Wireless World

ELECTRONICS, RADIO, TELEVISION

JULY 1963

VOLUME 69 No. 7
PRICE: 2s 6d.

FIFTY-THIRD YEAR OF PUBLICATION

Managing Director: W. E. Miller, M.A., M.Brit.I.R.E.
Iliffe Electrical Publications Ltd., Dorset House, Stamford Street, London, S.E.1

Please address to Editor, Advertisement Manager or Publisher as appropriate

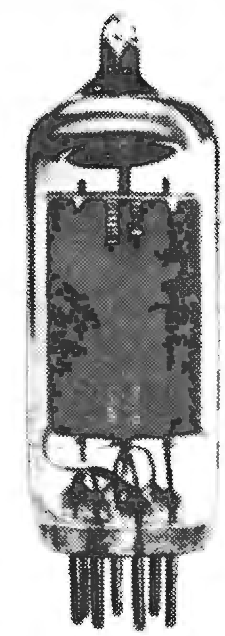
PUBLISHED MONTHLY (4th Monday of preceding month). *Telephone:* Waterloo 3333 (70 lines). *Telegrams:* "Ethaworld, London, Telex." *Cables:* "Ethaworld, London, S.E.1." *Annual Subscriptions: Home* £2 0s. 0d. *Overseas* £2 5s. 0d. *Canada and U.S.A.* $6.50. Second-class mail privileges authorized at 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:* 62, Buchanan Street, C.1. *Telephone:* Central 1265-6. *MANCHESTER:* 260, Deansgate, 3. *Telephone:* Blackfriars 4412. NEW YORK OFFICE: *U.S.A.:* 111, Broadway, 6. *Telephone:* Digby 9-1197.

LOCKED OSCILLATOR DISCRIMINATOR

using the Mullard EH90

AN economical circuit incorporating the Mullard EH90 has been devised for the detection of the frequency modulated sound transmissions, that will be used when the 625 line television system is introduced. This circuit is already appearing in some of the latest dual-standard receivers.

In the locked oscillator discriminator, the mean anode current of the EH90 is a function of the phase of the voltages at the control electrodes—the first and third grids. The tuned circuits at these grids are physically separated but are coupled by the electron stream within the valve. This electron coupling may be regarded as coupling by means of a negative capacitance. The negative sign indicates that energy is supplied by the electron stream, and this implies that amplification can be obtained between the two grids. As is normal with loosely coupled circuits, the phase angle between the two voltages is 90° at resonance. Feedback occurs through the internal capacitance between the two grids, and this maintains oscillation.



If the frequency of the signal applied to the first grid changes, the oscillator remains frequency-locked but the phase relationship between the voltages at the two grids varies in proportion to the signal frequency. The effective sum of the currents appears as an amplitude variation in anode current. Frequency modulations at the first grid are thus converted to amplitude modulations at the anode, and these are subsequently amplified.

EQUALISED HEATING PROPERTIES

OF MULLARD TELEVISION VALVES

All Mullard valves designed for operation in television series heater chains now possess equalised heating characteristics. These characteristics prevent damage to the valve heaters during the warm-up period and eliminate the need for a thermistor.

When the receiver is switched on, if one valve in the heater chain warms up more rapidly than the rest, the increase in the voltage developed across the heater of that valve can exceed the amount (50% above the nominal heater voltage) which can be tolerated during the warm-up period. This can shorten the life of the valve considerably, and to prevent it, heater chains have normally been designed to incorporate a thermistor, which reduces the rate of increase of the heater current, and prevents unequal rises in the temperature of the heaters from producing an excessive voltage across any heater.

WHAT'S NEW IN THE NEW SETS

These articles describe the latest Mullard developments for entertainment equipment

Now, however, Mullard have developed methods of manufacture which produce equalised rates of temperature rise in all their television valves. Extensive tests with a large number of valves in typical heater chains have shown that these equalised heating properties ensure that, without added protection, the voltage developed across any heater will not exceed the permitted 50% above nominal during the warm-up period.

LINE OUTPUT PENTODE

for dual-standard Television Receivers

The problem of ensuring comparable line timebase performance in new dual-standard receivers has been simplified by the introduction of the Mullard line output pentode, type PL500. This valve, which has improved performance compared with valves previously used for solus 405-line operation, enables consistency in performance to be achieved despite the fact that the energy requirements for 625-line operation are almost half as great again as for 405-line operation.

An exceptionally high ratio of anode current to screen-grid current is achieved in the PL500 by an entirely new form of anode—the 'cavitrap'. With this construction, secondary-emission electrons from the anode are recaptured by the partitions of the cavitrap anode. Because of the improved current ratio, the PL500 is capable of delivering greater deflection power which helps to prevent any significant change in performance between the two line standards.

MVM 1267

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The Devil We Know

IN these days, when attention is focused on space communication and satellites, the older-established methods of radio communication tend to be overlooked—but by no means neglected, as the recent I.E.E. Convention on H.F. Communication, reported elsewhere in this issue, clearly shows.

Whatever may be the outcome of the present intensive developments in satellite communications it is certain that the existing services are unlikely to become redundant while the volume of traffic continues to expand at its present rate. While new ground is being broken, the known areas are being more intensively cultivated, by methods in many ways as full of technical interest and with results at least as commercially valuable as those so far obtained from more exotic growths.

It was in the early 1920s that the work of Marconi and his colleagues, notably Franklin, resulted in what would now be termed a breakthrough in radio communication. Hitherto the use of ever higher powers on kilometre wavelengths seemed the logical course of development. This was wasteful because of the limitation of aerial size in relation to wavelength and the consequently poor directivity and low *effective* radiated power. Signalling speeds were slow (usually 20 words per minute and only 50 w.p.m. under favourable conditions of atmospheric noise). With the new shortwave beam aerial ranges were increased, using powers only 1/50 of those required on long waves, and signalling speeds went up to 300 w.p.m. At last radio was taking a really significant share of the telegraph traffic and making possible an intercontinental telephone service.

Inevitably the h.f. band (3 to 30Mc/s) soon became congested and the vagaries of the ionospheric climate, then incompletely understood, earned a reputation for unreliability for these services. At this point the majority of telecommunications engineers felt that h.f. had had its day and began to look for escape routes—cables, now revivified by polythene and submerged repeaters; the brute force of scatter rather than specular reflection from the ionosphere; and now satellites receiving and transmitting at frequencies which ignore the existence of the ionosphere altogether. But the fires of radiation in space are at the moment affording scant refuge from the frying pan of the ionosphere and, in spite of intensive forethought and the most meticulous preparation, have succeeded in penetrating the defences of the many of the first communications satellites.

No one doubts that these early troubles will be mastered, but meanwhile the traffic grows and we should be grateful to that minority of engineers who have retained faith in the h.f. bands and worked with ingenuity and persistence to salvage what is now very far from being a wasting asset.

Improvement has come from several directions —a better understanding of propagation conditions, greater flexibility in aerial systems and better discrimination against interference by the use of multi-tone signalling codes and by sophisticated error correction systems.

In addition to long-range forecasts of optimum working frequencies, based on the 11-year sunspot cycle, we now have day-to-day reports on the state of the ionosphere based on world-wide ionosphere soundings. If these are not sufficiently detailed, individual operators can at any hour of the day find for themselves the best frequencies for their own routes by the radar-like method of back-scatter or by the simpler and less expensive "ionogram" produced by sending and receiving a succession of pulses at logarithmically-spaced frequency intervals covering the whole band. This shows not only the frequency limits but also the existence of multipath propagation and therefore the frequencies to be avoided in the pass band.

