a set of circumstances has ever existed before, even experimentally, where a transmitter 2,300ft above sea level and within 13 miles of the coast has, within less than 100 miles over a path entirely of water, been faced with such a high gain very directional aerial, while at the same time receiving aerials have been set up in the shadow of the transmitter.

It is an interesting point that there is a second and similar array of sloping wire aerials on Guernsey, which was originally used for reception of the Alexandra Palace television transmissions. If the array still exists, then similar but somewhat reduced interference effect could be expected to occur in the Isle of Wight in the region of Ventnor.

Quite recently reports have been received of rhythmic changes of brilliance at Clacton and Harwich on the east coast. These observations were made while receiving the Crystal Palace transmission on Channel I, and were sufficiently slight that they were unlikely to be noticed by the average viewer. Nevertheless the effect has been identified as the same type observed at Plymouth. It has been shown elsewhere that isostematic interference requires that "the sea within the horizon of the receiving aerial must be directly irradiated by the transmitter." This condition does not exist in the region of Clacton and Harwich, as these places are some 60 to 70 miles from Crystal Palace and the transmitter has a horizon of about 35 miles. It is very interesting to note that a line drawn from Guernsey to Crystal Palace and extended to the east coast passes within 15 miles of Harwich and strikes the coast at Lowestoft. Clacton and Harwich are on the fringe of the London station and well within the expected spread of a reflection of Crystal Palace by the Guernsey aerials. Lowestoft would be expected to receive Norwich on Channel III and therefore not be subject to an interfering signal caused by a Channel I station.

Reports of observation of the beating effect could be expected from receivers tuned to Channel I situated on either side of a line drawn from Crystal Palace to Lowestoft and on the fringe of the London station reception area.

The "Effect" Inland?

Another recent report of beating and line displacement has come from Egg Buckland, a suburb of Plymouth five miles from the sea. This has not yet been confirmed by observation, but there seems little doubt that it is of the characteristic type. The site is heavily screened from North Hessary Tor by high ground and the direct signal is known to be very poor. It is significant that this site is not open to the sea and very unlikely to be subject to interference due to back-scatter from Plymouth Sound or even the English Channel.

During periods of severe interference from Continental television which is said to be due to sporadic E layer reflections, it has been noticed that the beating is also severe and that it moderates in severity at the same time as the sporadic E interference.

I hope I have shown that the many theories which have been propounded are not easily accepted by local workers hardened by many months of observation of the various effects produced by the interference. Perhaps the suggestion of another "impossible"—or should I say improbable?—cause, will stimulate further discussion on this most unusual, persistent, and very annoying interference with the reception of North Hessary Tor.

Finally I would like to thank S. H. Cooms, engineer-in-charge of the B.B.C.'s station at Plymouth, and other members of the Corporation for their assistance and advice, also members of the Post Office engineering staff.

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Further Notes on the ARR3 Sonobuoy Receiver

ADDITIONAL PRECAUTIONS AGAINST THE POSSIBILITY OF RADIATION

IF MODIFIED according to the article in last month's issue the local oscillator works at half the oscillator-low frequency. In other words, second-harmonic mixing is employed, the local oscillator frequency being given by $(f_{sig} - \text{i.f.})/2$ Mc/s. It turns out that this includes television Channel 1 (sound 41.5Mc/s, vision 45.0Mc/s). Thus if any appreciable amount of oscillator radiation is allowed to occur, interference with Channel 1 television may be caused. To avoid this possibility it is better, in areas served by a Channel-1 television transmitter, to use third-harmonic oscillator-high mixing; the local-oscillator frequency is then $(f_{sig} + \text{i.f.})/3$ Mc/s. Not only should this reduce radiation but it also avoids the generation of any signals at Channel-1 frequencies.

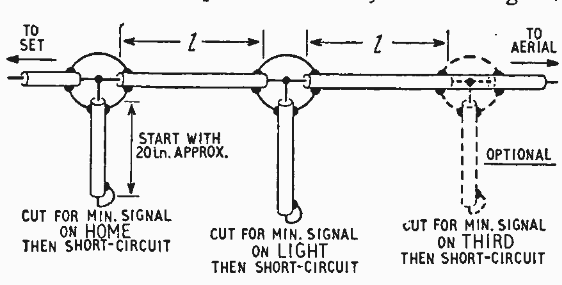
As the unmodified receiver covers the 60-72 Mc/s band using second-harmonic mixing the original oscillator coil should be satisfactory, without modification. Therefore, for use in Channel-1 areas L_{129} (the local-oscillator coil) should be left intact and reconnected when the other modifications have been carried out. Also, moving the aerial socket from the front panel of the receiver to the hole left by removal of C_{103A} (the aerial-circuit trimmer) should help.

If radiation still proves troublesome a filter must be constructed for the aerial lead. The diagram shows the general form and it will be seen that the filter consists of at least two λ/4 (Band II) short-circuited stubs connected across the aerial feeder. These are made from standard 80-Ω coaxial cable and are simple to adjust. Cut the feeder at a convenient point close to the receiver and connect in parallel a 20-in piece of cable. Tune to any station, say the Home Service and, either with a meter connected to the test socket points A and B, or observing the "magic eye," snip short lengths (¼in or so) from the stub until the signal is at minimum strength. (Take care that the stub is not accidentally short-circuited by stray ends of wire.) As soon as the minimum has been found, bare the cut end of the stub and short-circuit the inner to the outer. The signal should now return to its previous level. Repeat this at a distance "*l*" (approximate lengths given in the table) along the feeder towards the aerial; but this time tune to another station, say the Light programme. If radiation still occurs another stub, tuned to the Third programme and again spaced "*l*" away from the last, may be necessary.

TABLE

Local Television Channel	Approx. "*l*" (in.)
1	36
2	33
3	30
4	28
5	25

N.B.—It may be possible to improve filter action by adjusting section "*l*."



A λ/4 stub, when open-circuited at one end, presents a short circuit at the other. Thus the stubs were tuned, open circuited, by observing a signal minimum, then short-circuited. A short circuit at the end of the stub reflects an open circuit at the feeder at Band-II frequencies and thus should have no effect on Band-II signals. However, at the frequency causing interference they are shorter than λ/4 and thus produce a low reactance across the feeder, tending to short circuit any energy at this frequency. The "short circuit" will cause a standing wave on the line at the interfering frequency because one stub does not absorb all the energy: thus another is added λ/4 (at the interfering frequency) along the line, where there should be a voltage maximum and so on until the interference is reduced to an acceptable level. In practice two or three stubs should suffice.

The author has asked us to point out that he gave incorrect values for C_{118A}, C_{118B} and C_{128}—the padding capacitors in series with the tuning capacitor. In one receiver these were tubular ceramic types respectively 35, 35 and 40pF, whilst in another receiver they were 35, 35 and 50pF moulded mica components. He also suggests that, if all three f.m. stations cannot be accommodated within the tuning range of the receiver, the oscillator padder C_{128} could be short-circuited.

By G. W. A. DUMMER,* M.B.E., M.I.E.E.

Future Electronic Components

How New Techniques are Likely to Influence Their Design

The influence of components on constructional techniques has been considerable and as components have been miniaturized so equipment designers have been able to reduce the size of their equipments. With the advent of the most recent conventional sub-miniature components and transistors it is likely that the limit of miniaturization has been reached, and any further miniaturization now means a fundamental change in component design using the "active" or "working" element only. Flat-shaped components consisting of thin films of resistive materials, dielectric materials, magnetic materials and conductive materials, may be the next generation of components; resulting in what is now being termed "micro-miniaturization" techniques.

CONSTRUCTIONAL techniques in electronic equipment generally follow component design and the normal metal chassis, still widely used, employs standard components mounted on tag boards or stand-off insulators. This form of construction is being replaced to some extent by printed wiring boards on which components are mounted with the board forming its own insulator.

The use of transistors in conjunction with printed wiring and sub-miniature components has resulted in much smaller equipments and components are now being used in which the size has been reduced to almost the ultimate while still retaining conventional methods of attachment, end contacts, etc. Still further miniaturization can now only be effected through the use of the "active" or "working" element only of the component, i.e. "film" techniques. This should obviate the use of comparatively large end connections on tubular components and to a certain extent protective coatings may be reduced and the unit protected as a whole. This problem is aided by the low-voltage requirements of transistor components. For low-power ratings it now becomes possible to design components using extremely thin films of resistive, dielectric, magnetic or conductive materials.

These components may be mounted on plates in two ways, either on a large area single plate or a stack of small plates. It would be preferable to use small plates each carrying one, or possibly two, components in view of the high reject rate in the production of numbers of components on one plate. If each component is produced on its own small plate it can be manufactured, tested, inspected, etc, in a similar manner to normal component production in a factory. Many resistors and capacitors are, in fact, already in film form but wrapped round tubes and rods.

Research is being done on the development of resistive, capacitive, and magnetic films on insulating bases. Some of this work is described here.

* Royal Radar Establishment.

Resistive Films.—Methods of deposition of film resistors might be summarized as follows:—

Film Resistors
- Carbon composition films.
  - Cracked carbon films.
- Fired metal films (platinum/gold alloys, palladium/gold alloys, etc.)
  - Sprayed metal oxide films (tin/antimony, etc.).
- Evaporated nickel/chromium, etc., films.

Carbon Composition Films.—Films have been made from carbon composition mixtures with binders such as epoxy resins, which can be applied to flat surfaces. Control of thickness, carbon content, geometrical dimensions, etc., are not easy but they can be overcome to some extent by accurate process control. Flat-tape resistive-films have been developed in the U.S.A. and many printing and ingenious application techniques are being evolved to provide accurate control of resistance value.

Cracked Carbon Films.—The process of cracking carbon is well known. It consists of depositing a suitable hydrocarbon vapour at about 900 to 1100°C on to a ceramic rod or plate, to produce a coherent carbon layer. The value of the resistance obtained is controlled by the pressure of the vapour, temperature of firing and the time of exposure. Increase of resistance value and final adjustment is carried out by a diamond grinding wheel cutting insulating tracks into the coating. Protection of the film is difficult.

Platinum/Gold Alloy Fired Films.—Films of noble metals fired on glass or glazed ceramic plates have proved extremely stable. The proportions in which the metals are mixed affect the resistivity and the temperature coefficient. An alloy of 80/20 gold/platinum gives a resistivity of 60 micro-ohm/cm. Resistivity and temperature coefficient are dependent on each other and an alloy of 80/20 gold/platinum alloy gives a temperature coefficient of 0.025% while

60/40 alloy has a temperature coefficient of 0.06%.

Resistors are made by first coating a plate of chemically-clean glass with a solution of gold and platinum compounds mixed in an essential oil (such as oil of lavender or oil of rosemary) and firing in an air oven at about 400°C. This reduces the metal compounds to metal but in this form the metal does not adhere to the glass and can readily be engraved with a sharp point or by photo-mechanical methods, to any required pattern to increase the resistance and adjust it to the required value. The plate is then fired again at about 600 or 700°C (depending upon the substrate) to form an extremely adherent film of metal. The change in value between these two firings is negligible and can be predicted.

Palladium/Gold Alloy Fired Films.—Films may be produced of palladium/gold alloy deposited by thermal reduction of the metallic resinate on a ceramic plate. The palladium or platinum resinate is dispersed in a high boiling point ketone and the dispersion is sprayed on to a clean dry ceramic plate. It is dried in air and fired at 300°C to reduce the palladium resinate and then fired again at between 400 and 750°C to oxidize the residual carbon and ensure thorough adhesion. Meandering of the pattern is used to adjust the resistors to the required values.

Sprayed Metal Oxide Films.—Metallic oxide films have now been in use for some years and are well known in America (being manufactured by the Corning Glass Company). Although many oxides can be used, tin and antimony are the most common combinations and chlorides of these metals are sprayed on to a glass surface which is at red heat. The reaction which takes place yields a glass-like layer of oxide. This layer may vary in thickness from a few hundreds to many thousands of Angström units.

The electrical resistance of the film can be varied over a wide range of values by changing the composition of the spraying solution.

Of the tin/antimony series probably the most suitable oxide film for stable resistors is that of 7% antimony and 93% tin, this composition having the smallest temperature coefficient.

Many factors affect the film in production, such as the temperature of firing, etc. On the other hand, the films themselves are extremely stable and whilst resistance value must be kept reasonably low, long-term tests have shown that stabilities of the order of 0.1 to 0.2% can be obtained after lives of several thousand hours.

Evaporated Nickel/Chromium, etc., Films.—A small amount of the metal or alloy is heated (usually electrically on a tungsten wire or spiral) and is vaporized molecularly in all directions. The vacuum required is of the order of 10^{-5} mm Hg. The choice of heater material and its form depend upon the metal to be evaporated. For instance, aluminium may be evaporated from a loop of tungsten wire, since on melting the metal wets the tungsten and adheres to it, but silver and gold are best evaporated from a small tungsten boat or a conical basket. The evaporation temperatures of nickel and chromium are not too far separated so that evaporation of an alloy gives a deposit of similar composition.

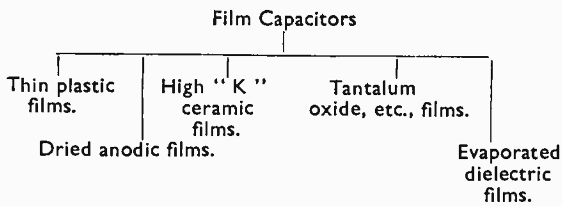
Either noble metals or high resistivity alloys can be evaporated. With noble metals no oxidation and little chemical change take place with time but resistivities are very low. This necessitates either thinner films or larger areas with greater path lengths to obtain reasonable resistance values.

With high resistivity alloys, control of the thickness of the oxide film is difficult and is affected by factors such as the temperature of the base and a tendency to absorb residual oxygen from the atmosphere. On the other hand, due to the higher resistivities smaller size resistors can be obtained.

One of the most difficult problems in forming resistors, particularly if they are to operate at 200°C or above, is end contacts. Methods of thickening up the film before attaching contacts are being studied.

Normally connections are made to metals (such as silver or platinum/gold alloys) which are previously fired on to the base and evaporation takes place over some of this metallized area. Solder connections may subsequently be made to the fired metal.

Dielectric Films.—Some possible techniques are summarized below:—



Thin Plastic Films.—Thin films have been made from high molecular weight polystyrene cast from a solvent on the polyester film used as a carrier. Subsequent stripping results in a good quality film which has been produced in a thickness of 0.0001 in (2.5 μ). Such films are relatively easily handled on the carrier and when stripped from the backing make up into small capacitors with a volumetric gain of about five over paper capacitors. The dielectric properties are identical with normal polystyrene.