To exploit the information so obtained calls for skill and agility on the part of operators, and a degree of flexibility in equipment not possible with the early fixed curtain aerial arrays. Universally steerable systems with electronic adjustment of tilt and azimuth can now quickly adapt to changes of bearing and downcoming angles in the radio wave. Even in the present difficult period, approaching sunspot minimum, circuits are being kept open; but both operators and equipment are being worked a little harder.

So, while future satellite systems are being made ready, subscribers should be grateful to those who have kept in good repair the h.f. lines of communication without having to call in the equivalent of Dr. Beeching. There may be even some who will sympathize with the old lady who, when offered a flight in an aeroplane, said that she intended always to travel by train "as the good Lord intended."

Design of Ceramic Loudspeaker Magnets

MAKING THE MOST OF NEW ANISOTROPIC MATERIALS

By A. E. FALKUS,* B.Sc.(Eng.), M.I.E.E.

PERMANENT magnets made from barium ferrite having the formula Ba Fe_{12} O_{19} have been known since 1926. This material in isotropic form has a relatively high working value of magnetomotive force per cm. length, being about 1,000 oersted when working under optimum conditions, as compared with 530 oersted for Alcomax 3 now in common use for loudspeaker magnets.

Unfortunately, the working flux density is very low, being about 1,000 gauss, as compared with a corresponding figure of 10,200 gauss for Alcomax 3. As a result, a loudspeaker magnet using this material would require ten times the cross sectional area and, although the ingredients of the magnet are relatively cheap and plentiful, the cost of the much larger iron circuit renders the design uneconomic, even if the much greater bulk of the complete speaker was not an embarrassment.

It has been found possible to greatly improve the flux-carrying ability of the barium ferrite by grinding the material to a fine powder and then pressing the particles together again in the presence of a strong magnetic field which aligns the particles in the required direction. The pressing is then sintered resulting in a magnet having improved magnetic properties in the required direction. Considerable development was required to produce this anisotropic material on a commercial scale but it is now readily available in this country under the trade names of Magnadur 2 and Feroba II.

The published average characteristics of Magnadur 2 and Feroba II are:—

	(BH) max. (Megagauss-oersted)	Working H at (BH) max. point (Oersted)	Working B at (BH) max. point (Gauss)
Feroba II	3.2	1330	2400
Magnadur 2	3.2	1450	2200

In practice we have found little difference between these materials, although individual magnets vary somewhat from one to another. We are, however, using the figures for Magnadur 2 since most of our work has been done with this material.

It will be seen that the value of (BH) max. for the anisotropic ceramic is little more than half that of the Alcomax 3 alloy, but this is more than offset by the relative cheapness of its basic ingredients, especially for the larger sizes of loudspeaker magnet. The increased value of H and much lower value of B as compared with Alcomax 3, however, renders the enclosed centre pole design uneconomic for the ceramics and a simple ring magnet construction with top and bottom iron collecting plates and central iron pole is the most practical construction. This is shown diagrammatically in Fig. 1.

Applications: It will be noticed that, in addition to the magnetic leakage which occurs above and below the air gap, as in the capped-slug centre pole design (see "Loudspeaker Magnet Design," *Wireless World*, January 1960) there is also a considerable leakage between the top and bottom plates around the outside of the magnet ring. This leakage, which may amount to a quarter of the total lines carried by the magnet, can be serious enough to rule out the use of ceramic magnets for some applications. For instance, it may seriously distort the picture in a television set, it can interfere with the operation of transistors and rod aerials, and may destroy the record on a magnetic tape.

In addition to the lower cost of the ceramic material, its high value of magnetomotive force results in an appreciable reduction in height of the magnet which may sometimes be very useful when the front-to-back dimension of the speaker is severely limited by the space available. It is this feature which has made possible the slim loudspeaker assemblies now so popular for "hi-fi" in the home.

Design Considerations: It will be seen from Fig. 1 that the total flux carried by the magnet divides into two parts. One portion enters the central iron pole-piece or peg, while the remainder passes around the outside of the magnet and may be called the outside leakage.

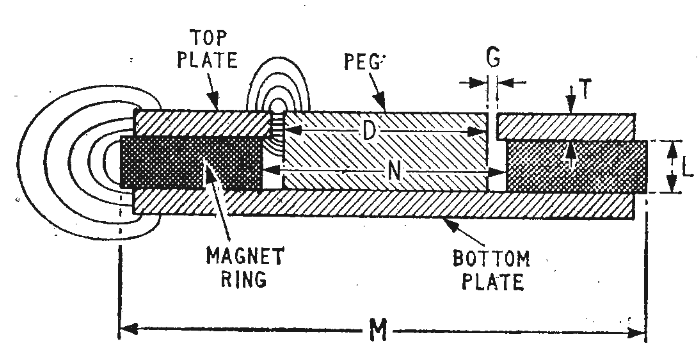
The peg flux in turn divides and a part passes usefully across the air gap while the remainder leaks across above and below the gap.

It was shown in our previous article (see above) that the useful gap flux is

$$\frac{LH\pi DT}{G}$$

where H is the working value of the magnetomotive

Fig. 1. Section of ceramic ring magnet showing stray fields.



*Fane Acoustics Ltd.

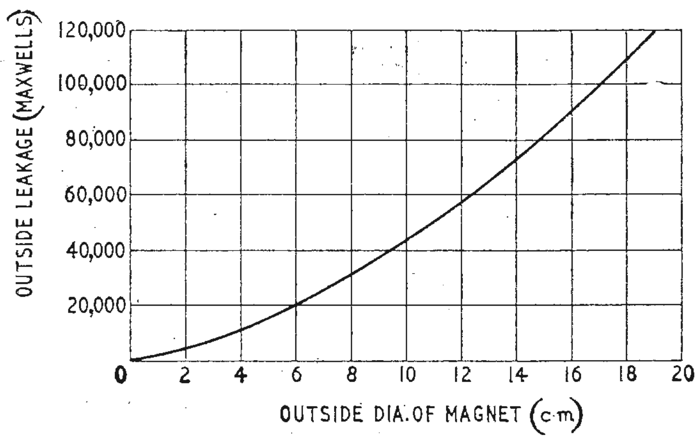


Fig. 2. Outside leakage flux of ceramic magnet.

force of the magnet material and the dimensions are as in Fig. 1.

Also the leakage flux from the centre pole above and below the gap amounts to

$$3.5\,LH\pi D$$

From this it follows that the proportion of the centre-pole flux that passes usefully through the air gap, i.e., the centre-pole efficiency, is—

$$\frac{T}{T + 3.5G} \times 100\%$$

In order to complete the design, however, it is necessary to be able to foretell the amount of the outside leakage around the edges of the magnet ring.

Outside Leakage: The outside leakage may be considered as being in two parts. The first part consists of the magnetic lines passing from the cylindrical edge of the top plate to the cylindrical edge of the bottom plate separated from it by L the length of the magnet. The second part consists of the magnetic lines passing from the flat top surface of the top plate to the flat bottom surface of the bottom plate.

If we consider the edge leakage first, assuming a constant plate thickness, this will be equal to the magnetomotive force multiplied by the cross-sectional area divided by the distance, i.e., proportional to

$$\frac{LH\pi M}{L}$$

Since H is a constant for a given magnetic material it follows that the edge leakage is directly proportional to M, the outside diameter of the magnet.

Similarly the leakage between the flat surfaces of the top and bottom plates is proportional to their area, i.e. to M^2. Thus the total outside leakage may be taken to be

$$C_1M + C_2M^2$$

where C_1 and C_2 are constants depending on the characteristics of the magnet material and the units employed.

To evaluate the constants C_1 and C_2, measurements were made of the outside leakage flux of a large number of different sizes of ceramic magnet assemblies. The values of the outside leakage were plotted against the outside diameter of the magnets and they were found to lie on a smooth curve which is given in Fig. 2. The expression of this curve is found to be

Outside leakage $= 1{,}900M + 230M^2$.

where the outside leakage is in maxwells and M = outside diameter of magnet ring in cm.

Magnet Design for a Specific Performance: To calculate the optimum dimensions of a ceramic ring magnet to produce a flux density of Bg gauss in a gap of width G and depth T and a pole diameter D, we may proceed as follows:—

Ring Thickness:

The magnetomotive force required across the gap is Bg G oersteds. Allowing for a 10% loss to drive the flux through the iron circuit the total m.m.f. of the ceramic ring must be 1.1 Bg G. The thickness of the ring L is therefore

$$L = \frac{1.1\ Bg\ G}{H}\ \text{cm}$$

Peg Flux:

The total gap flux is the gap area, π DT, multiplied by Bg, the gap flux density.

The peg efficiency is

$$\frac{T}{T + 3.5\,G}$$

The total peg flux P is therefore

$$\frac{T + 3.5\,G}{T} \times D\ T\ Bg\ \text{maxwells}$$

Magnet Area:

The magnet must have the correct cross-sectional area so that when carrying the peg flux P together with the outside leakage flux, it is working at its optimum flux density B gauss. The total flux carried by the magnet is

$$P + 1900\ M + 230\ M^2$$

The cross-sectional area of the magnet must therefore be

$$\frac{P + 1900\ M + 230M^2\ \text{sq. cm.}}{B}$$

Inside Diameter of Ring:

Now the inside diameter of the ring N must be at least equal to D + 2 G to allow free passage for the voice coil. In practice it will be found desirable to allow rather more clearance than this and a good plan is to make N = D + 4 G cm.

Outside Diameter of Ring:

Now the outside diameter of the ring is M, its cross-sectional area is therefore

$$\frac{\pi}{4}(M^2 - N^2)\ \text{sq. cm.}$$

Thus, to obtain optimum flux density in the magnet

$$\frac{P + 1900\ M + 230\ M^2}{B} = \frac{\pi}{4}M^2 - \frac{\pi}{4}N^2$$

Solving this for M, we have

$$M = \frac{0.864 + \sqrt{0.746 + 0.001238P + 2.139\ N^2}}{1.362}$$

where M = outside diameter of ceramic ring in cm.
P = peg flux in maxwells.
N = inside diameter of ceramic ring in cm.

Example of Complete Design: Suppose we require a ceramic ring to provide a gap flux density B = 12,000 gauss in an air gap of width G = 0.030in and depth $\frac{1}{8}$in. with a pole of $\frac{3}{4}$in diameter.

The mean diameter of the gap = 0.75in + 0.03in = 0.78in.

The cross-sectional area of the gap = 0.780 $\times$ π $\times$ 0.125 $\times$ 6.452 sq. cm. = 1.98 sq. cm.

Total gap flux $= 12{,}000 \times 1.98 = 23{,}760$ maxwells.

The centre pole efficiency is

$$\frac{T}{T + 3.5\,G} = \frac{0.125}{0.125 + 3.5 \times 0.030} \times 100\% = 54.3\%$$

The total peg flux P is therefore

$$\frac{100}{54.3} \times 23{,}760 = 43{,}760 \text{ maxwells}$$

The inside diameter of the ring N, is: $D + 4G = 0.75 + (4 \times 0.030)$in. $= 0.87$in. or 2.21 cm.

The outside diameter of the ring M, is:

$$\frac{0.864 + \sqrt{0.746 + 0.001238 \times 43760 + 2.139 \times (2.21)^2}}{1.362} = 6.57 \text{ cm. or } 2.59\text{in.}$$

The value of the magnetomotive force required across the air gap to give 12,000 gauss is

$12{,}000\ G = 12{,}000 \times 0.030 \times 2.54 = 914$ gilberts.

Allowing for losses in the iron circuit, the total magnetomotive force required from the magnet is

$914 \times 1.1 = 1005$ gilberts.

The required thickness of magnet material is therefore

$$\frac{1005}{H} = \frac{1005}{1450} = 0.694 \text{ cm. or } 0.273\text{in.}$$

The dimensions of the required ring are thus—

O.D.	2.59in
I.D.	0.87in
Thickness	0.273in

Design of Iron Circuit: The thickness of the top plate is usually made equal to T, the depth of air gap required. The peg is normally a parallel slug of mild steel diameter D though if a very deep gap is being employed, it will be found worth while to increase the diameter of the peg below the lowest point of the voice coil travel to prevent magnetic saturation.

The thickness of the bottom plate is usually determined by the cross-section required at the circumference of the peg to carry the peg flux.

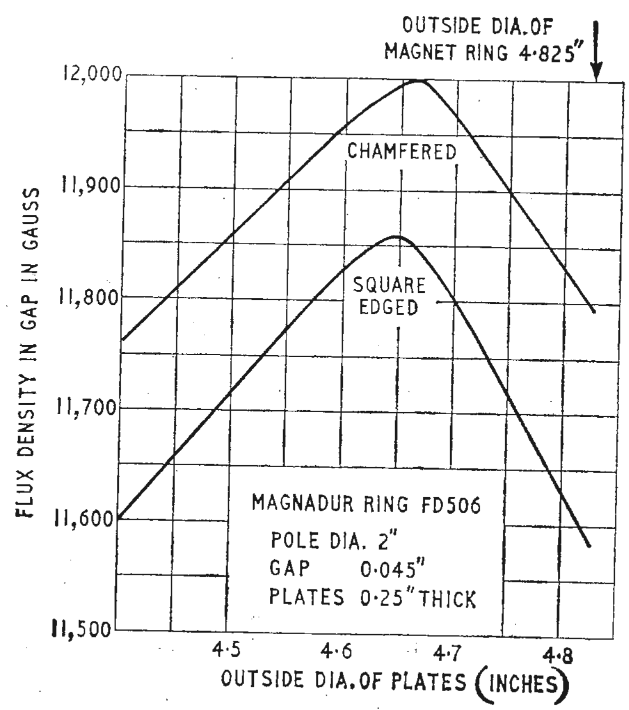


Fig. 3. Optimum diameter of plates.

If the thickness of the bottom plate is S cm. and the working flux density in the iron circuit is not to exceed, say, 14,000 gauss, then it will be seen that

$$S = \frac{P}{14{,}000\,\pi D}$$

This assumes a parallel peg. If the lower portion of the peg is increased in diameter, this larger value may be taken in the above expression for S.

It will often be found in practice, particularly in the larger sizes of loudspeaker, that although it may be desirable to increase the base of the peg to reduce its saturation and permit a thinner base plate to be used, this is impossible as the full length of the peg is required to accommodate the maximum excursions of the voice coil.

It is of interest to note that for maximum gap flux from a given ceramic ring, the top and bottom plates should be made a little less than the outside diameter of the magnet ring. The reason for this is that the outer portion of the ring is providing the leakage flux and this leakage is reduced by removing the iron, as far as possible, from the leakage flux path. This point is dealt with more fully below.