A high molecular weight co-polymer of styrene with α-methylstyrene appears to be ideal for the extrusion of thin films. Early work produced such films of 0.0005 in (12 μ) but it is anticipated that the thickness can be greatly reduced. Capacitors made from this film should be usable at 125°C or higher according to the proportions of the materials making up the co-polymer. The same co-polymer can be cast to produce films down to 0.0001 in but these are slightly brittle.

A lacquered technique is being investigated where high molecular weight polystyrene or the co-polymer is deposited only 0.00002 in (0.5 μ) in thickness. In conjunction with evaporated aluminium electrodes this construction should produce very high capacitance in a small volume.

Although metallizing, demetallizing and stripping of these films has been done experimentally, work is now in hand to evaluate the various type of films and constructions in the form of capacitors.

Dried Anodic Films.—Films have been made experimentally in which high purity aluminium foil is anodized in a borate bath as for a standard electrolytic capacitor. It is then dried out and at the same time a dilute solution of epoxy resin is run in to fill the cracks and to seal the film. The film then consists of approximately 80% alumina and 20% epoxy resin. The ends are thickened up by the epoxy resin coating before the evaporation of the counter electrode takes place (to strengthen the end connection). This limits the maximum operating temperature to approximately 150°C. The losses, permittivity, etc., are comparable with a mica capacitor especially for large capacitance values.

High "K" Ceramic Films.—Band casting processes have been developed for producing comparatively thin films of high "K" ceramic material. The ceramic "slip" is fed on to a slowly moving stainless steel belt and levelled by a "doctor" bar before passing through drying and firing ovens. In other methods a small bottomless box with a gate in the trailing side, contains the slip. The box is drawn along a glass plate, leaving behind a thin layer of slip, the thickness being controlled by the depth of the gate and the speed of drawing. Films as thin as 0.005 cm have been drawn by this method.

Evaporated Films.—This type is now receiving considerable attention. Silicon monoxide has been evaporated for some years as an optical protective coating and these films have been made into capacitors giving about 2,500 pF/cm^2 on glass bases and with aluminium electrodes. It is possible to operate these capacitors at temperatures up to about 200 to 250°C. Improved characteristics such as high breakdown, lower loss, etc., have been obtained by the use of silicon dioxide in the place of silicon monoxide. Experimental capacitors have also been made using zinc sulphide. Films 10,000 Angström units thick give breakdown voltages of approximately 100 V with a capacitance of 10,000 pF/cm^2.

Materials which might be evaporated as possible dielectrics include:—

Magnesium fluoride	Cadmium sulphide
Calcium fluoride	Silica
Calicum silicate	Silicon monoxide
Zinc sulphide	Glass of various types
Lead sulphide	Magnesium aluminate.

Magnetic films—Some possible techniques are summarized below:—

Magnetic films
- Films rolled from powder.
- Films by electro-deposition processes.
- Evaporated films.
- Films rolled and thinned by etching.

Evaporated Films.—These films are used mainly in computer drums and the technique is similar to that described for resistive materials but the evaporation is carried out in a strong magnetic field to orientate the dipoles as evaporation takes place.

Alloys such as 70/30 nickel/iron are commonly used. The evaporation temperatures of nickel and iron are sufficiently close to avoid separation of the compounds.

"Flash" evaporation techniques can also be used for alloys in which the metal is dropped on to an extremely hot plate so that vaporization takes place instantly.

Magnetic films have been evaporated up to about 2 microns in thickness and their magnetic properties are now under investigation.

Film-Type or Flat-Plate Semiconductors.—With the introduction of film-type components it is obviously desirable to fabricate germanium and silicon transistors in flat plate form. Considerable work on this has been done by laboratories in the United States of America, who have prepared diffused junction types of germanium transistors in a total volume of 1/50in^3 so that they can be inserted into thin ceramic plates. Conducting electrodes of aluminium are then evaporated on to the surface.

Future Techniques.—It is suggested that the next form of construction after the present transistorized equipments (using printed wiring and sub-miniature components) will probably be that of film-shaped components with flat type transistors.

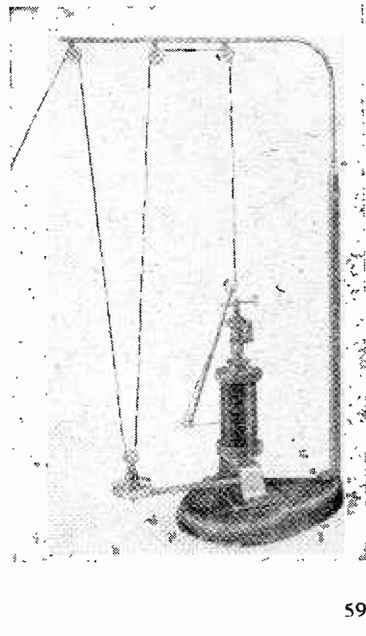
Looking even further into the future it seems certain that the work on solid state physics which is now receiving so much attention will provide molecular amplifiers and oscillators of new types which may eventually take the place of the film-type components Masers, parametric amplifiers, etc. are already indicating the future. There seems no doubt that "molecular electronics" will eventually play a large part and affect constructional techniques of electronic equipment over the next ten years.

Fine Wire Feed Mechanism

THE wire feed and tensioning mechanism illustrated has been developed especially for use where very thin instrument wires, up to No. 52 s.w.g., have to be wound on to delicate pieces of electronic or test equipment. It is claimed that wires of this thinness can be wound safely and without risk of breaking at a speed of up to 60in/sec.

During winding operations the reel of wire remains stationary and a lightly-supported arm pulled by the wire rotates around the reel, the wire being led away to the "work" over a series of pulleys. As shown in the illustration the wire hangs in a "V"-shaped loop formed by a weighted jockey pulley, the jockey weight applying the required tension to the wire. This weight is poised above a pan attached to the end of a pivoted lever. The slightest slackening in the tension on the wire allows the weight to settle in the pan and this depresses the pivoted lever which applies a braking action to the rotating arm thus restoring the tension on the wire. If the wire should jam on the reel the jockey weight can rise several inches without increasing the tension or breaking the wire and its upward movement gives visible warning of trouble ahead.

The wire feeder stands 15in high, costs £23 and is made by Kinetrol Ltd., Trading Estate, Farnham, Surrey.



Wire tensioning and feed mechanism for very thin instrument wires (Kinetrol); as very fine wire would not be visible, thicker wire has been used in the illustrations.

Checking Crystal Oscillators

Measurements to Make Sure of Satisfactory Performance

By D. J. SPOONER

IT has been said that a crystal oscillator doesn't have to be designed—just put it together and it works.

True enough, it does, and in the days when crystals were large and robust and a 5-Mc/s crystal meant 5-Mc/s and no questions asked, that was all that mattered. But of late crystals have got smaller and smaller, and better and better frequency tolerances are demanded.

Smaller crystals are more delicate and, if they are not to be damaged, the power dissipated in them must be kept down to a few milliwatts. Even a small receiving pentode such as an EF91 can feed enough power into a crystal to cause a permanent change of frequency or even to destroy it altogether.

A crystal which has 5Mc/s engraved on its case will oscillate at 5Mc/s only if it is connected to a maintaining circuit having the correct value of input reactance. Variations in input reactance can cause frequency errors of the order of 0.05%, whereas international regulations may require that the frequency error of even a small mobile transmitter be less than a tenth of this amount.

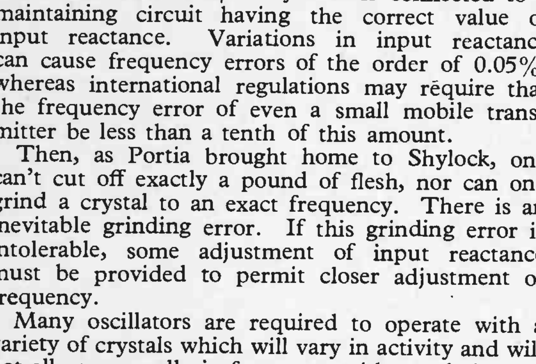
Then, as Portia brought home to Shylock, one can't cut off exactly a pound of flesh, nor can one grind a crystal to an exact frequency. There is an inevitable grinding error. If this grinding error is intolerable, some adjustment of input reactance must be provided to permit closer adjustment of frequency.

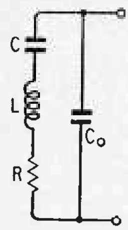
Many oscillators are required to operate with a variety of crystals which will vary in activity and will not all vary equally in frequency with equal changes of circuit reactance.

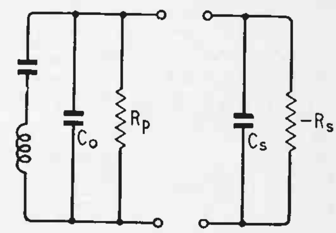
Standards of minimum activity and maximum dissipation have been laid down* and it behoves us to ensure that our oscillator will not fail to oscillate with a crystal of minimum activity nor require it to dissipate too much power. There are, as yet, no standards laid down for those crystal parameters which control the variation of frequency with circuit reactance, but an indication of probable production spread can be obtained from the manufacturer.

* In Defence Spec. DEF. 5271

Fig. 1 Crystal oscillator using the Colpitts circuit.







Left:—Fig. 2 Equivalent circuit of test crystal. Right:—Fig. 3 On the left Fig. 2 is redrawn to show the equivalent parallel resistance. On the right is the equivalent circuit of the maintaining system.

Let us assume, then, that we have an oscillator of the Colpitts type shown in Fig. 1, whether designed or put together, and that we wish to discover whether it will fulfil all our requirements. To make the necessary measurements we shall need the following apparatus:

1. A test crystal of approximately the frequency required.
2. A standard crystal test set.
3. Frequency measuring equipment giving discrimination to one part in a million. (Apparatus of the counter type is preferable as measurements can then be made in rapid succession.)
4. A valve-voltmeter with very low input capacitance—preferably not more than 2pF.
5. A low-frequency capacitance bridge giving reasonable accuracy in the range 5 to 30pF.

First we must evaluate the parameters of our test crystal, the equivalent circuit of which is shown in Fig. 2, where:

L is the motional inductance
C the motional capacitance
C_o the shunt capacitance
and R the equivalent series resistance (e.s.r.)

Since the test set will measure the crystal activity in terms of the equivalent parallel resistance (e.p.r.) the circuit can be redrawn as in Fig. 3, together with the equivalent circuit of the maintaining circuit. Here R_p is the e.p.r. of the crystal, C_s the input capacitance of the maintaining circuit and $-R_s$ its equivalent negative parallel resistance. C_o is simply the shunt capacitance of the crystal electrodes and may be measured by means of the low-frequency bridge. It will be somewhere in the range 5 to 30pF.

R_p at a particular value of circuit capacitance C_{s1} can be measured by means of the crystal test set. Its value at any other circuit capacitance C_{s2} is then

$$R_{p2} = R_{p1}\frac{(C_{s1} + C_o)^2}{(C_{s2} + C_o)^2} \quad \ldots \quad (1)$$

$$\text{And } R = \frac{1}{4\pi^2 f^2 (C_o + C_s)^2 R_{p1}}$$

$$= \frac{2.54 \times 10^7}{f^2 R_p (C_o + C_s)^2} \quad \ldots \quad (2)$$

Where R is expressed in ohms, R_p in kilohms, $(C_o + C_{s1})$ in pF and f is the frequency of oscillation in megacycles per second.

To find C and L we plug the crystal into the test set and measure the frequencies of oscillation f_1 and f_2 at two values of input capacitance C_{s1} and C_{s2}.

Then, if $f_1 = f_o + df_1$ and $f_2 = f_o + df_2$ where f_o is the frequency engraved on the crystal case.

$$C = 2\frac{(C_{s1} + C_o)(C_{s2} + C_o)(df_2 - df_1) \times 10^{-6}}{f_o (C_{s1} - C_{s2})} \quad (3)$$

where, C, C_o, C_{s1} and C_{s2} are expressed in pF, f_o in Mc/s and f_1 and f_2 in c/s.

$$\text{And } L = \frac{C + C_o + C_s}{4\pi^2 f_o^2 C(C_s + C_o)} \text{ henries} \quad \ldots \quad (4)$$

It only remains to state the manner in which the frequency of our test crystal varies with circuit capacitance. If f is the frequency of oscillation at any value of circuit capacitance C_s and $f = f_o + df$

$$\text{Then } df = \frac{m}{C_s + C_o} + k \quad \ldots \quad (5)$$

$$\text{where } m = \frac{(C_{s1} + C_o)(C_{s2} + C_o)(df_1 - df_2)}{C_{s2} - C_{s1}} \quad (6)$$

$$\text{and } k = df_1 - \frac{m}{C_{s1} + C_o} \quad \ldots \quad (7)$$

Note that, when $C_s = \infty$, $df = k$. Therefore, $k = f_r - f_o$ where f_r is the series resonant frequency of L and C.

Having found out all about our test crystal we can now use it to measure the performance of our oscillator.

First we measure the frequency of oscillation, which turns out to be say $f_o + df$.

By rewriting equation (5) as

$$C_s = \frac{m}{df - k} - C_o \quad \ldots \quad (8)$$

we can evaluate C_s.

Having made any adjustment necessary to correct C_s we next determine the value of R_p at the chosen value of C_s and also R_{pmin}, the minimum value of e.p.r., from the standards laid down*, using equation (1) if necessary. The crystal is then shunted by a resistor to reduce its e.p.r. to R_{pmin}, a blocking capacitor being inserted to prevent disturbance of the bias conditions.

Then, if E is the r.m.s. voltage across the crystal, the power dissipated is

$$W = \frac{E_2}{R_{pmin}} \times 10^3 \text{ milliwatts} \quad \ldots \quad (9)$$

Note.—C_s should be adjusted after the voltmeter has been connected to compensate for the voltmeter capacitance.

To ensure that the oscillator will start with any crystal, it should be possible to shunt the crystal down to about $\frac{R_{pmin}}{3}$ before oscillation ceases, as some crystals have much lower values of e.p.r. at small amplitudes.

Let us assume that the cutting tolerance of the crystal is such that it may have any frequency in the range of f to $f + df$, for which we wish to compensate by varying the input capacitance of the maintaining circuit from C_s to $C_s + dC_s$.

$$\text{Then } dC_s = -\frac{2df(C_s + C_o)^2}{fC + 2df(C_o + C_s)} \quad \ldots \quad (10)$$

Having found out from the manufacturer what the variation of C and C_o is likely to be we can put extreme values into equation (10) and determine how much adjustment of C_s we must allow.