Optimum Diameter and Shape of Plates: As mentioned above, the top and bottom plate should be made smaller in diameter than the magnet ring to reduce the outside leakage and obtain the highest possible flux density in the air gap. In addition, a

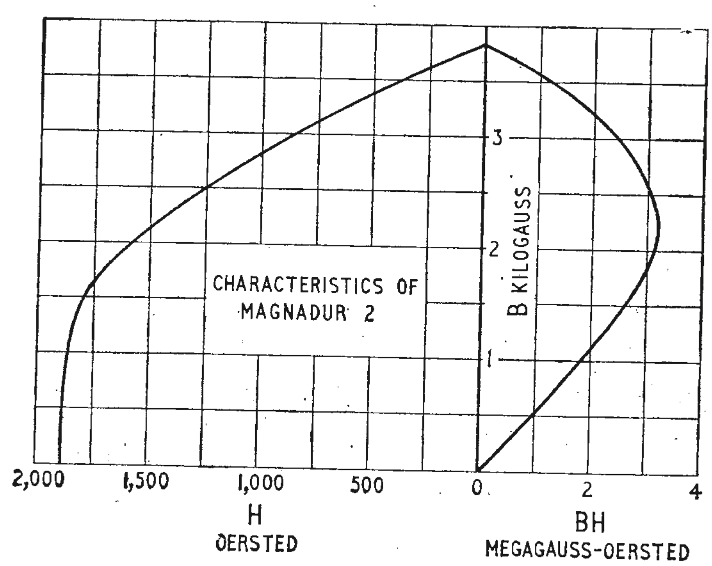


Fig. 4. Magnetic characteristics of ceramic magnet.

further improvement can be obtained by chamfering the edges of the plates. Clearly the outer portions of the plates are carrying little of the useful gap flux and a chamfer will increase the leakage path between the top and bottom plate.

To illustrate this point a sample ring of Magnadur 2 measuring O.D. 4.825in, I.D. 2.24in and thickness 0.472in was fitted with top and bottom plates of diameter equal to the ring. The peg was a parallel slug of 2in diameter working in an 0.045in width of gap. Both plates were ¼in thick.

The assembly was magnetized and the flux density in the gap measured. The plates were then removed

TABLE 1
STANDARD SIZES OF MAGNADUR 2 CERAMIC MAGNET RINGS

Ref. No.	Dimensions of Ring: Inside Dia. (Inches)	Outside Dia. (Inches)	Thick-ness (Inches)	Typical Applications: Pole Dia. (Inches)	Gap Width (Inches)	Gap Depth (Inches)	Flux Density (Gauss)
FD 501	0.866	1.77	0.315	0.562	0.030	0.125	9,000
				0.625	0.0325	0.156	7,500
FD 502	0.945	2.36	0.315	0.562	0.030	0.125	13,500
				0.750	0.030	0.125	11,500
FD 503	1.22	2.87	0.394	0.625	0.0325	0.125	15,000
				1.0	0.040	0.187	10,500
FD 504	2.01	4.02	0.394	1.0	0.040	0.156	12,500
				1.5	0.045	0.312	8,000
FD 505	2.01	4.02	0.551	1.0	0.040	0.156	14,000
				1.5	0.047	0.312	9,000
FD 506	2.24	4.76	0.472	1.5	0.047	0.250	12,000
				2.0	0.045	0.250	12,000
FD 507	2.24	5.27	0.551	1.5	0.047	0.250	14,500
				2.0	0.045	0.250	14,000
FD 5025	2.24	6.10	0.690	1.5	0.047	0.250	18,500
				2.0	0.045	0.250	17,000
FD 5037	3.20	7.24	0.728	2.0	0.050	0.312	17,500
				3.0	0.505	0.375	14,500

and reduced in diameter by 0.050in. The magnet was then reassembled and remeasured. This process was repeated a number of times and the results are given in Fig. 3.

The same magnet ring was then reassembled with a new set of plates with the edges chamfered at an angle of 30°. The same series of tests was repeated and the results are also included in Fig. 3.

It will be seen that the maximum gap flux density obtained with the chamfered plates is 12,000 gauss compared with 11,860 gauss for the square edge plates —i.e. an improvement of 1.2%. Further this occurs at a slightly larger diameter for the chamfered plates. The optimum diameter of the square-edge plates is 4.65in, i.e. 0.175in less than the diameter of the magnet and this optimum diameter is fairly critical. In practice, unless the chamfer can be obtained at little extra cost, it is probably not worth while, but each case should be treated on its merits.

Standard Sizes of Ring: Unlike Alcomax 3 magnets where the tooling cost for a new shape is small, and, in fact, seldom charged for by the magnet manufacturers, in the case of anisotropic ceramic rings the tooling cost is considerable and may amount to £1,000 for a large ring.

On the other hand, the shape of the magnetization curve (see Fig. 4) for the ceramic materials is such that we can depart appreciably from the optimum ratio of length to cross-sectional area without any great reduction in the working value of B × H. From the figure it will be seen that working values of H can be used from 1800 oersteds down to 900 oersteds without the B H product falling below 2.6 megagauss-oersteds.

When deciding whether an existing ceramic ring will be satisfactory for any purpose for which an exact fit is not available, these curves will enable the value of the BH to be calculated when the existing ring is used. Providing this value is above about 2.6 the result will probably be satisfactory. As a result of these considerations it is usual to meet most requirements with a series of standard sizes of ring. This method has all the additional advantages of standardization such as ease of obtaining initial samples, etc.

In Table 1 (left) is given a series of nine standard sizes of Magnadur 2 rings which are readily obtainable in this country and which will cater for the majority of applications of ceramic magnets in both small commercial loudspeakers as well as the largest sizes up to 3in pole diameters. It must be understood that the gap dimensions and associated flux densities given in this table are only typical examples of the many different combinations of pole diameter and gap sizes which can be usefully employed with each size of magnet ring.

In addition to this series of Magnadur 2 rings, there are also available nine sizes of Feroba II rings which supplement the available choice of the most suitable size of ring for any particular purpose. These are given in Table 2. It should be noted that these rings are available with a range of thicknesses for each set of diameters so that more latitude is allowed to the designer to obtain the most economical magnet assembly.

Magnetization and De-magnetization: In order to obtain the maximum flux density in the air gap of an anisotropic ceramic loudspeaker magnet it is essential to magnetize it after the assembly of the completed iron circuit. This calls for very powerful magnetizing equipment for the larger rings. To completely demagnetize a large ceramic magnet assembly is very difficult indeed. However, for the purpose of cleaning the air gap of a loudspeaker it is only necessary to reduce the gap flux to zero which

TABLE 2
AVAILABLE SIZES OF FEROBA II CERAMIC MAGNET RINGS

No.	Inside Diameter (inches)	Outside Diameter (inches)	Thickness (inches) Min.	Max.	Std.
1	1.190	1.990	0.300	0.500	0.300
2	1.180	3.214	0.450	0.600	0.550
3	1.265	3.798	0.500	0.800	0.720
4	2.226	4.031	0.450	0.800	0.454
5	2.200	4.220	0.500	0.800	0.535
6	2.000	4.300	0.500	0.800	0.800
7	2.095	4.875	0.500	0.800	0.550
8	2.095	5.472	0.550	0.800	0.650
9	2.095	5.974	0.550	0.800	0.800

can be done in the same equipment as is used for magnetizing by using a reversed current of suitably reduced amount.

Although it is comparatively simple to reduce the gap flux to zero in this way by trial and error methods, it is usually found that, although the gap flux may be zero, the inner portion of the magnet is magnetized in opposition to the outer portion and it is difficult to remove the top and bottom plates.