No attempt will be made here to decide if the circuit chosen is the best for our purpose. All that has been dealt with elsewhere, but, having made this series of measurements, we can rest assured that any reasonable crystal will oscillate in the circuit, will not be damaged and can be adjusted to the required frequency.

APPENDIX

Derivation of equation (3) :—

$$f_1^2 \frac{(C_{s1} + C_o)}{C + C_o + C_{s1}} = f_2^2 \frac{(C_{s2} + C_o)}{C + C_o + C_{s2}}$$

$$\therefore C = \frac{(C_{s1} + C_o)(C_{s2} + C_o)(f_2^2 - f_1^2)}{f_1^2 (C_{s1} + C_o) - f_2^2 (C_{s2} + C_o)}$$

Now if f_o is any fixed frequency near to f_1 and f_2 which may, for convenience, be the frequency engraved on the crystal case, we may write

$$f_1 = f_o + df_1 \text{ and } f_2 = f_o + df_2$$

Then C =

$$\frac{(C_{s1} + C_o)(C_{s2} + C_o)(f_o^2 + 2f_o df_2 + f_o^2 - 2f_o df_1)}{(C_{s1} + C_o)(f_o^2 + 2f_o df_1) - (C_{s2} + C_o)(f_o^2 + 2f_o df_2)}$$

$$= 2\frac{(C_{s1} + C_o)(C_{s2} + C_o)(df_2 - df_1)}{(C_{s1} + C_o)(f_o + 2df_1) - (C_{s2} + C_o)(f_o + 2df_2)}$$

But $f_o + 2df_1 = f_o + 2df_2 = f_o$ with an error of, at most, a few parts in 10^4.

$$\therefore C = 2\frac{(C_{s1} + C_o)(C_{s2} + C_o)(df_2 - df_1)}{f_o (C_{s1} - C_{s2})}$$

$$= 2\frac{(C_{s1} + C_o)(C_{s2} + C_o)(df_2 - df_1) \times 10^{-6}}{f_o (C_{s1} - C_{s2})} \quad (3)$$

Where C, C_o, C_{s1} and C_{s2} are expressed in pF, f_o in Mc/s and df_1 and df_2 in c/s.

Derivation of equations (5), (6) and (7) :—

$$\text{At resonance } 4\pi^2 f^2 LC \frac{(C_s + C_o)}{C + C_o + C_s} = 1$$

$$\therefore f^2 = \left(\frac{1}{4\pi^2 LC}\right)\left(\frac{1}{C_s + C_o}\right) + \left(\frac{1}{4\pi^2 LC}\right)$$

$$\therefore f_o^2 + 2f_o df = \left(\frac{1}{4\pi^2 LC}\right)\left(\frac{1}{C_s + C_o}\right) + \left(\frac{1}{4\pi^2 LC}\right).$$

$$\therefore df = \left(\frac{1}{8\pi^2 f_o LC}\right)\left(\frac{1}{C_s + C_o}\right) + \left(\frac{1}{8\pi^2 f_o LC} - \frac{f_o}{2}\right)$$

But $\left(\frac{1}{8\pi^2 f_o LC.}\right)$ and $\left(\frac{1}{8\pi^2 f_o LC} - \frac{f_o}{2}\right)$ are constants

We may therefore write $df = \frac{m}{C_s + C_o} + k$ .. (5)

then $df_1 = \frac{m}{C_{s1} + C_o} + k$ (i)

$df_2 = \frac{m}{C_{s2} + C_o} + k$ (ii)

Substracting $df_1 - df_2 = m\left(\frac{1}{C_{s1} + C_o} - \frac{1}{C_{s2} + C_o}\right)$

$$\therefore m = \frac{(C_{s1} + C_o)(C_{s2} + C_o)(df_1 - df_2)}{C_{s2} - C_{s1}} \quad .. \quad (6)$$

and from (i) $k = df_1 - \frac{m}{C_{s1} + C_o}$ .. .. (7)

Derivation of equation (10):—

$$\frac{f^2 (C_s + C_o)}{C + C_o + C_s} = \frac{(f + df)^2 (C_o + C_s + dC_s)}{C + C_o + C_s + dC_s}$$

from which $dC_s = -\frac{2df(C_s + C_o)(C + C_o + C_s)}{fC + 2df(C + C_o + C_s)}$

Since C is unlikely to exceed about 0.05pF whereas $C_o + C_s$ is unlikely to be less than 25pF, with an error of only some 0.2% we may write

$$dC_s = -\frac{2df(C_s + C_o)^2}{fC + 2df(C_o + C_s)} \quad .. \quad .. \quad (10)$$

Commercial Literature

Stereophonic twin-channel pre-amplifiers and power amplifiers; a brochure containing descriptions and specifications of four models from The Dulci Company, Villiers Road, London, N.W.2.

Cable Insulator Tester, intended for cable on the move during production, using a high-voltage but non-lethal h.f. spark adjustable from 500V to 25kV. The high voltage generator is housed in a small case integral with the test electrode. Leaflet from the Addison Electric Company, 10-12 Bosworth Road, London, W.10.

Signal Generator covering 2Mc/s-225Mc/s in seven ranges. Commonly used i.fs for communications and radar equipment can be checked for centre frequency and bandwidth without necessity for range switching. Modulating circuits (external or 1kc/s internal) are designed to reduce unwanted f.m. to a minimum. This Type 378 and other instruments and accessories described in a catalogue from Avo, Ltd., Avocet House, 92-96, Vauxhall Bridge Road, London, S.W.1.

Molybdenized Lubricants consisting of combinations of oils, greases, silicones and other fluids with molybdenum disulphide, which has a laminar crystal structure (giving low coefficient of friction) and the property of bonding to metals. Suitable as a dielectric lubricant and for electromechanical assemblies. Booklet of properties and forms available, from Rocol, Ltd., Rocol House, Swillington, Leeds.

Two-Phase L.F. Oscillator, suitable for servo engineering work, giving two outputs 90 degrees apart over the spectrum 0.01c/s to 11.2kc/s in five ranges. The v.l.f. generation is achieved with two integrator stages and a 180-degree sign changer. Bulletin from Muirhead & Co., Beckenham, Kent.

Silicone Rubbers, capable of withstanding temperatures of 250-300° C for short periods and remaining flexible at lower than −50° C. Illustrated booklet summarizing grades, properties and applications from Imperial Chemical Industries, Nobel Division, Silicones Department, Ardeer Factory, Stevenston, Ayrshire.

Radio-gram Chassis, a.m./f.m., with 9 valves and 2 diodes, giving 6 watts push-pull output. Separate bass and treble controls, tape record and playback facilities, pick-up inputs and a.f.c. on f.m. are provided. Leaflet on this "Jubilee" model from Armstrong Wireless & Television Co., Warlters Road, Holloway, London, N.7.

Microphones and Accessories, including ribbon velocity, full-vision, noise-cancelling, lapel and chest-harness types, Illustrated catalogue from Lustraphone, St. George's Works, Regent's Park Road, London, N.W.1.

R.F. Transistors of the drift type with "built-in" accelerating fields. A leaflet describing the principle and giving brief characteristics of eight types with 30Mc/s alpha cut-off and one v.h.f. type with 100Mc/s cut-off. From Amalgamated Wireless Valve Co., 47, York Street Sydney, Australia.

Printed Circuits, an introductory illustrated booklet on their advantages and method of manufacture from Bribond, of Burgess Hill, Sussex, who specialize in producing prototypes and manufacture their own copper-clad laminates.

Flexible Multi-channel Transmitter, 2½kW, for h.f., built up from one or more r.f. units, a modulation unit and one or more power units. Up to four r.f. units, each on a frequency in the range 1.6-27.5Mc/s, can be run simultaneously. Modulation can be telephony, f.s.k. or on/off c.w. Technical data in a descriptive brochure on the HC220 series from Marconi's Wireless Telegraph Co., Marconi House, Chelmsford, Essex.

CLUB NEWS

Battersea.—The London Shortwave Club is being re-formed and it is planned to hold meetings each Friday at the Battersea Men's Institute. Interested readers in the locality should get in touch with K. R. Piper (G3LOO), 2 Catherine Terrace, Stockwell, S.W.8.

Birmingham.—A demonstration of sound reproduction, including stereophony, will be given by a representative of Altobass Ltd., at the December 5th meeting of the Slade Radio Society (G3JBN). Meetings are held at 7.45 at The Church House, High Street, Erdington.

Bradford.—December meetings of the Bradford Amateur Radio Society include a talk by A. R. Bailey (G3IBN) on resistor/capacitor bridges on the 16th, and a film show by Mullard on the 30th. The Club meets on alternate Tuesdays at 7.30 at Cambridge House, 66 Little Horton Lane, 5.

Cleckheaton.—A. E. Falkus, of Fane Electronics, will speak on high-fidelity sound reproduction at the December 10th meeting of the Spen Valley Amateur Radio Society at 7.30 at the George Hotel.

Liverpool.—At the December 2nd meeting of the Liverpool and District Amateur Radio Society, F. H. P. Cawson (G2ART) will speak on aerial matching. Meetings are held every Tuesday at 8.0 at Gladstone Mission Hall, Queens Drive, Childwall.

Prestatyn.—"Getting the best from your receiver" is the title of the talk by J. T. Lawrence (GW3JGA/T), secretary of the Flintshire Radio Society, at its meeting on December 1st. Meetings are held on the first Monday of each month at 7.30 at the Railway Hotel.

South Kensington.—The Science Museum Radio Society was re-named the Civil Service Radio Society in September. Membership is open to all civil servants and their wives and meetings are normally held on the first Tuesday of each month at 5.30 at the Science Museum. Films will be shown at the meeting on December 8th.

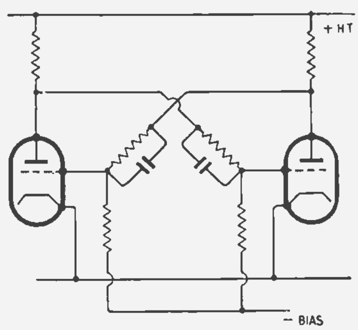
Wellingborough.—At the December 11th meeting of the Wellingborough and District Radio and Television Society (G3KSX) G. Abrams will speak on wartime experiences with radio countermeasures. The club meets each Thursday at 7.30 at the Silver Street Club Room.

Technical Notebook

Single-Channel Pseudo-Stereophony described by Manfred R. Schroeder in the *Journal of the Audio Engineering Society* for April 1958 follows on from some 1954 work of H. Lauridsen of the Danish National Broadcasting System. Lauridsen combined the single channel, delayed by from 50 to 150 milliseconds and fed so as to produce opposite phases but equal amplitudes at the ears, with the undelayed single channel fed with the same phase and amplitude to each ear. Loudspeakers (with summation of signals in the air) as well as headphones were used. In the loudspeaker experiments the two loudspeakers and the listener were in line. One loudspeaker (fed with the undelayed signal) faced the listener and thus formed a point source, and the other (fed with the delayed signal) was at right angles to the first and thus formed a dipole source. A subjective impression of sound coming from all directions with a wide apparent source and good feeling of presence was felt using either headphones or loudspeakers. Lauridsen's experiment can be shown to be equivalent to feeding the undelayed single channel with a different frequency and phase response in the path to each ear. In this equivalent experiment, the intensity varies sinusoidally with frequency, with maxima at one ear corresponding to minima (zeros) at the other; and the phase difference between the two ears is equal to $\pm\pi/2$, jumping from one value to the other at frequencies which are integral multiples of one half the reciprocal of the delay. Schroeder's further experiments were designed to separate the effects of the different frequency responses from those of the different phase responses. It was found that the different frequency responses were the more important factors in producing the spatial illusion described, the different phase responses being neither necessary nor sufficient. Moreover, with Lauridsen's original arrangements, the illusion could still be obtained using filters as broad as 200 c/s which correspond to delays as short as 2.5m sec. The simple fact that in these experiments some frequencies are heard mainly with one ear and others mainly with the other is thus probably the explanation of the illusion.

Magnetically Regulated H.T. supply capable of providing 2300 volts at 15-50mA with 0.25 per cent regulation has been developed at Bell Telephone Laboratories in the U.S.A. An interesting feature of the design is the isolation of the control and output sensing circuits from the high voltage output. This is accomplished by placing the control element—a self-saturating magnetic amplifier—on the low-voltage input side of the regulated supply and by adding an auxiliary winding for the output sensing. Silicon rectifiers are used both in the high voltage output circuit and in the voltage reference circuit. A conventional voltage doubler serves as the high voltage rectifier, with sufficient capacitance employed in the filter to reduce the maximum r.m.s. ripple to $\frac{1}{2}$ per cent at 50mA. The reference voltage is provided by a series chain of six 6-volt temperature-compensated Zener diodes connected in a bridge circuit. The output voltage is maintained to the desired accuracy with variations in line voltage from 105 to 130 volts, with load current changes of 15 to 50mA, and over an ambient temperature range of $-40°$ to $+85°$C. Over a restricted temperature range and with added refinements, this circuit has regulation capabilities of ± 0.1 per cent.

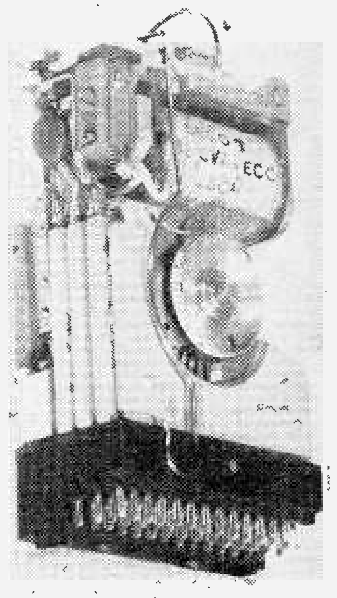
Negatively Biased Multivibrator.—In the November issue of *Electronic & Radio Engineer*, A. Bar-Lev describes the characteristics of a new type of multivibrator with electronically variable frequency. Unlike most circuits of this kind, in which frequency control is effected by a positive bias, a negative bias is used. This is shown to result in excellent linearity and better frequency stability.



Frequency is variable over a 5 to 1 range. The multivibrator has been used as a frequency modulator for recording very low frequency waves on magnetic tape. An advantage is its high grid input impedance, which results from the fact that little grid current flows.