Methods of Assembly: Ceramic magnet rings can sometimes be supplied with three or more holes which can be used for brass screws to hold the top and bottom plates together. A simple and more economical method of assembly, however, is to use an epoxy resin adhesive to join the plates to the magnet ring. The top plate is usually provided with tapped holes or other means of mounting to the loudspeaker chassis.

Temperature Effects: The performance of ceramic magnets is affected by changes of temperature to a greater extent than metal magnets. The effects are not, however, enough to alter the performance of a loudspeaker to a perceptible extent except under conditions of very extreme cold, i.e. below −15°C.

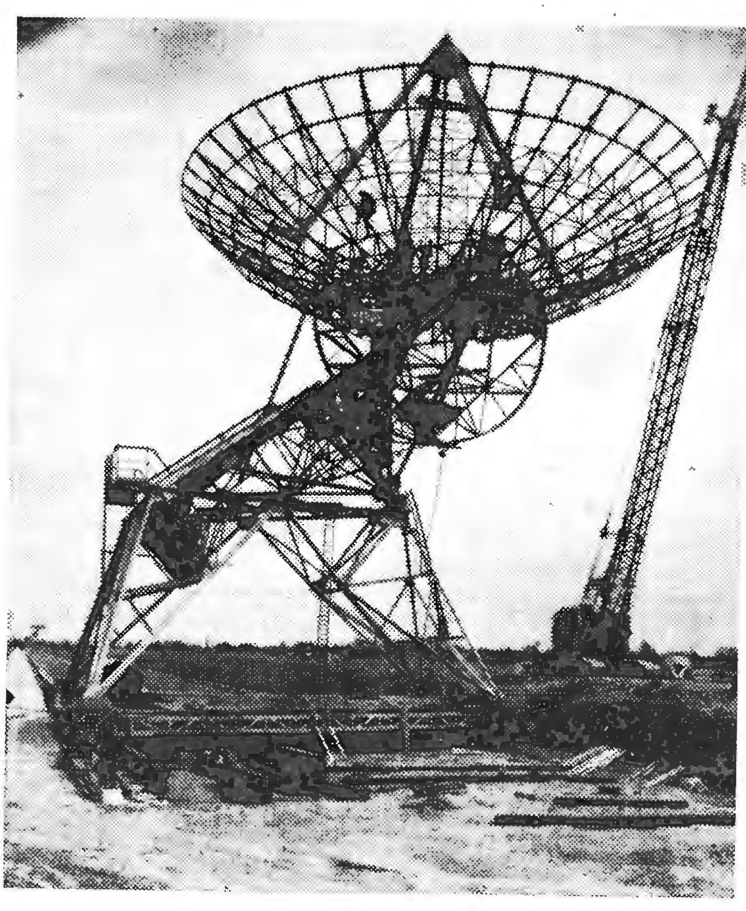
Oddly enough a ceramic magnet gives its maximum performance at normal room temperature. As it is heated above this point the gap flux density falls off about 0.1 to 0.15% per degree C but on recooling it returns to the original value.

On cooling from room temperature the performance also falls at about the same rate but, in this case, if the temperature drops below −15°C the change becomes irreversable and the magnet does not fully recover on rewarming. This effect is reduced by ensuring that the magnet is operating below the optimum working value of H. For magnets likely to be exposed to extreme cold, therefore, the thickness of the magnet ring should be increased beyond that which would normally be used.

Acknowledgements: The author would like to express his thanks to Mullard Limited for permission to publish the information regarding Magnadur 2 magnet rings and to Swift Levick and Sons Limited for permission to publish the information regarding Feroba II magnet rings.

CAMBRIDGE RADIO TELESCOPE

CONSTRUCTION of the new radio telescope for Cambridge University, which was started in April last year, is nearing completion and is now expected to be finished this autumn. The Ministry of Public Building and Works is constructing this radio telescope at the Mullard Radio Astronomy Observatory at Lords Bridge, Cambridge, at a cost of £450,000. This has been undertaken to enable Professor Martin Ryle and his colleagues at Cambridge University to continue their studies of the structure of the universe. The work of Professor Ryle and his colleagues attracted considerable public interest when it was announced that the results of radio astronomy experiments supported the "big bang" theory of creation of the universe as distinct from the theory of continuous creation.



Apart from the controversial aspects of Professor Ryle's radio astronomy experiments, his name has been linked with a new approach to the problem of constructing large radio telescopes capable of probing millions of light-years away into the universe. The method he has developed, and is to be used in the new radio telescope, is based on the use of two or more aerial elements, whose relative positions may be changed. Observations are made with the aerials in different positions and the results are subsequently combined in a computer at Cambridge University, to provide a radio map of the sky. This method is called aperture synthesis, and has been used in the two large radio telescopes at the Mullard Observatory for the past six years.

The new telescope, which has three paraboloids—one of which moves on rails—will operate in a similar way: the signals from the three dishes will be recorded with the movable dish set in a number of different positions along the half-mile rail track. Then the recordings will be combined, resulting in a map of the sky equivalent to that which would be provided by a radio telescope with a dish of about a mile diameter. Each dish can be steered and used as an individual radio telescope, but normally all three will be controlled in unison from the central control building under the middle dish.

Each parabolic aerial weighs 118 tons and is constructed mainly of galvanized steel sections with an aluminium mesh reflector. The mobile aerial travels along 2,500 feet of 44-ft gauge railway track and is driven through a hydraulic transmission system to give it speeds infinitely variable from zero to one mile per hour. When in motion the carriage travels on eight two-wheeled bogies, but during operation machined pads are lowered to settle on to the rail surface. Once in position, hydraulically operated clamps grip the rail head.

The receivers to be mounted at the focus of the three reflectors will be constructed by Cambridge University, who will also make the main receivers and data recording equipment to match the characteristics of the university computer.

RADIO AND ELECTRONIC COMPONENT EXHIBITION

Reviewed by "Wireless World" staff

As far as the basic components of the radio and electronics industry are concerned the 1963 exhibition could be regarded as indicating that the manufacturers were stabilizing their products. That is to say, rather than introducing new types, gaps in existing ranges of components were filled in. If any trends were obvious these were, as expected, in the fields of miniaturization, integrated circuitry and film components.

Resistors:—Apart from refinements in the now conventional composition and wirewound fixed resistors, the newer metal-film types of the Electrosil, Alma, Plessey, Welwyn and Morganite ranges were of interest. This class of resistor probably represents the best available from the standpoint of reliability. All metal-film resistors exhibit very low noise and the shelf life is claimed to be comparable with that of the best precision wire-wound resistors. Perhaps the most significant property of metal-film resistors is their exceptionally high stability. The manufacturing technique varies from producer to producer. The Welwyn resistors are based on a nickel alloy resistance element deposited on a ceramic substrate. The desired resistance value is then obtained by grinding a helical groove through the film at a specific pitch. The ceramic body and its resistive coating is then protected by an epoxy resin moulding.

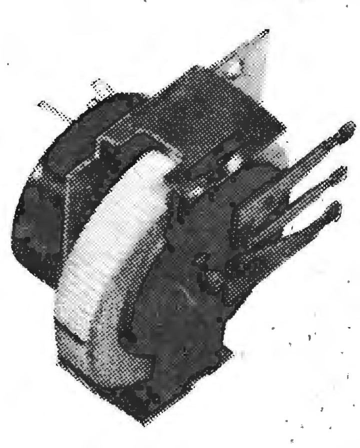
Variable resistors and potentiometers that caught the eye were the miniature carbon potentiometers of the Morganite Resistor Company (these were only 22mm in diameter and had twin-pronged wipers claimed to reduce considerably rotational noise), the plastic-spindled miniature potentiometers of East Grinstead Electronic Components and the edge-operated variety of Egen Electric. This latter type, the 430, is intended for record players and tape recorders and incorporates an "on/off" switch as well as tags suitable for conventional wiring and printed circuit techniques. Mechanical designers faced with the problem of fitting presets where they can easily be adjusted will find their problems eased with the introduction, by A.B. Metals, of a new series of potentiometers that can be adjusted by a finger or, by a screwdriver, from both ends. Of the wide range of resistors, fixed and variable, shown on the Plessey stand, a subminiature edge-operated potentiometer, $\frac{5}{16}$in diameter designed for use in hearing aids, attracted much attention. This new type has a moulded track resistive element claimed to give noise-free operation and negligible wear.

Capacitors:—Developments significant in the capacitor industry as a whole were confined mainly to making the components smaller for a given capacitance and working voltage, and the use of new materials. A number of companies introduced tantalum fixed capacitors. The advantages of tantalum capacitors are the extremely low electrical leakage current, high capacitance per unit volume and an exceptional stability over a wide temperature range. A new range of miniature multiplate ceramic film capacitors known as "Caspak" were introduced by Plessey. Four capacitance values are available 0.002μF, 0.047μF, 0.1μF and 0.22μF (all 75V d.c. wkg.). Their low inductance and freedom from "self-healing" properties (which result in random pulse generation) is claimed to make them particularly suitable for use in digital circuits. Both E.M.I. and T.M.C. introduced tubular capacitors using metallized polythene terephthalate. The advantages claimed for this type of dielectric medium include exceptionally high insulation resistance and stable capacitance. Suflex, well known for their plastic film capacitors, exhibited a new 30V range of polystyrene capacitors. These showed a useful reduction in size over those currently available.

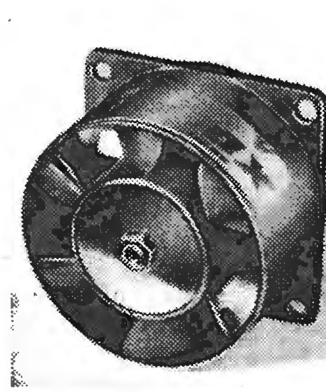
Examination of the various displays of variable capacitors showed a distinct reduction in size of these components since the last exhibition was held.

Chokes and Transformers:—Ardente showed their range of miniature transformers. These were constructed to make them eminently suitable for printed circuitry. The Belclere Company also had a comprehensive range of windings and included a transformer design kit enabling a designer to build a number of prototype components before placing a quantity order. Hinchley introduced a series of portable isolating transformers and their increased range of windings suitable for printed circuits included transformers and chokes using metric lamination sizes more generally used in other European countries.

Parmeko showed for the first time their new range of constant-voltage transformers. These are designed to supply a specified output voltage which remains constant to within $\pm 1\%$ for a wide variation of input voltage. As well as displaying mains and output transformers for well-known thermionic audio circuits, Par-



Egen Type 430 edge-operated carbon potentiometer.



Airmax axial-flow blower, claimed to be the world's smallest, moving about 5cu ft/min at 1,000 r.p.m. Power supply is 26V, 400c/s, 3-phase.

tridge exhibited transformers wound specifically for use with transistor circuitry.

Materials:—The introduction by Mullard of their new transducer material "Piezoxide" attracted considerable interest. This is a ceramic piezoelectric material based on lead zirconate-titanate with additives to give a range of electro-mechanical properties. The substance can be pressed into a variety of shapes. At present four grades are available for applications ranging from sensing heads and acceleration gauges to ultrasonic transducers. A demonstration showed a slab of "Piezoxide" which, when subjected to pressure from a lever operated by a rotary cam, fired a conventional sparking plug. The material is claimed to have great mechanical strength and is impervious to moisture.

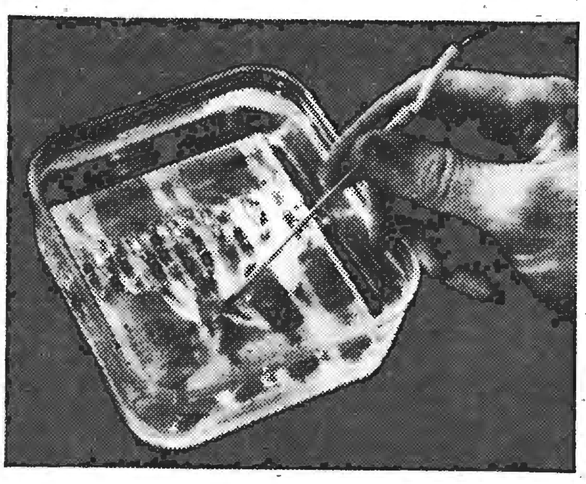
With the increasing use of potting techniques in electronic circuitry have come some new developments. On the Midland Silicones stand some interesting non-rigid encapsulating materials were shown. The DP2603 self-healing dielectric gel is supplied as a fluid. This, after addition of a catalyst and curing at a low temperature, develops into a soft gel. It thus forms a protective cushion around circuit components. The gel is claimed to have excellent dielectric properties, low water absorption and a good heat resistance. Because the gel does not get into a hard state, probes can be inserted for circuit testing and faulty components can be replaced. Another compound, MS potting material DP2608, after setting is a transparent, flexible resin suitable for protecting components from vibration and shock, as with the former compound all the components are visible.

In many cases the protection of a whole circuit by resin encapsulation is impracticable but protection of individual components within the circuit may be considered desirable. This can now be achieved without resort to outlay on special plant, mixing of chemicals or the use of moulding equipment. CIBA (A.R.L.) the manufacturers of "Araldite" make this possible with the introduction of "E-Pak". This consists of cases (supplied in different shapes, sizes and colours) and preformed pellets of "Araldite" epoxy resin, appropriate in shape and size to the component to be protected. The pellets are dry and non-toxic. Under the influence of heat they melt, fill the moulded cases containing the components to be protected and then set to form a high-strength solid.

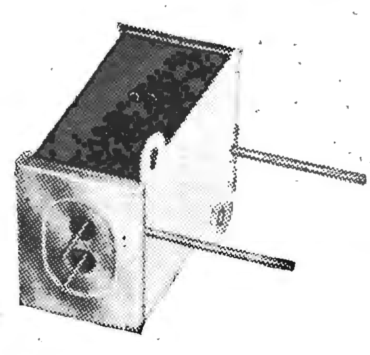
In the realm of laminated materials, rods and tubing, Bakelite introduced a number of new products. Of these, a styrene/butadiene rubber-surfaced material can be used very effectively for capacitor sealing discs. In the same field, the glass/epoxy, copper clad grade CGE 70 Formica material was shown. The features of this new grade are its retention of mechanical properties at elevated temperatures and low dielectric loss characteristics. Vero Electronics announced that "Veroboard" can now be supplied in a double-sided version and demonstrated samples. They also introduced their 0.1in pitch "Veroboard" which has been developed to cater for high component densities using miniature components.

Turning from sheet materials to wires and cables, new ground was broken by B.I.C.C. when they demonstrated their new miniature 75Ω coaxial cable. This had a polythene outer sheath and a polypropylene dielectric. It is available in both single and double braided versions. The same company took advantage of the show to introduce their new miniature connecting wires, with 0.005in p.v.c. insulation. Strand sizes are offered as 7/.0024 or 7/.0036in. Connollys demonstrated their improved "Conterex" enamelled wire. The new variety is claimed to have a superior resistance to heat-shock, longer thermal life, improved solvent resistance and an increased resistance to abrasion. The improvements have been effected by the use of polyester enamelled wires, jacketed with a linear polymer.