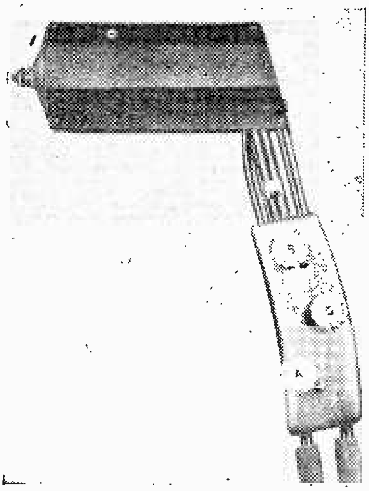
Ceramic Coatings on steel, brass, copper, aluminium and other metals, as well as glass and plastics, can be obtained by a new process recently developed by the United Insulator Division of T.C.C. This makes possible the manufacture of parts which would otherwise be too large, too complex or too small in cross-section to be fabricated in solid ceramic. In the new process the ceramic material is heated to a temperature in excess of 3000°F and applied at high pressure to the part to be coated, which is kept cool. The thickness of coating can be anything from a few thou' to 20mm or more. Various types of ceramic materials are being used for the process—electrically insulating or conducting, high-temperature and heat insulating, piezo-electric and high-permittivity dielectric. The cost of the coatings (which go under the trade name "Unikote") is generally less than that of the equivalent parts made in solid ceramic. A range of standard components is being introduced and a service is available for coating items supplied by customers.

Miniature Uniselector with 36 contact segments, recently introduced by Siemens Edison Swan, measures only $3\frac{3}{4}$in $\times$ $2\frac{3}{16}$in $\times$ $1\frac{5}{32}$in and weighs 12 ounces. It is a plug-in device and operates from 22-V or 50-V supplies by a ratchet-and-pawl system,



which moves the wiper assembly over the bank of contacts at 60 steps per second. All wiring terminations to the driving mechanism and the contact bank are made by a 42-point plug and jack. When plugged in the uniselector is held in position by a spring clip.

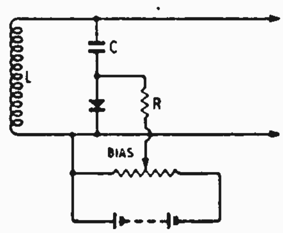
Welding Aluminium, silver soldering, brazing and glass working for radio and electronic construction becomes a practical proposition in small workshops with the aid of a new gas torch which operates from the public gas supply at normal pressure. Designed by Dr. C. R. Burch and shown at the 1953 Physical Society's Exhibition, the torch has now been put on the market by the B.B.S. Development and Manufacturing Company. Air blown from a fan at 0·5 lb/sq in is necessary. The gas and air are preheated to 750°C in a unit in the body of the torch, using part of the gas supply for heating. When the two streams are mixed they ignite spontaneously and the resultant flame emerges from a short red-hot venturi tube, producing a temperature in excess of



2000°C. The flame is 4-5cm in length, has a small diameter of about 5mm, burns quietly and cannot be blown out. Running costs of the torch are low compared with oxy-acetylene or oxy-coal-gas. It uses 14·5 cu ft of gas and 7·2 cu ft of air per hour.

Synthetic Sapphire Spacers in rod form are being used in the electron guns of travelling-wave tubes for airborne equipment, according to a note from the Union Carbide International Company of New York. Apart from being able to stand up to the severe conditions of shock and vibration, the synthetic sapphire has the advantage of eliminating gassing in the tubes at high temperatures because of its lack of porosity. It also permits seals to be made easily with metals, glasses and ceramics. The dielectric properties are said to be excellent, while the hardness is next to that of diamond.

Voltage-Controlled Capacitance in semiconductor diodes is now a fairly well-known phenomenon and several firms are producing diodes specifically intended for use as variable reactance elements. The diagram shows, for example, how such a diode can be incorporated as a variable capacitance in a tuned circuit, the voltage bias being in the reverse direction. A small low-loss fixed capacitor C can be introduced as shown to mitigate any reduction in Q caused by the diode's reverse resistance across the circuit. This does restrict the possible range of capacitance variation for tuning, but it has the incidental advantage of blocking the bias voltage from any subsequent circuitry. Resistance R should be high (perhaps several megohms) to prevent loading in a high-Q circuit. But, as the International Rectifier Corporation point out in their *Rectifier News* for August-September, 1958, if R is a significant proportion



of the diode leakage resistance, a drift problem can arise. Any large adjustment of bias may produce a slow change in diode temperature. This will cause a change in diode leakage current, which in turn will affect the current in R and consequently the voltage bias—the final result being, of course, an undesirable drift in tuning capacitance. The effect can be eliminated, however, by using a choke instead of R, or perhaps a choke with a small resistance in series to give supplementary impedance.

Extending T.W.T. Frequency Range by just saturating the tube with an input signal within its normal frequency range is described by L. D. Buchmiller and G. Wade in a letter to *Proc. I.R.E.* for July, 1958. The travelling-wave tube electron beam is non-linearly modulated by the saturating signal so that this signal will intermodulate (mix) with any other lower-level modulating signal. The extended frequency range can be regarded as being due to a double mixing process of this type. An input signal outside the normal pass-band of the t.w.t. will still produce a small amount of beam modulation. This mixes with the over-modulation produced by the saturating signal to give modulation at the difference frequency between the two signals. If this difference frequency is within the normal pass-band of the t.w.t. it is amplified in the usual way. At the output the saturating signal mixes again with this amplified difference frequency signal to produce an amplified version of the input signal outside the normal pass-band. When this method was used with an S-band (3kMc/s) tube, although the bandwidth for the normal pass-band gain of about 32dB was not increased, the bandwidth for smaller gains of 20dB or less was increased by about 10 per cent.

Controlled Storage Phosphor.—A new type of c.r.t. screen phosphor with the property of storing images for periods of up to twenty minutes, which can then be released by shining infra-red radiation on the face of the tube, has been developed by Ferranti. This property of long-term storage makes the phosphor suitable for radar applications in which it is required to make previously received images visible at will. If the phosphor were used in a radar tube it would be possible to store a long succession of images so that an indication of the path of a moving echo could be obtained over a period of several minutes. Traditionally the storage of images has been achieved by long-persistence phosphors, but these are not able to hold information for periods of several minutes before viewing. Any attempt to do this would require such intense traces that permanent phosphor damage would occur. A solution to this and other problems associated with long-persistence screens is provided by the new phosphor. It consists of two distinct layers, the one nearer the observer being the storage phosphor, while the other "backing layer" converts the electron energy into blue, violet or ultra-violet light. The afterglow is under the control of the operator, who may release it at any moment he wishes, at an intensity which will ensure that no persistent image remains when the next field is presented. An infra-red source is arranged so as to illuminate the whole screen of the tube uniformly when switched on, with provision for its intensity to be varied. This can be done by using a viewing hood in which a number of small-filament lamps are mounted facing the screen. Each lamp is screened by a filter to reduce visible illumination while passing short and medium infra-red.

TV Bandwidth Compression system being tried at Imperial College, London, involves continually storing a certain time interval of picture information and making all its edges and boundaries more equally spaced in time. At the receiver a relatively simple network restores the spacing to form a coherent picture.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents.

Stereophonic Broadcasting

I WOULD like to reply to "Free Grid's" comments (November issue) on the choice of channels for the B.B.C.'s experimental stereophonic sound broadcasts. For once, he does not seem to be living up to the title of his column.

As the system at present used for these experiments is incompatible, in that neither of the two transmission channels will by itself give properly balanced reproduction, the stereophonic broadcasts must be made at times when the transmitters are not broadcasting normal programmes. If the experiments are to be carried out at a convenient hour of the day for listening, this limits the choice of channels to the Third Programme medium-wave and v.h.f. channels and the television sound channels. It follows, therefore, that "Free Grid's" suggestion that a second medium wavelength should be used as an alternative to the television sound channel is impracticable.

Using the Third Programme medium-wave and v.h.f. transmitters for one stereophonic channel and the television sound channel for the other ensures that the maximum number of listeners can take part in the experiment if they so wish. This arrangement also permits the best matching of the characteristics—of the programme lines. The possible alternative arrangement of using the Third Programme medium-wave transmitters for one stereophonic channel and the Third Programme v.h.f. transmitters for the other is less attractive on both these counts.

It is emphasized that the stereophonic broadcasts, as stated in our announcements, are experimental and not to be regarded as a programme service. In these circumstances we would not, as "Free Grid" suggests, expect a sound-only licence holder to buy a television receiver and take out a television licence solely for the purpose of taking part in the experiments. If in the future stereophonic sound broadcasts are introduced on a regular basis it is hoped that a satisfactory compatible system will be found requiring only one transmitter.

London, W.1. L. W. TURNER,
British Broadcasting Corporation.

Stereo Under Fire

I FEEL that Mr. G. A. Briggs' strictures on stereo cannot be allowed to pass unchallenged.

Whilst it must be admitted that queer things occurred in demonstration rooms at the Audio Fair and again at the Radio Show, the facts are that conditions were abnormal—as Mr. Briggs agrees—and it is difficult to imagine comparable conditions arising in the home. One does not send an infant to the execution chamber as a remedy for its teething troubles and I do not think we should consign stereo to oblivion because unexpected and unforeseen snags arose under the particular conditions in which the demonstrations were given.

Surely the criterion one should employ in judging stereo is whether or not it achieves its objective, which is to provide more realistic reproduction of sound in domestic surroundings. If one is honest one must admit that absolute realism is unattainable: it is not possible to recreate a performance by a symphony orchestra "as large as life" in one's own living room. The most one can hope to do is to create an acceptable and pleasing illusion and, in my opinion, stereo does enhance the illusion of reality. Admittedly some material does not lend itself to this new technique, but where a sense of movement or spaciousness is desirable in the interests of realism, then there would appear to be a reasonable case for employing stereo.

It would be rash to infer that the ultimate has been reached in the development and design of stereo and its ancillary equipment; and it is too early to express any opinion on whether disc or tape recordings will become the more popular. One thing is fairly certain and that is that if and when we get stereo broadcast programmes, a new standard of sound reproduction will become established, a standard which the listener will also demand from his discs and tapes.

London, N.W.2. H. C. RYLATT,
The Dulci Company, Ltd.

HAVING read the leters you have published about stereophonic reproduction, I am surprised that no one has questioned its desirability, or suggested that it is all a "gimmick."

When people refer to "music lovers," they always appear to refer to lovers of orchestral music, ignoring the great repertoire (perhaps greater) of piano, chamber music and lieder, none of which stands to gain anything from stereophonic reproduction.

But orchestral music stands to gain nothing either. Stereophonic reproduction puts one in the front of the stalls, which is the worst possible place to be; one should get sufficiently far back so that the sound seems to come from a point source. To be near the orchestra enables one to pick out the individual instruments more readily (helpful if studying the score) but this is a very different occupation from listening to the music. Indeed, every effort is directed to blending the various individual sounds into a single unified sound. Surely stereophonic reproduction is foreign to this basic musical concept.

May I suggest a simple experiment for "hi-fi" enthusiasts using a two-speaker system with a fairly low crossover frequency. With the treble speaker on one side of the room and the bass speaker on the other, the violins and basses will be readily separated. This is very simple, surprisingly realistic, and will ensure the maximum of "gimmick" for the minimum additional outlay.

Croydon. B. WALLACE.

L. STREATFIELD'S adverse comments in the November issue on the present-day position with regard to two-channel stereo are well merited. However, he really need not be so puzzled as to why stereophonic demonstrations as such are never impressive. I have noticed over and over again (and so has everyone else I have questioned on the subject) that after a minute or two, when one's interest has been engaged by the performance, one ceases to be aware of the stereophonic effect as such unless one's attention is drawn by crude, obvious "gimmickery." The same remarks, incidentally, can be applied to 3D films; once the attention is engaged one ceases to be aware of the stereoscopic effect, hence the necessity for hurling a continual barrage of missiles at the audience to remind them of the fact that they are not watching an ordinary movie.

If the public interest has been slight in the much more forceful 3-dimensional visual image, it is not surprising the cinema industry has found that stereophonic sound adds little to the presentation of a motion picture* and that its value as a box-office attraction is negligible.

Manchester. A. D. LEVAGGI.

* Its absence would at once be apparent, except perhaps in the back seats when the picture is of the "wide-screen" variety.—ED

WITH the development of the technique of stereo sound new words are necessary to describe apparatus and methods used. Most of these new words will use the prefix stereo.

It should be understood that in the visual sense many words prefixed by stereo have accepted and defined meanings. It would be confusing to employ the same words to describe stereo sound.

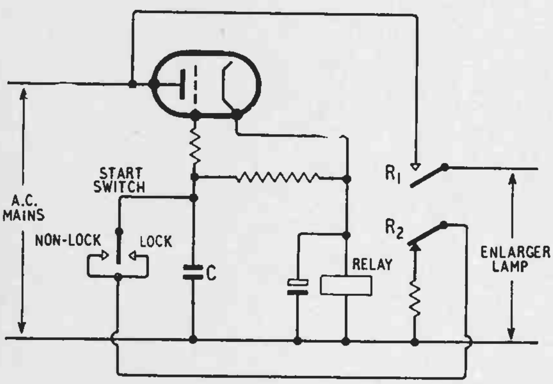
"Free Grid" in the October issue refers to the use of the word "stereogram" to describe an instrument capable of playing stereo discs. This word, however, is already defined as "paired photographs or drawings intended to be viewed in a stereoscope to give the appearance of relief." The above definition and some others using the prefix stereo can be found in "A Dictionary of Opticians and Optometrists," published by the Hatton Press.

Let us hope that everyone concerned with sound stereo will avoid the use of words which have an accepted meaning visually. Particularly since mistakes now could have serious repercussions in the event of stereo television being developed.

Chorleywood, Herts. N. ROSKROW.

Photographic Timer

I REFER to J. H. Jowett's article "Inexpensive Photographic Timer" (August, 1958, page 385). I have used a similar timer which was built some four years ago but with a slightly different form of switching as shown below in the accompanying circuit.



The simplicity of this arrangement is immediately apparent by using the second pair of contacts R_2 on the relay and a three position telephone key.

In the quiescent condition the relay is operated with the enlarger lamp switched off and the start circuit prepared by contacts R_2. The telephone key is operated and released on the non-lock side, discharging C, releasing the relay and starting the timing cycle. Since R_2 contacts open when timing is started, the time period is independent of the time that the start switch is operated. At the end of the timed period the relay again operates, switching off the enlarger lamp and automatically preparing the start circuit for the next operation.

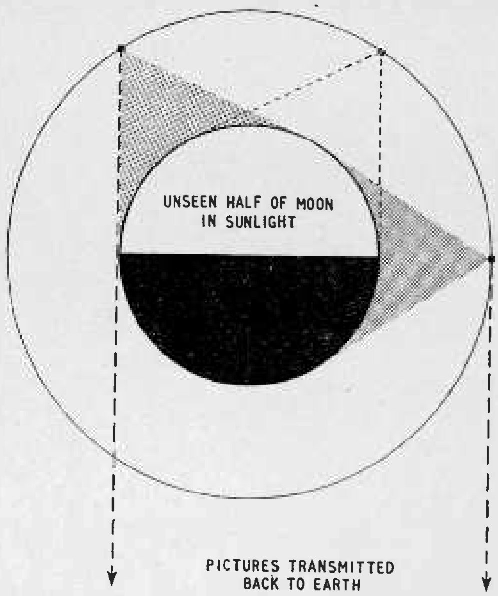
It is necessary that the telephone key and relay contacts R_2 are of good insulation resistance as these are effectively in parallel with C. The lock position in the start switch is used when focusing and setting up the enlarger.

Miri, Sarawak. J. D. YATES.

"*Shooting the Moon*"

I READ with interest the views of your reader D. B. Pitt (November issue), but must disagree with his views on the so-called problem of televising the "unseen" side of the moon.

If the final stage of the moon rocket were to orbit the moon (diameter approx. 2,160 miles) at a height of, say, 1,000 miles above the surface (this is reasonably near after the quarter of a million it has already travelled from earth), the television camera would need a wide-angle lens covering approximately 70° to see the whole presented face of the moon. Viewing the moon at this close range would be like looking at a football with one eye at 5in from the leather. A complete hemisphere would not be visible; one is just *too* close.



When the space vehicle, orbiting at a height of 1,000 miles, is at the same distance from earth as the moon and over the dividing line of the known and unknown faces, some 30% of each side would be visible to the camera. Immediately before being eclipsed behind the moon some 60% of the "dark" side could be seen; the remainder could be viewed as the space vehicle reappeared from the other side after eclipse. But the picture transmitted to earth would need some analysing if the final stage were spinning "head over heels" at a speed of, say, two revolutions per second!

The singular desire to televise the "dark" side of the moon along with the other information transmitted back to earth is like wanting to see the mud on the reverse side of a football. The answer: it is probably very much like the mud on this side!

Tolworth, Surrey. M. V. GAVIN.

Licence Reminders

MR. T. A. O'BRIEN states in his letter in the September issue that the Post Office would prefer people to take out licences without any prodding. My own licence expired on August 31, 1958, and on August 30 I went to the post office, handed in my old licence and £1. Much to my astonishment they refused to renew it. Why? Because I had not my warning notice which had, of course, not even been sent to me.

I consider this a complete waste of time, money, and paper. Now the P.O. can wait my convenience.

Stafford. W. R. GREGORY.

Tape Spools

I AM somewhat puzzled by the eternal plea from many tape enthusiasts for an easy-to-thread tape spool.

To produce a good tape recording requires a reasonable degree of technical skill, and the experienced recordist soon acquires the knack of threading up within a second or two, without fancy clips, etc. Provided the reel flanges have a large enough hole to permit the insertion of a finger to grip the tape on the hub, a single turn is usually quite sufficient to grip the tape end. I have to hand five so-called "easy-to-thread" spools, and without exception it takes longer to thread with these than by the generally practised method. Clip hubs are to be frowned upon, since they are always liable to cause breakage or stretching of the tape at the end of fast rewinding.

Norwich. R. WILLIAMSON.

HALL AND HOLES

By "CATHODE RAY"

The Importance of Not Taking Things for Granted

WE hear quite a lot these days about "Hall effect." What is it? I must disappoint any hi-fi enthusiasts who are hoping that it is some interesting acoustical peculiarity of auditoria. Still less has my title any bearing on the spooneristic vicar's announcement that the Mothers' Meeting would be hauled in the hell below. It is strictly compatible with *Wireless World*. For the holes in question are the much-debated things (or non-things?) in transistors. Hall effect has recently gained immense importance among semiconductor researchers, and it appeared in new developments on at least three stands at the last Physical Society Exhibition.

But like so many of these things that hit the contemporary technical headlines, it is no new discovery. It dates back, in fact, to 1879—long before holes, or even electrons, were thought of. I found it well worth while turning up the original paper, written by a Mr. E. H. Hall, Fellow of Johns Hopkins University, U.S.A., reporting his discovery of the effect now named after him. Having done so I shared some of Lord Kelvin's enthusiasm that led him to describe the discovery as the most important (regarding electricity) made since Faraday.

Here was a young man of 24, studying electricity under his teacher, Prof. Rowland. His textbook was one that remains to this day as a great classic—Clerk Maxwell's "Electricity and Magnetism" in two volumes. But Hall wasn't prepared to accept without question even the highest authority's teaching on one of the basic principles of electricity.

Fig. 1 shows the principle concerned, on which all electric motors depend. When a conductor carrying a current is situated in a magnetic field it experiences a force, along a line at right angles to the current and the field. There are, of course, two directions along any line, and the usual way of remembering which is the right one is by Fleming's celebrated left-hand rule. For the benefit of any whose education in this respect has been absent or forgotten, Fig. 2 shows how the left hand must be held, with thumb and first two fingers all at right angles to one another. Then if the Forefinger is pointed in the direction of the magnetic lines of Flux, and the seCond finger in the direction of the Current, the thuMb shows the direction in which the conductor tends to Move. If you apply this to Fig. 1 you will check that the wire is urged outwards from the magnet as shown.

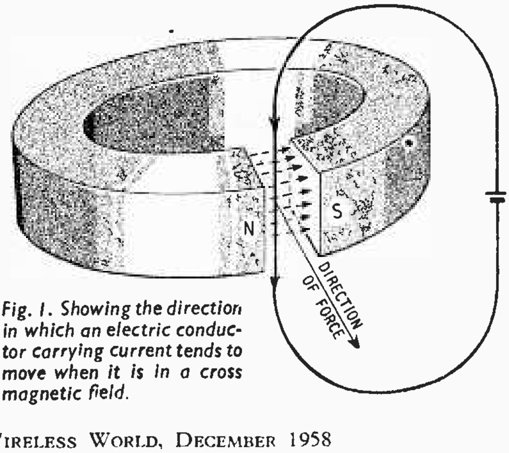
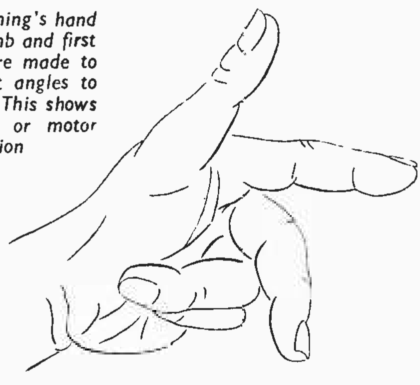


Fig. 1. Showing the direction in which an electric conductor carrying current tends to move when it is in a cross magnetic field.

Now this is the point: if the conductor is prevented from moving, what (if anything) happens to the current? We, with our knowledge about currents being movements of electrons, wouldn't need any very brilliant inspiration to guess that the same influence might tend to push the electrons to one side within the wire. In fact, most of you are probably much more familiar with the deflection of naked electrons by the magnetic scanning fields in the domestic cathode-ray tube than with the deflection of whole conductors carrying them. But remember that in 1879 nobody had ground for anything much better than wild guesses as to what an electric current was. Clerk Maxwell, brilliant man though he was, emphasized that the conductor and the current were two very different things, and because the conductor was forced to one side it didn't mean that the current (whatever it was) would be, and he personally thought it wouldn't be.

Fig. 2. In Fleming's hand rules the thumb and first two fingers are made to point at right angles to one another. This shows the left-hand or motor rule in operation



Young Hall wasn't at all convinced by this, and said so to his teacher, who confessed that he, too, had had doubts and had carried out experiments to try to detect a displacement of the current, but they had failed to show any. (Several other experimenters had also tried and failed, for during the nineteenth century the relationships between electricity and magnetism were their main preoccupation.) Quite rightly, as we shall see, Rowland guessed that one reason for failure was that the conductors used were too thick. So he advised Hall to make sure by using gold leaf—which is something like a millionth of an inch! His strip of it was 2 cm wide and a few cm long. Between points on each edge (A and B in Fig. 3) he connected an extremely sensitive high-resistance mirror galvanometer—another reason for the failure of previous experiments was the insensitiveness of the methods tried. Then, with a strong magnetic field through the strip (at right angles to the paper in Fig. 3) and current along it, Hall found quite large galvanometer deflections, steady so long as current and field were steady, and in a direction that reversed if either current or field was reversed. Assuming uniformity of the conductor, A and B would ordinarily be at the same potential no matter how much current was flowing. The fact that a magnetic field causes a potential difference to appear is evidence that the current itself is forced to one side of the conductor.

In this first and other papers, Hall describes the many painstaking experiments he carried out with different current and field strengths and different materials and dimensions of conductor, and the care he took to guard against error and misleading indications and to account for discrepancies. Anyone

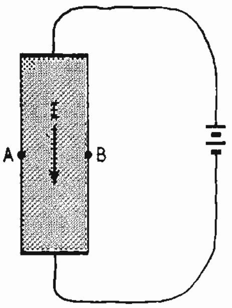


Fig. 3. Hall effect consists in the appearance of a potential difference between points A and B on a current-carrying conductor, where none would exist if there weren't a magnetic field through the conductor.

who intends to go in for research work would do well to study these papers, which are to be found in vols. 9 and 10 (1880) of the *Philosophical Magazine.* I reckon Hall fully deserved the doctor's degree he was awarded soon after. Later on he became a Professor of Physics. Even in his first paper he arrived at the correct "law" for this effect; but more interesting still is what he had to say about the direction or polarity of the p.d.

The way he put it was that if the current is regarded as a stream flowing from the positive pole of the battery to the negative (as was—and still is—arbitrarily assumed) the polarities of his observed p.ds would mean that two parallel currents in the same direction would repel one another. But if from negative to positive, the results would mean they would attract one another. He went on—"It is, of course, perfectly well known that two *conductors*, bearing currents parallel and in the same direction, are drawn toward each other. Whether this fact, taken in connection with what has been said above, has any bearing on the question of the absolute direction of the electric current, it is perhaps too early to decide."

These words show that Hall's questioning of authority was true independence of thought and not youthful lack of modesty and caution. We now probably feel he would have been justified in drawing the definite conclusion—eighteen years ahead of confirmation of the fact by discovery of the electron —that the electric current flowed from "negative" to "positive." Anyway, this seems to have been the first definite clue to the direction of actual flow of electric current.

We would probably reach the same conclusion a little differently. We might use the Fleming rule to show which way the conductor would be forced, and then say that this is the way the current inside the conductor was being pushed. If the current consisted of positive charges moving (in accordance with the observed "like charges repel; unlike charges attract" law) from positive to negative ends of the conductor, then the nearer edge of the wire in Fig. 1 would presumably become positive with respect to the other. But in fact, as Hall found, it becomes negative. Therefore, we would say, the current consists of negative charges flowing from − to +.

In the meantime, of course, we would have been overtaken by events now 60 years past, and for every *Wireless World* reader who would turn to Fleming's rule (or even know of its existence) probably hundreds would think of the much more direct and visible demonstration of the actual deflection of electrons to one side when they pass through the magnetic fields set up by the scanning coils in a cathode-ray tube. Of course we can't conveniently use the domestic TV tube for the purpose of finding out which way it is deflected, and we can never remember; but if we try it with an oscilloscope or look it up in a book we shall find the electrons are deflected to the side where (if they were streaming through a conductor instead of through empty space) a negative Hall potential is found. The deficiency of electrons on the other side causes a relatively positive potential.

Any such accumulation of electrons on one side sets up an electric field which tends to repel others away from that side, and a balance is finally reached between this anti-Hall influence of the electric field and the Hall influence of the magnetic field.

That is the cue for textbooks to derive a formula from which the amount of Hall p.d. can be calculated for any given current, field, conductor dimensions, etc. And although it may seem a deplorably dull and textbookish kind of thing, that is precisely what we are about to do. But I assure you it is necessary in order to get the full benefit of the (I hope) interesting part, which, like a good story, has an unexpected twist in its tail.

The Formula

We have, then, an electric current, the strength of which we shall as usual call I, consisting of a stream of negative charges (electrons) flowing oppositely to the conventional positive-to-negative current direction along a conductor (for simplicity having a rectangular cross-section) placed say vertically in a back-to-front magnetic flux B. This flux displaces the charges in the conductor so as to set up an electric field E from side to side. The force on an electric charge in an electric field is (in a suitable system of units such as m.k.s.) equal to the charge multiplied by the field. The charge on one electron is denoted by e, so the force on it is eE. The force on an electron moving with velocity v at right angles to the flux B is Bev. For a steady balance they must be equal and opposite, so

$$eE = -Bev$$

$$\text{and} \quad E = -Bv \quad \ldots\ldots \quad (1)$$

What we are given, however, is not v but I. That is equal to the total charge passing a given point per second. It obviously depends on the velocity of the electrons (v) and on their density, or number of them in unit space, say per cubic metre. This is denoted by n. The total negative charge per cubic metre is therefore ne. If the cross-sectional area of the conductor were 1 square metre, the charge passing per second (I) would be nev. The actual dimensions being say a metres broad by b metres thick, I must be equal to $nevab$.

$$\text{So } v = \frac{I}{neab}$$

and substituting this (1) we get

$$E = -\frac{BI}{neab}$$

The electric field is equal to the total p.d. between A and B (call it V) divided by the distance a between them; therefore:

$$V = -\frac{BI}{neb} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

So we find that the Hall voltage is directly proportional to the amount of current flowing and to the strength of the magnetic field, which is just what we would have expected. Rather less expected, perhaps, is the fact that it is *inversely* proportional to the thickness of the conductor and to the density therein of the electric charges constituting the current. But a little thought should make it clear that the scarcer the charges the faster they have to move to be a given amount of current, and the faster they move the more strongly they are deflected by the magnetic field. (The reason a as well as b doesn't appear below the line in (2) is that the wider the conductor the more a given E adds up to give the total V, and this exactly offsets the effect of the greater number of electrons.)

Seeing that Hall had no knowledge of what electric current was, and therefore knew nothing of n and e, he deserves great credit for drawing the conclusion (in his very first paper) that the transverse p.d. per cm seemed to be proportional basically to B and v. Which, as (1) shows, was precisely right.