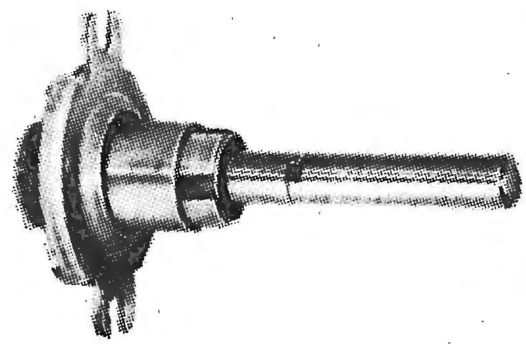
Relays:—Could be seen in great profusion over the exhibition hall. As in many other fields the tendency was to miniaturization or to handling greater currents than previously with the same size component. Diamond H introduced a new time-delay relay which can be delayed up to 15 minutes or when ordered especially, up to 25 minutes. The device makes use of a cold-cathode tube and a printed circuit board. Gaining in popularity is the relay which can be plugged into an international octal base. Examples of this type could be seen on the Arrow stand. The 10 amp Type H relay of NSF is a miniature hermetically sealed relay. This relay is believed to occupy less space than any other 4-pole changeover rotary-type relay of similar rating. The cases are hermetically sealed after filling with an inert gas at a pressure five pounds above atmospheric pressure. This technique prevents corrosion and ensures optimum contact performance throughout the working life. A new relay on the stand of G.E.C. differed from other types by the same manufacturer in that the armature operated a sub-miniature micro-switch instead of springsets. The operating point of the armature can be set by an adjustable bias spring. Micro-switches give the relay the advantages of a snap-action electrical switch, completely enclosed contacts and facilities for obtaining closer operate, non-operate, hold and release current figures. ERG introduced a new miniature reed relay type AB1434. Features of this type include a very fast operate time, low current consumption, magnetic screening of the coil to eliminate undesirable effects due to interaction with other relays, and the ease of in-



Left: Circuitry encapsulated in Midland Silicones gel Type DP2603



Above: ERG reed relay Type AB1434.



Left: Jackson dual-ratio reduction drive.

Enthoven "Miniscope" soldering iron using a 2.5 to 6V supply. The heating time is five seconds, the iron is switched on by depressing the lever.

terchangeability of the hermetically sealed reed switches.

A relay with no moving parts and, therefore, no contact bounce, was shown by Mullard. A 24V, 60mA lamp is arranged to illuminate four pieces of cadmium sulphide photoconductor. When the lamp is lit, the resistance of the photocells falls from over 10 MΩ to 15Ω. Each cell can dissipate 150 mW and can handle 140 V a.c. or 200 V d.c. At this stage it would not be amiss to mention the relay servicing tools shown by Spear Engineering. The whole set comprises contact adjusters of various shapes and sizes, a spring removal hook and a contact burnishing tool.

Switches:—Originally developed for broadcasting and studio work, the E.M.I. PSI push-button switch is now made available for general use. Up to 14 assemblies are contained in a frame, each consisting of up to 12 changeover contacts. The buttons are illuminated, and can be arranged to interlock, the action of each button in relation to any other being either "gapping" or "lapping." Contacts are either make-before-break or *vice versa,* and are of 30W rating.

Glassware:—To eliminate the sudden and expensive results of arcs and voltage breakdowns in large pieces of equipment such as transmitters, Marconi-Osram have introduced the E3020 surge diverter. This consists of a cold-cathode trigger tube which will operate on an anode voltage of 500V, although withstanding 6kV. The tube will pass 2000A peak and strikes with 2.5kV on the trigger electrode. In use, a transformer is connected with its primary in the supply line to the protected load. If the current through the load rises rapidly due to a flash, the transformer secondary triggers the tube, which discharges the power supply capacitance and operates a relay in its cathode circuit, disconnecting the supply.

A double-triode shown by Brimar is intended for pre-amplifier input and similar low-noise applications. The amplification factor is claimed to be the highest in the world at 140.

Mullard had a new range of valves designed for dual-standard television receivers. U.h.f. signal frequencies are taken care of by the PC88 r.f. amplifier triode and the PC86 self-oscillating mixer. High g_m is obtained by the use of frame grids, and an asymmetrical construction gives reduced interelectrode capacitances.

Flywheel control of line timebase oscillators is probably easiest to arrange on dual standard receivers when a sine-wave oscillator is controlled by a reactance valve. The PCF802 triode-pentode is designed for this application and has a high-μ triode so that the tuned circuit is not excessively damped.

An extremely high-sensitivity instrument cathode ray tube shown by Mullard is the D13-22. This is a five-inch tube, and a new mesh p.d.a. system gives, in addition to high deflection sensitivity, low background illumination. The mesh gives a scan which is less p.d.a.-dependent than is usual, and high contrast is obtained by the use of 15kV on the mesh. P.d.a. ratio is 10 and typical *y* sensitivity is 2.9V/cm.

Two magnetrons and an X-band klystron were featured among the new products of Mullard. The Type YJ1030 is a tunable magnetron intended for use in airborne transponder equipments operating at a frequency of approximately 5.65Gc/s. Special features include a low weight of 7oz and rugged construction. Its very low temperature coefficient of 50kc/s per degree C, ensures good frequency stability. With the maximum pulse input of 1.8kV, 0.8A this magnetron gives a pulse power output of 160W. Maximum pulse duration is 3.0μsec at a duty cycle of 0.002. The other new magnetron Type YJ1040 is a 14kW pulsed variety intended for use in high-altitude airborne radar equipments operating in the frequency range 9.345 to 9.405Gc/s. The new Mullard X-band klystron type YK1040 weighs 4oz and operates at frequencies between 9.0 and 9.6Gc/s; coupled cavity tuning is incorporated. A new X-band klystron developed for f.m. systems, the R9687 by E.M.I., has an improved electron gun design which is stated to be completely free from ion oscillation, thus eliminating spurious modulation of the output. This low-power klystron operates in an external resonator and, in suitable cavities, is useful in the frequency range 6,500Mc/s to 12,000Mc/s. The microwave display of Marconi-Osram featured a wide range of travelling wave tubes. The M.O. ophitron, an electrostatically focused backward wave oscillator, was demonstrated. A new magnetron Type M514 was exhibited by the English Electric Valve Company. It was designed for marine radar equipments and has a peak power output of up to 20kW. The manufacturers claim that life test samples achieved more than 5,000 hours operating time with no detectable change in performance.