In metals, every atom contributes at least one mobile (i.e., current-carrying) electron, so the charge density is high and the Hall voltage low. In semiconductors—for reasons we have studied in recent months—the charge density is low and the Hall voltage relatively high. So it is easier to measure. A pretty obvious application of the Hall effect is for measuring magnetic flux density; it has in fact been so used for some time—even commercially in a quiet way. If the conductor were metal, the Hall voltage would be too small to read on a reasonably workmanlike instrument. A direct-reading fluxmeter, described in Nov. 1950 issue of *Wireless World* (p 415), had a thin piece of germanium mounted on the end of a probe for inserting wherever the field was to be measured. The main part of the instrument comprised a $4\frac{1}{2}$-V battery, means for setting the current from it through the germanium to a standard amount, and a millivoltmeter for reading the Hall voltage. It was calibrated directly in flux density by means of fields of known strength, measured by some alternative but less convenient method.

The current-carrying electrons in n-type germanium have a mobility (i.e., velocity per unit of applied electric field) about 100 times as great as those in copper, but certain compound semiconductors do better still. Indium antimonide is all the rage now, for its electron mobility is about 20 times more than in germanium.

Flux-density measuring is, as I said, obvious as an application for Hall effect, but there *are* alternatives. The reason why Hall effect has become really important, in practice as well as theory, is that it provides a means for measuring the vital statistics of semiconductors. For example, current-carrier density, n. You will see that everything else in equation (2) can easily be measured, enabling n to be calculated. One beauty of the method is that the scarcer the current carriers in the material the greater is the Hall voltage. Apart from intrinsic conduction (if you forget what that is, my last explanation of it was in the July issue) the number of current carriers in a semiconductor is almost the same as the number of atoms of impurity it contains. The more the impurity content falls below the ability of the most delicate chemical analysis even to detect, the more readily it is measurable by Hall effect.

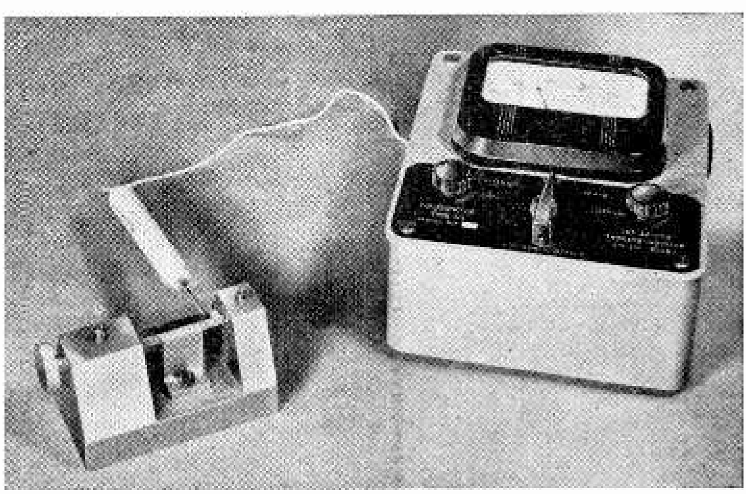
Other Applications

Another thing the semiconductor eggheads want to know is the mobility of the current carriers. As (1) shows, the Hall voltage very simply gives their velocity. Mobility is not quite the same, being velocity per unit of electric field causing them to flow, and the electric field is e.m.f. per unit length. This can quite easily be measured.

Hall found his experimental work revealed various puzzling discrepancies. This hardly surprises us, for since his "effect" was discovered lots of others have cropped up, and some care has to be taken to disentangle the Hall voltage from them. The precautions are discussed in a paper by Lindberg in *Proc.I.R.E.*, Nov. 1952, p. 1414.

There are other applications. When you have any system in which a quantity x is directly proportional to two other quantities y and z, you have a linear modulator or multiplier, in which x is the result of modulating y by z or vice versa. A valve suitably used will work as a modulator, but to make it even

Application of the Hall effect to measuring magnetic fields. The B.T.H. Type G gaussmeter being used to test the magnets of a differential cut-out.



approximately linear it has to be biased so that there is an output even when y or z are zero. In a Hall system, x is the Hall voltage, y the current, and z the flux density, and a single Hall circuit element works linearly right from the zero point.

Another thing is measuring the power of radio waves. Such waves consist of varying electric and magnetic fields, in time phase but at right angles to one another in space. That is just what is needed to create a Hall voltage, which, of course, can be measured if it is not too weak. This method has been demonstrated for power frequencies, audio frequencies, and radio frequencies up to thousands of Mc/s.

But I'm not going into detail with all the applications, because I want to leave room for one important point.

Hall was a good deal puzzled by the different results given by different materials, and tried to find some property of materials to which they were related. His failure to do so is not surprising, because the number of mobile electrons in a material depends in very complicated ways on its atomic structure, the finding out of which was mostly still in the far future 80 years ago. The thing that should have puzzled him most, but didn't because Prof. Rowland thought he knew the answer, was the fact that although most experiments gave a Hall voltage of conventionally negative sign—hinting strongly, as Hall realized, at the electric current being a flow of negative charges—a few gave positive voltages.

For the rest of his life Hall sought the explanation, and many others joined in, but the mystery deepened rather than cleared as one theory after another was disproved. The obvious answer is that a positive Hall voltage means that the current consists of positive charges. But the equally obvious reply to this is to ask why and how current in some materials are by positive charges instead of (or in addition to) electrons.

So far as we are concerned the interesting materials are semiconductors such as germanium and silicon, and anybody who knows the least thing about them will say "Oh, yes; *n* type material has electrons, and *p* type material has holes, which are equivalent to positive charges, so *n* type will give negative Hall voltages and *p* type positive." And they will be

Fig. 4. Table showing the directions of force and Hall voltage under different conditions, assuming a magnetic field towards you.

KIND OF CHARGE	DIRECTION IN WHICH CHARGE MOVES	"DIRECTION OF CURRENT"	DIRECTION OF FORCE	DIRECTION OF HALL VOLTAGE
−	↑	↓	←	←
	↓	↑	→	→
+	↑	↑	→	←
	↓	↓	←	→

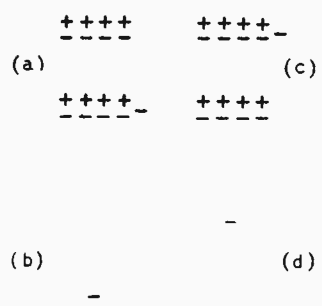


Fig. 5. (a) Two atoms of germanium or silicon are here represented by minus signs for valency electrons and plus signs for surplus protons. (The inner electrons are neutralized by an equal number of protons and are not shown.) The lower atom has gained one electron from an n-type impurity atom. Cancelling out unlike charges we have the equivalent (b). (c) Here the spare electron has migrated to the upper atom, and the equivalent is now (d).

dead right according to the books. The books tell us that positive Hall voltages were the first experimental evidence of the existence of holes. It all seems very clear and straightforward, but in case there is any doubt shall we just check over the polarities?

The clearest way of doing so, I think, is to make a table of all the possibilities, as in Fig. 4. The top half shows what happens if the current carriers are assumed to be negative (electrons) and the lower half applies to positive carriers. For each of these, the upper line refers to an upward movement of the charges; the lower to downward movement. "Direction of current" is in inverted commas because it is a convention, based on the assumption that the carriers are positive. So on the positive-charge lines the arrow points the same way as for "Direction in which charge moves"; on the negative lines, the opposite.

The "direction of force" is found by the left-hand rule (Fig. 2) from the direction of current, the direction of the magnetic field being assumed to be towards us. In the last column the arrow points from positive towards negative points on the conductor. For instance, on the first line, where negative charges are pushed to the left the Hall arrow points to the left. But on the last line the charges pushed to the left are positive, so the Hall arrow must point to the right*.

So we see that for a given direction of flux and current the Hall voltage has one polarity when that current consists of positive charges in the "direction of current," and the opposite polarity when it consists of negative charges in the opposite direction. So the polarity of the Hall voltage enables one to tell whether the current is made of positive or negative charges. Which is why the Hall effect is so instructive. As all the books say. But we haven't taken their word for it; we have checked it most carefully with Fig. 4, and you must by now be quite satisfied.

Or are you? Have you a feeling, like I had, that

* Incidentally, positive and negative charges (in equal quantities forming neutral atoms) can be made to move through a magnetic field in the same direction simply by moving the material itself. Fig. 4 shows that these charges will be urged in opposite directions, combining to set up a "Hall voltage" which is none other than the e.m.f. indicated by Flemings *right*-hand or generator rule, on which all dynamos depend.

in spite of everything, something is wrong? Here it comes, then! The very same books that explain how valuable the Hall effect is for telling whether a current is made of negative or positive charges will, more likely than not, explain somewhere else that movements of holes in one direction are *really* movements of electrons in the opposite direction. I myself have emphasized this quite strongly on several occasions. Which was probably why I was afflicted by such a feeling of wrongness by what might have been expected to be the gratifying news of the ability of Hall effect to distinguish between negative charges flowing in one direction and positive charges flowing in the opposite direction—the "direction of current" in both cases. It seemed to me that here was a discrepancy of too clear-cut a kind to be laughed off as just one of those things. One would think that the books that made such contradictory statements would consider a few words of explanation were called for. But no. To date, I have seen no word of explanation either in those books or anywhere else. It appears in no known work. Claims from authors of the unknown exceptions will be gladly received, and if they are not too numerous will be given commendatory publicity at the earliest opportunity. In the meantime, I will have to do my best to supply an explanation, and hope it will be more successful than my first attempt to remedy the absence of official explanation of failure to find a *p-n* junction p.d. by experiment.

A reminder that electron movements are in a nearly empty "conduction band" in a Fermi energy-level diagram, while holes are electron movements in a nearly full "filled band," doesn't seem to me to make the matter clear. Instead I go back to the simple diagrams that show *n*-type material with a small proportion of impurity atoms, each having one surplus electron, which is free to move under the influence of an applied e.m.f. A pure germanium atom has four valency electrons, neutralized by four spare protons, so can be represented as in the upper part of Fig. 5(a). Electrically it is non-existent. Below it is a germanium atom with one of the spare electrons temporarily in its orbit. Electrically it is one negative unit. So the electrical equivalent of these two atoms is as shown at (b). If now the spare electron moves to the upper atom, as at (c), the result electrically is as shown at (d). Clearly a negative charge has moved upwards, and the operation constituted a tiny electric current downwards.

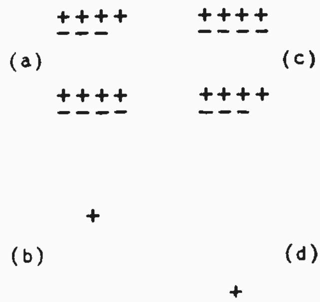
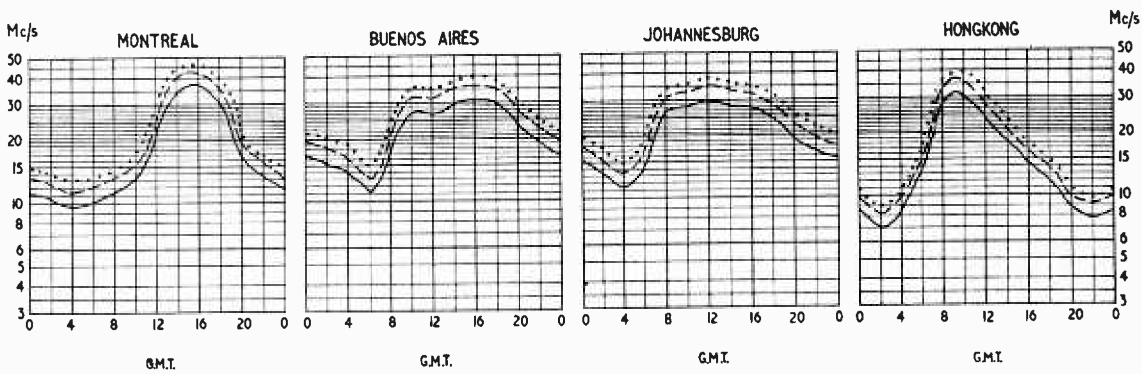


Fig. 6. Similar to Fig. 5 except that in (a) the upper atom, being short of one electron is a hole and the lower one is neutral.

Compare Fig. 6, in which the upper atom in (a) is a hole. The electrical equivalent is as (b). Again an electron moves upwards, from the neutral atom to the hole (c) and the electrical result is (d). In this case too an electron has moved upwards, constituting a tiny electric current downwards. But to a watchful eye sensitive only to electric charge, what has happened is that a positive charge has moved downwards —see Fig. 6(b) and (d) for proof; they are quite different from Fig. 5(b) and (d)! Yet it remains true to say that in both cases what has "really" happened is that an electron has moved upwards. While, then, it is quite right to make that point when first explaining the nature of holes, the difference between Fig. 6 and Fig. 5 should also be made clear, otherwise your pupil (if he has a mind at all) is in for a nasty shock when he reaches Hall effect. He will in fact be in quite a hole.

SHORT-WAVE CONDITIONS

Prediction for December



.... FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

———— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

THE full curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during December.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

Electroluminescent Pattern Display

First Stages in the Development of a Flat Screen for Picture Presentation

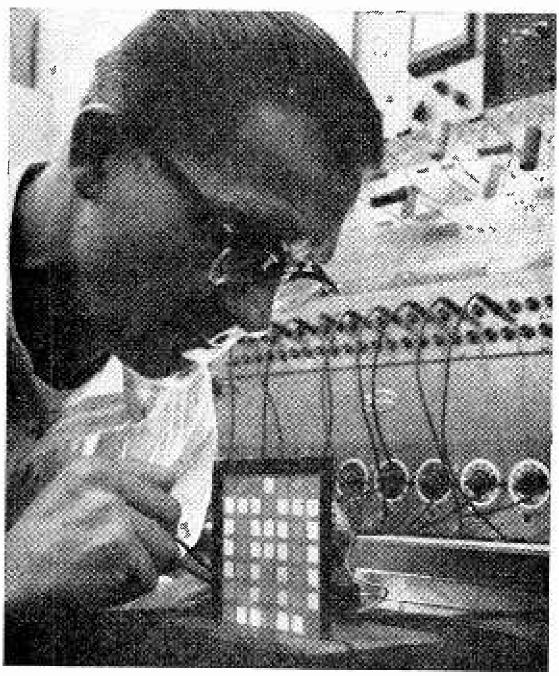
By MICHAEL LORANT

TELEVISION-ON-THE-WALL has perhaps moved a step closer to reality. A new experimental display screen—said to be brighter than any previously reported and no thicker than a picture frame—has recently been developed at the Westinghouse Research Laboratories in Pittsburgh, Pennsylvania, U.S.A. This screen represents an important step forward in efforts to replace the bulky cathode-ray tube with a flat, bright solid-state screen.

The new development, called an "Elf" screen, gets its name from the two words "electroluminescent" and "ferroelectric." The screen combines in a single structure an electroluminescent panel * and a flexible, built-in storage control structure made of ferroelectric material.

A satisfactory solid-state display screen is an important objective of modern electronics research. When such a screen is fully developed, it will do such things as display radar pictures or other information in aircraft, show the ever-changing air traffic pattern around an airport, or bring television-on-the-wall to the average living room. The inherent disadvantages of the cathode-ray tube have stimulated interest in a solid-state display screen for both military and commercial applications. Recent progress in the development of bright and efficient electroluminescent phosphors leads us to believe they offer the best approach to such a flat, efficient non-vacuum display.

* See "Electroluminescence," by D. W. G. Ballentyne, *Wireless World*, March 1957.



Experimental version of the "Elf" screen.

Present experimental models of the "Elf" screen are less than $\frac{1}{4}$in thick and have a brightness three times that of a conventional c.r.t. television screen. The contrast ratio between light and dark areas can be higher than 100 to 1. Images can be stored on the "Elf" screen for several minutes or, by means of the ferroelectric storage and control system, can be changed many times per second. The idea of using ferroelectrics for this purpose originated with Dr. P. M. G. Toulon, research scientist of the company. There are no inherent limitations on the size of the screen.

Many military applications require somewhat lower picture repetition frequencies than are used on c.r. tubes for television, which brings on the serious problem of flicker. This fact, plus the low maximum brightness of the c.r. tube, has placed limitations on its usefulness in a variety of situations. The "Elf" screen overcomes the problems of low brightness and excess flicker by providing for continuous—not interrupted—excitation of the luminescent material. The built-in ferroelectric cells control the display of information by applying a pattern of electric charges which activate the screen material by their associated fields. Once a charge distribution is established, the screen is excited without interruption for the complete duration of the picture. Then the charge distribution is changed to form a new picture. The result is an image of high average brightness and very low flicker.

A practical form of the "Elf" screen is still in its early stages of development, with commercial screens several years away. A practical screen is actually fabricated by preparing a laminated "sandwich" of electroluminescent and ferroelectric layers which have been divided into the multiplicity of separate elements required to produce a detailed picture. Coarse displays of this type have been made experimentally, giving resolutions of 4 to 10 elements per inch. The one outstanding feature of the cathode-ray tube which will not be easy to duplicate is the ease of scanning. This is the major problem to be overcome in perfecting the "Elf" solid-state screen. So far a method of distributing video information to the screen elements has been tested and found capable of working at megacycle switching rates.

Domestic television represents the most demanding application for any solid-state display device of this kind. But high picture quality, rapid picture rate and minimum cost are rigid requirements for a commercial product in this field. Therefore it seems likely that military equipment will be operating with a solid-state screen long before the "mural size" television on the living-room wall.

Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Multi-turn Indicating Dial

HELICAL potentiometers provide an exceptionally long resistance track for the size of the component, but as it is achieved by several revolutions of the operating spindle a special indicating dial is necessary if any form of calibration is required.

A dial designed primarily for this purpose is included in the range of components and fittings made by Wirepots, Ltd., New Road, Rainham, Essex. It is a skirted-type dial and incorporates a revolution counter. Standard models allow for a total of either 10 or 15 complete revolutions of the spindle and the skirt graduations (0-100) indicate fractions of a turn.

The dial is precision machined in one piece from light alloy and the gearing is claimed to have negligible backlash. It can be supplied in natural or in various anodized colours with suitably contrasting engraving. The model illustrated measures $1\frac{3}{4}$in in diameter overall, has a milled finger grip of $1\frac{1}{4}$in diameter and is for $\frac{1}{4}$-in spindles.

Among other products of this firm is an orthodox midget wirewound potentiometer measuring 0.916in in diameter rated at 2W and available in values up to 50kΩ, also some locking devices for pre-set controls.

Sub-miniature Trimmer

THE illustration shows a tiny air-dielectric trimmer in which both fixed and moving vanes are machined from solid metal. Known as the "Minitrimmer" it has a minimum capacitance of 1.8pF and a capacitance swing of 7.3pF. The air gap is 0.009in, the test voltage is 1,000 d.c. and the insulation resistance 5kMΩ. Two models are available, a standard type (SMT9/7.3) and a differential type (SDMT9/7.3).

The rotor is supported in a single bearing of generous length for the size of the component, which measures 0.374in square and 0.477in high. Adjustment is by means of a screwdriver slot in the end of the rotor "spindle."

One application is in printed circuits and long connecting lugs are normally fitted for this purpose, but alternative styles are available, details of which can be obtained from the maker, Oxley Developments Co., Ltd., Priory Park, Ulverston, North Lancs.

Amateur Call Sign Tags

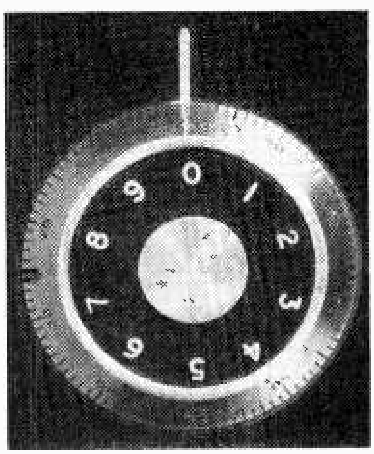
THE maker of a metal tag for car ignition keys, which normally bear the car registration number, has recently had requests for similar tags stamped with the call signs of amateur transmitting stations. The tag, which measures $1\frac{3}{4}$in × $\frac{3}{8}$in, can be attached to a key ring or used to "adorn" items of radio equipment at the home station, in a car (mobile) or when "going portable."

As the illustration shows the lettering is in the natural metal, polished and embossed on a black background. These tags cost 4s each and are obtainable from Kar Kee Tags, 116, Commercial Road, Totten, Southampton, Hants.

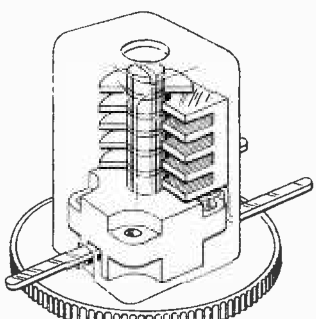
Free-standing Loudspeaker System

A FLAT baffle with panels at each side and at the top, folded inwards to form a shallow open-backed cabinet as in the illustration, is used as a mount for the four loudspeakers in the new Fane Acoustics "Quartet" loudspeaker system. By a suitable choice of panel dimensions and loudspeaker positions, good loading and clean response down to a frequency of 25c/s are claimed. This frequency compares favourably with that (80c/s) for a flat baffle with sides of 32in and 36in, roughly equal to the contour dimensions along the surface of the "Quartet." (The height and maximum width of the "Quartet" are both $25\frac{1}{2}$in.) While a corner position does somewhat enhance the lower bass, the "Quartet" can be stood satisfactorily almost anywhere in a living room, provided that a few inches clear space are left behind it. A hand hold is provided underneath the top of the cabinet, and its total weight is 22lb.

The two 6in × 5in tweeters are mounted with their

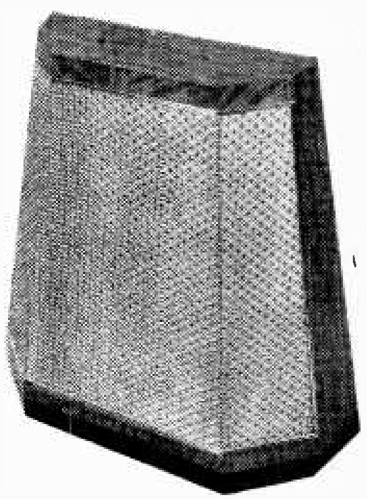


Wirepots 10-turn, precision indicating dial suitable for helical potentiometers.



Oxley sub-miniature air-dielectric trimmer standing on a sixpenny piece.

Amateur call sign tag (Kar Kee Tags).



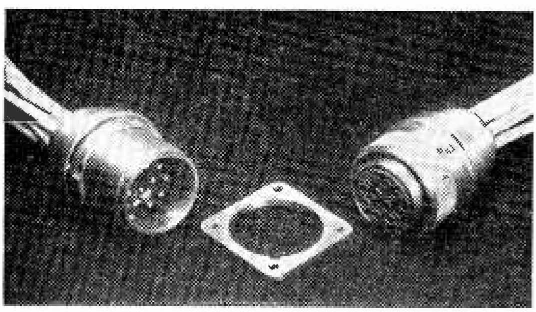
Fane Acoustics "Quartet" loudspeaker system.

major axes vertical, one in each of the side panels nearest the front, to give good horizontal dispersion of high-frequency sounds. The response is actually within about ±5dB from 25 to 16,000c/s for points within 45° of the forward axis in a horizontal plane at a distance of 4 feet. The frequency response of the 12in curved-sided cone bass speaker is arranged to fall off rapidly above 1,000c/s by using a heavy voice-coil and soft pulp cone material, and an electrical crossover at 1,900c/s is also provided. An 8-in middle-frequency speaker (also with a curved-sided cone) has a response to beyond the other electrical crossover point at 3,400c/s. The cross-over circuit uses one capacitor and two series-connected chokes in a quarter-section, parallel type network, one terminal of the 8-in unit being taken to the join of the two chokes. The inductances of the 12-in and 8-in loud-speaker voice coils are also part of the crossover network. Complete with loudspeakers, the "Quartet" costs £35. The address of its manufacturer is Fane Acoustics, Ltd., 1, Wellington Street, Batley, Yorkshire.

New Plessey Plugs and Sockets

IN an effort to simplify the frightening multiplicity of parts for the "AN" type multipole plugs and sockets, Plessey have introduced a range of connectors which will mate with the American "AN" types, but which has fewer than 1,000 parts as against about 13,200. This range—known as the "UK-AN" range—is designed to meet the Ministry of Supply Specification EL1884 and Radio Component Specification 321: these are more stringent than the American specifications.

The mouldings carrying the pins are of a silicone rubber, so allowing a reasonable amount of pin movement; but they also provide unbreakable and moisture-



Two Plessey "UK-AN" connectors and the mounting plate fitted to convert either from a "free" connector to a "chassis-mounting" type. It will be seen that no rear cover is necessary unless the plug is loaded with a screened cable.

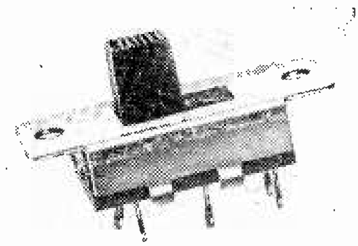
and tracking-proof insulation and pressure sealing. The retaining rings are made from an aluminium-bronze alloy and a most important feature is that the individual pins and sockets are wired apart from the plug body, by either crimping or soldering, and then inserted in the rubber moulding.

Full details are available from the Plessey Co. Ltd., Electrical Connectors Division, Cheney Manor, Swindon, Wiltshire.

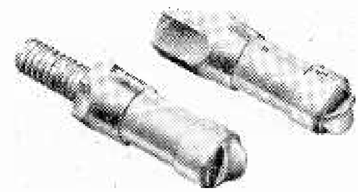
Stand-off Insulators

WITH the addition of the two new stand-off insulators shown in the illustration there are now some 25 different types in the range made by Jackson Bros. (London), Ltd., Kingsway, Waddon, Surrey. Small insulators of this kind are invaluable as wiring and component supports in electronic equipments employing orthodox wiring.

The two new models are known as Types J and JS respectively and each consists of a short ceramic rod



Arcolectric miniature two-pole slide switch.



Types J and JS (with stud) stand-off insulators (Jackson Bros.).

with metal caps at both ends. In the case of the Type J the base cap is drilled and threaded 6BA while in the Type JS it has a short 6BA stud. The former measures $\frac{19}{32}$in and the latter $\frac{15}{32}$in high.

A wide-angle groove in the top cap accommodates two or more wires and its shape facilitates soldering them in position. Both types cost 1s each.

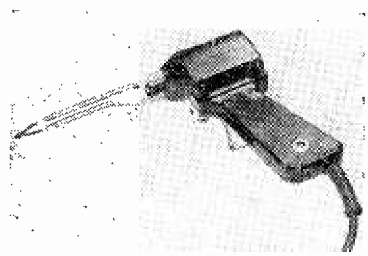
Miniature Slide Switches

A RANGE of small, inexpensive slide-action switches suitable for use in radio and electronic equipments in which the current load does not exceed 1A a.c. or 0.25A d.c. at 250V has been introduced by Arcolectric (Switches), Ltd., Central Avenue, West Molesey, Surrey. The principal features of the new switches are self-cleaning wiping contacts, low rates of wear and deterioration and positive spring location of the sliding carriage. The insulation will withstand a "flash" test at 2,500V a.c. between the frame and any contact for one minute without breakdown.

Types at present available are single-pole and double-pole on/off or changeover and prices range from 2s to 2s 6d each.

Lightweight Soldering Gun

WEIGHING only 1½ lb the electric soldering gun illustrated reaches its working temperature in approximately 7 seconds after switching on. An unusual, but most useful feature, is the inclusion at the root of the hairpin "bit" of a small lamp for illuminating the area of soldering operations. The hairpin bit is easily replaced if necessary. The gun is for use on normal a.c. mains, consumes 55 watts, costs £2 5s 0d and is made by Creators, Ltd., Sheerwater, Woking, Surrey.



Lightweight electric soldering gun (Creators, Ltd.).

DECEMBER MEETINGS

Tickets are required for some meetings; readers are advised therefore to communicate with the secretary of the organizing society.

LONDON

2nd. Association of Supervising Electrical Engineers.—"Progress in electronic switching in telephone exchanges" by N. C. Smart (G.E.C.) at 7.30 at Windsor Castle Hotel 134 King Street, Hammersmith, W.6.

3rd. Radar and Electronics Association.—"Exploration of the upper atmosphere by rockets and satellites" by Dr. R. L. F. Boyd (University College) at 7.0 at the Royal Society of Arts, John Adam Street, W.C.2.

4th. Television Society.—"A new development in flying-spot film scanners" by E. H. Traub (Rank Cintel) at 7.0 at 164 Shaftesbury Avenue, W.C.2.

9th. Scientific Film Association.—"Presenting science and technology to specialist and layman—the contribution of film" at 8.0 at Mullard House, Torrington Place, W.C.1.

9th. I.E.E. Graduate & Student Section.—"The application of electronics to jet engine control" by H. E. Coles at 6.30 at Savoy Place, W.C.2.

10th. I.E.E.—"Bridging the Atlantic" by A. H. Mumford at 5.30 at Savoy Place, W.C.2.

10th. Association of Supervising Electrical Engineers.—"Radar—aids to navigation" by A. Vaux (Decca) at 7.45 at Eltham Green School, Queenscroft Road, Eltham, S.E.9.

12th. Radar & Electronics Association, Student Section.—"The manufacture of magnetrons and klystrons" by D. W. L. White (Mullard) at 7.0 at the Norwood Technical College, Knight's Hill, S.E.27.

15th. I.E.E.—"The acoustic design of talks studios and listening rooms" by C. L. S. Gilford at 5.30 at Savoy Place, W.C.2.

17th. Brit. I.R.E.—"A Vidicon camera for industrial colour television" by I. J. P. James at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

19th. B.S.R.A.—"Microphone balance techniques" by J. Borwick at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

BIRMINGHAM

2nd. I.E.E.—Faraday Lecture on "Automation" by Dr. H. A. Thomas at 7.0 at the Town Hall.

BRISTOL

9th. Television Society.—"Cyldon tuners" by an engineer from Sydney S. Bird, Ltd., at 7.30 in the Colston Room, Hawthornes Hotel, Clifton.

CAMBRIDGE

9th. I.E.E.—"B.B.C. sound broadcasting on v.h.f." by E. W. Hayes and H. Page at 8.0 at the Cavendish Laboratory.

CHESTER

10th. Society of Instrument Technology, Royal Aeronautical Society and British Interplanetary Society.—"Interplanetary Instrumentation" by B. P. Clear at 7.30 at the Grosvenor Museum, Grosvenor Street.

CHRISTCHURCH

10th. Institution of Production Engineers.—"The electronic control of machine tools for aircraft production" by H. Ogden at 7.30 at the Ballroom, King's Arms Hotel.

EDINBURGH

19th. Brit.I.R.E.—"Design and construction of precision toroidal potentiometers for data transmission" by H. J. Arnott at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

FARNBOROUGH

10th. I.E.E.—"Transistors in communication and control equipment" by E. Wolfendale at 6.30 at R.A.E. Technical College.

GLASGOW

18th. Brit.I.R.E.—"Design and construction of precision toroidal potentiometers for data transmission" by H. J. Arnott at 7.0 at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent.

LEICESTER

4th. I.E.E.—Faraday Lecture on "Automation" by Dr. H. A. Thomas at 7.15 at the De Montfort Hall.

LLANDAFF

10th. Brit.I.R.E.—Discussion on "The training of electronics and radio engineers" at 6.30 at the Technical College.

MANCHESTER

4th. Brit.I.R.E.—"High input impedance d.c. amplifiers" by S. Stuart at 6.30 at the Reynolds Hall, College of Technology, Sackville Street, 1.

10th. I.E.E.—"Electronic devices in guided missile systems" by Dr. G. H. Hough at 6.45 at the Engineers' Club, Albert Square.

MIDDLESBROUGH

3rd. I.E.E.—"Colour television" by C. J. Stubbington at 6.30 at the Cleveland Scientific and Technical Institute, Corporation Road.

NEWCASTLE

10th. Brit.I.R.E.—"High resolution airfield control and ground surveillance radar" by P. H. Walker at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

15th. I.E.E.—"Magnetic tape for data recording" by Dr. C. D. Mee at 6.15 at King's College.

PORTSMOUTH

5th. Institution of Electronics.—"The applications of transistors in communications and control equipment" by E. Wolfendale (Mullard) at 7.0 in the Anglesea Road Annexe of the College of Technology.

RUGBY

10th. I.E.E.—"Recent uses of ultrasonics in investigating the characteristics of materials" by Dr. J. Lamb at 6.30 at the College of Technology and Arts.

SHEFFIELD

17th.—I.E.E.—"A new cathode-ray tube for monochrome and colour television" by Dr. D. Gabor, P. R. Stuart and P. G. Kalman at 6.30 at the Grand Hotel.

WOLVERHAMPTON

10th. Brit.I.R.E.—"Electronic instruments in motor vehicle research" by J. C. Dixon at 7.15 at the Wolverhampton and Staffordshire College of Technology, Wulfruna Street.

RANDOM RADIATIONS

By "DIALLIST"

Reaching for the Sky

WHEN the I.T.A. transmitter at Mendlesham, Suffolk, comes into action, as it is due to do towards the end of next year, it will have the tallest aerial mast in this country. It will tower 1,000 feet above the ground. With its high-gain directional aerial giving a maximum e.r.p. of 200kW the new station should give splendid results over a wide area. Having few hills of any height, or deep narrow valleys, East Anglia must be near the television engineers' idea of paradise, for it is almost entirely free from the causes of headaches which are so numerous in some other parts of England, to say nothing of Scotland and Wales. What a landmark the mast will be when it's completed. Dwellers in East Anglia had a longish time to wait before they got TV at all, for as E. L. E. Pawley wrote in the November issue of *Wireless World*, it wasn't until February, 1955, that the Norwich station began work on low power and until June 1958 that it went up to full power. Though its e.r.p. is no greater than 15kW in the most favourable direction, it gives very satisfactory reception. Mendlesham, with more than a dozen times this output, should make it possible to use fairly simple Band III aerial arrays in many districts.

Exaggerated ?

THE alarming reports about the possible risk to life and limb from N.A.T.O. forward-scatter stations, were, it seems, not a little exaggerated. It was suggested that each station would have a danger zone extending for a mile or so in the direction of its transmissions and that any houses or farms within this would have to be evacuated. This was promptly denied by the authorities, who said that only small areas would have to be fenced off and that outside these the intensity of radiation would be only a minute fraction of the amount which could possibly do any harm to anyone. The Medical Research Council and the D.S.I.R. have still to report on this matter, but it seems unlikely that either will find that there is reason for alarm. Any reader who served in Army radar during the war may recall that rumours got about that operators and mechanics were running serious risks from radiation. That was in 1943, if I remember aright, and I recollect that for a time it wasn't easy to convince either men or women that they weren't in any danger at all and could volunteer for such jobs without any qualms.

Replaceable Panels

THE replacement panel system used in this season's Cossor television receivers, strikes me as eminently sound and I'm sure it will be welcomed by servicemen. Here it is in a nutshell. Each of the main working parts of the set are mounted as a unit on its own panel—or board, as Cossors prefer to call it. There are seven of these boards; sound output, frame timebase, line timebase, e.h.t., power unit, I.f., control panel. All have printed circuits and each carries a full guarantee as a unit. A very good point is that any of them can be removed and replaced. And I believe you don't have to remove the set from its cabinet to do so. I'm all in favour of such methods of making servicing easier and simpler.

Relay Services

SOUND and television relay systems are being installed in more and more towns where local conditions make reception by means of individual aerials a difficult business. It has always seemed to me that "piped" services were the only answer to the problems that arise in so many difficult areas. To be assured for two or three shillings a week of a strong, clear signal is the greatest possible boon to folk who have hitherto had to put up with poor TV pictures and with fading or otherwise distorted sound. For some reason, which I don't quite understand, dealers are sometimes opposed to the installation of relay systems. This puzzles me because there can't, I'd have thought, be much satisfaction in selling sets to customers who are going to be continually grousing about bad reception.

The Stuff to Give 'Em

MULTIMUSIC, Ltd., manufacturers of the Reflectograph tape recorder, are about to launch a guarantee scheme for their products on the lines that I've been advocating for years for domestic sound and television sets. All of their tape recorders will carry a comprehensive guarantee for twelve months covering every part of them, including the valves. That's as it should be and I wish their policy all success. To me it has always seemed ridiculous that there should be three different guarantees for a TV set: three months for the valves, six for the c.r.t.* and twelve for the other bits and pieces. Even more absurd is it that you couldn't sell British valves in any other countries unless they there carried a full year's guarantee. Isn't it about time that our radio industry took steps to straighten things out?

* The makers of Ambassador & Baird television sets introduced some time ago an extra year's guarantee for the tubes used in their sets.—ED.

TV Aerial Clutter

IT'S rather surprising that next-door neighbours in semi-detached houses and those who live in buildings which have been divided up into flats don't make more use of communal television aerial arrays. When I lived not far from London I used to pass every day a house turned into five flats, whose single chimney stack supported no fewer than five Band I and three Band III arrays. For several people to be able to use the same aerial a distributor and an amplifier are, of course, necessary. I should imagine that a communal aerial would provide much better reception than is obtainable from a "personal" aerial with one or more others quite close to it. A clutter of aerials on a chimney stack certainly does not enhance the beauty of any building and must impose considerable strain in a high wind.

Television Gets Moving in France

STATISTICS published some time ago in *Télévision* show that TV as a form of home entertainment is now making very rapid progress in France. At the end of 1956 the total of domestic television receivers in the whole of France was only 442,433. By December 31st, 1957, it had risen to 683,229, an increase of 240,796 in twelve months. In other words, the total rose in the course of last year by more than 50 per cent, which is a remarkable increase. It is, I believe, largely due to the expansion of the television networks; prior to 1957 there were many districts, and even whole *Départements*, in which reception was very poor, or even not possible at all. There still are some of these, particularly in the mountainous parts of the country; but the problem is being tackled energetically and more and more booster transmitters, mostly radio-linked, are coming into use. Will France reach her first million TV set owners by the end of this year? My forecast is that she will.

UNBIASED

By FREE GRID

Raster House

AS the plan of the new Television HQ at the White City resembles a Lissajous figure—if you care to use a little imagination when looking at the drawing in the October issue—I should like to suggest that Raster House might be a good name for the new building. Those of you with so little imagination that you cannot see the resemblance between the plan of the new B.B.C. building and a Lissajous raster, might be reminded that there is—on first thoughts—little resemblance between a ship and the nave of a church, and yet the word "nave" was adopted because the ratio of length to breadth of this part of a church is similar to that of a ship (Latin: *navis*).

Talking of rasters reminds me that the Editor told me recently that a reader, Mr. W. Bold, of Urmston, Lancs., had asked what is the origin of the word and whether it has any connection with the Urdu word "rasta," meaning a path. It certainly has a connection since Urdu is descended via Sanskrit from the same primitive Indo-European tongue which gave us Latin and Greek as well as most of the modern European languages.

Raster is a very old word in English, and when Chaucer went for a shave he probably visited a "rastyr howse," as barbers' shops were known of old; I don't think the expression survives now unless in Cambridge where a "chymist" still exists. The TV raster is less likely to be descended from the Latin verb "*rastare*= to shave," as from its mate "*radere*=to draw a line," the past participle of which, *rasum*, gives us words like erase. However, the immediate ancestor of raster is probably "rastrum." This means a rake which is certainly an instrument for drawing parallel straight lines.

But none of this philological philandering tells us when and by whom the word raster was dug up and applied to TV scanning. Can any of you dispel my ignorance on this point?

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Stereo Defended

MR. BRIGGS' criticisms of stereo sound in the last issue interested me. I am sorry to say that I agree with many of them, but I don't agree with his opinion that stereo was launched on the public six months too soon. That is quite wrong. Had it been delayed six months an excuse would have been found for a further delay. It can only win its spurs in the hard school of experience and public criticism.

The same thing was said in 1922 about the launching of sound broadcasting. It was, so the critics said, started too soon. Even though the first radio exhibition had been held a month before the B.B.C. started regular broadcasting on November 14th, 1922, there was a famine of good sets at reasonable prices. Had it been delayed six months, things would have been no better; indeed it was not until the coming of the screen-grid valve in 1927 that really worthwhile sets became available.

The screen-grid valve itself was quite rightly launched before its time. As a result of the experience gained, the screen-grid valves of the following year were very much more reliable and their circuitry better understood.

The horseless carriage was launched on the public roads long before its time. What a thoroughly unreliable contraption it was. But it was because of its seemingly premature launching that we have our reliable cars today instead of some years hence.

No, I am all for prematurity and that is why I should like to see coloured 10,000 line and stereoscopic TV launched tomorrow. If that were done we should soon have sets capable of receiving it; thoroughly unreliable ones, of course, but better than nothing.

Robot of the Rod

IT astonished me to read recently in the lay press a letter from a correspondent who claimed that he was in a position to manufacture an electronic caning machine which would take the place of the hit-and-miss methods now employed by schoolmasters. He writes as though there were something new in the idea, whereas I described such a machine in the January, 1955, issue.

"In my young days"

My machine not only made the punishment fit the crime but made it fit the criminal also because, before getting to work, it measured the victim's sensitivity to pain and other things necessary to ensure the "fair shares" so beloved of people today.

In my young days it was the custom of schoolmasters to draw a chalk line on the seat of the offender's trousers to ensure that all strokes fell on the same spot, thus causing more pain with less effort. My machine did this by electronic means but it left a weal which nowadays, of course, a boy would show to his parents so that it could form the basis of a summons for assault, a thing which was certainly "not done" when I was a boy.

I have since produced an improved version, with which there is no weal; two electrodes are placed a few inches apart on a boy's anatomy and a carefully graduated electric current passed between them. This produces just as much pain as the old method but leaves no mark.

"ψ"

I WAS very interested in "Cathode Ray's" statement in the November issue that an electron occupies the tiny volume where ψ waves don't cancel each other out.

ψ is, of course, our friend "Psi," the 23rd letter of the Greek alphabet, and I am, therefore, tempted to simplify "Cathode Ray's" definition by saying that an electron is another name for a psychic cymatope*. The only trouble is that the word psychic has got so hopelessly mixed up with ghosts and suchlike intangible things that my simplification might lead people to believe that "Cathode Ray" was writing about these clammy entities. So far he has not done so, although I hope that one day he will cross the frontier between physics and metaphysics.

However, what I want to know right now is the reason why ψ is used to describe these "waves of what nobody knows," as "Cathode Ray" calls them. Was it that ψ happened to be unused for anything else, or was there a better reason as with x for the unknown quantity?

ψ is, of course, the initial letter of the word Psyche, which, apart from being the name of the lady who got Eros such a bad name, means, among many other things, the "soul of the universe," the "very core of things," the "basis of all things." Can it be that ψ waves are regarded in certain scientific circles as "the ultimate" (just as atoms were a few generations ago, and as, indeed, their name implies)? In my opinion, the use of the symbol ψ implies this.

* "Free Grid's" own word purporting to mean a place filled by a wave.—ED.