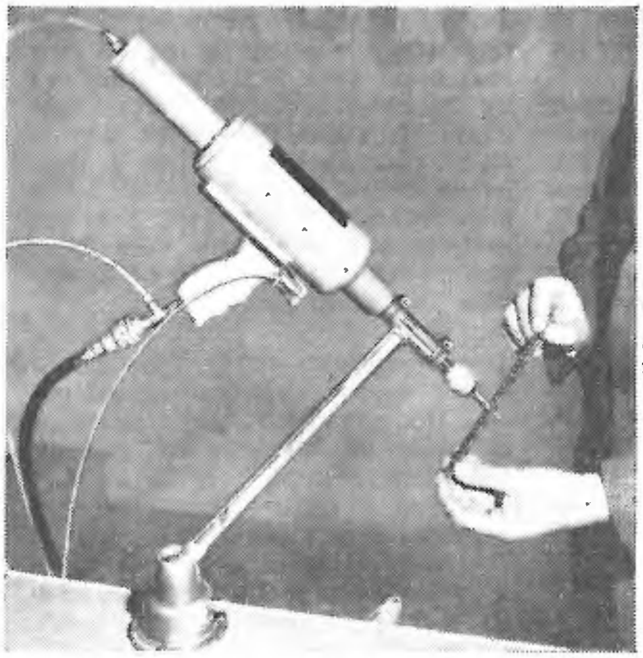
Semiconductors:—The predictable trends towards volume microscopic and frequency astronomic show no indication of flattening off, and the term "microscopic" is in no way stretched to describe many modern devices. Power handling capabilities are resolving their conflict with frequency; the prediction, rather recklessly made in the early 1950's, that transistors would see valves off, sounds much less Wellsian than it used to.

Some of the smallest devices were shown by Mullard, who had a planar n-p-n transistor measuring 0.05-in diameter. This is an experimental unit intended for use in microcircuits, and has a β of between 40 and 120 at 10mA collector current. f_1 is 300Mc/s. S.G.S.-Fairchild had comparable devices, known as Molytabs. These, again, are 0.05-in diameter, and are electrical equivalents of many of the firm's other units. S.T.C. Miniflake transistors are silicon epitaxial devices supplied without cases for thin-film work. Complete circuits in the S.T.C. thin film range include amplifiers and logic networks, and are standardized at 0.5-in square.

Texas Instruments displayed a number of multiple units—diodes and transistors. A typical unit is the 2A5A1 multiple diode, which consists of ten diodes, with "cathodes" taken to 10 lead-out wires, and two groups of five "anodes" to a further two wires. Closely matched forward characteristics are claimed, and the whole unit is contained in a standard JEDEC TO-5 can. A good example of the modern transistor was also given by Texas 2N2864, which is an n-p-n silicon epitaxial planar unit giving 1W as an amplifier at 100 Mc/s.

Further examples of what can be crammed into a TO-5 were on SGS-Fairchild's stand, where dual transistors and mixtures of diodes and transistors were shown. The firm have extended their range of Micrologic integrated circuits with the μLr and μLd shift register and logic elements. The μLd comprises two double input gates with a propagation delay of 40nsec at 3V and can be used as a gate with up to four inputs, an inverter or a flip-flop. Delay is virtually independent of temperature.

High power and frequencies were noted on several stands and a typical example is the Mullard AFY19,



Riveting machine by Chobert (marketed by Avdel), for quick insertion of rivets and solder tags into metal and plastic. Tool is pneumatically operated.

which delivers 0.4W at 180 Mc/s. In TO-5 form, the unit is rated for 32V maximum collector current, and current gain is over 33 at 100mA. f_1 is about 350 Mc/s. Computing diodes by Mullard are well represented by the AAY32 gold-bonded type, which has a 30V p.i.v. rating and a recovered charge of between 20-100 picocoulombs. The experimental planar device possesses a p.i.v. of 50V and a recovered charge of less than 20pC. Both these units are 3.5 mm diameter and 7.6 mm in length.

Ferranti had their new range of silicon integrated circuits which are in two broad classes—linear and digital. A typical "Microlin" circuit consists of a two-transistor complementary linear amplifier made on two silicon chips. The p-n-p transistor is on one chip, and the n-p-n device and five resistors on the other. With a voltage gain of 16, the response is -3dB at about 1Mc/s. Input impedance is about 1 kΩ and output impedance 30Ω. The whole amplifier is in an 8-lead TO-5 case shortened to 0.18 in. The "Micronor" logic elements consist of up to nine transistors or diodes and four resistors in a shortened TO-5.

A.E.I. showed a range of passivated planar epitaxial transistors, particularly fast switching types. Passivation consists of the use of an oxide coating over the junctions, which gives complete protection against ambient gases. Exceptional stability is obtained, and higher breakdown voltages, lower saturation voltages and lower capacitance are among the advantages of the technique.

The limitation of semiconductor rectifiers for power work is the extreme sensitivity to transient overvoltages in the reverse direction. Formerly, attempts have been made to increase the reverse turnover voltage, and it has even been necessary to protect the temperamental silicon with the selenium that it is supposed to supplant. Three firms have introduced rectifiers which do not suffer from high dissipation in the reverse direction and which will operate happily in the avalanche region. A.E.I., S.T.C. and Lucas (G. & E. Bradley) showed examples. A.E.I. had a 1200V p.i.v., 10A silicon device, the SLZ1203A, S.T.C. their R.A.S. 300 1.25A series and Lucas a 400V, 10A unit. A further advantage of the avalanche rectifier is that the rapid current increase at the avalanche point gives a voltage limiting action, which means that a series combination of units needs no voltage dividing resistor chain.

Semiconductors that do not seem to fit tidily into neat categories are E.M.C.'s Quantrol and the Hughes current regulator. The Quantrol is a two-wire device that acts as an a.c. switch. Several megohms are in circuit until the volts across the unit reach the "threshold" voltage, which lies between 20 and 200V. The Quantrol then breaks down in some way and becomes a short circuit. Turn-off is by injecting a direct-current pulse into the unit. This description is, we know, rather vague, but information on the Quantrol is not readily forthcoming.

The Hughes current regulator is also a two-lead unit which exhibits a characteristic something like the output curve of a pentode. Current ranges of 100 μA to 200 mA are obtained at a tolerance of $\pm 5\%$. Between 10V and 40V, current regulation is better than $\pm 1\%$.

An infra-red producing diode was shown by Texas. When the junction is forward-biased, infra-red radiation at a wavelength of 0.897μ is emitted, the power of which increases linearly with current greater than a few milliamps. Modulation frequencies up to 100 Mc/s are usable, and operation is possible over a temperature range of -195°C to 125°C. The unit is housed in a TO-18 case, and it is intended for use in short range communications.

Audio:—Exhibits that could fall under the heading of audio were mainly confined to the transducer field, though many well established turntables, tape recorders and motors were in evidence. Greencoat Industries displayed a new three-speed battery-powered record player Type KT9. On the same stand the exceptional stability of their d.c. motors was demonstrated. Cosmocord had a number of new items on show; the RE6 Acos earphone supplied complete with ear clip, ear plug and miniature or subminiature jack plug was designed for use with transistor radios. The Acos Mic 39 was introduced, this has a dynamic insert and has high and low impedance matching outputs. The frequency response of this microphone extends from 80 to 10,000 c/s $\pm$3dB. The Goldring Manufacturing Company demonstrated a new stereo cartridge the Type CS90. A ceramic cartridge, it uses a diamond replaceable stylus with a 0.0005in tip. The frequency response extends from 30 to 18,000 c/s.

A record changer Model UA15 by B.S.R. measured only 4$\frac{5}{8}$in in height from the top of the motor board. The unit has a four-speed turntable and can be supplied for all mains voltages, 50 or 60 c/s, or for 9V battery operation. Other new products on this stand included a ceramic cartridge Type C1 and a "Gardisk" retractable cradle. This device ensures that if the pickup arm is accidentally pushed across the record, the stylus retracts, thus minimizing damage to the record.

In the loudspeaker division of the audio industry, a greater range in sizes of speakers was available and it was also noted that more ceramic magnets were being used. The public address side of Goodmans Industries introduced a new 100W speech loudspeaker. The overall dimensions of this Type PA100 loudspeaker were approximately 2ft 6in $\times$ 9in $\times$ 3$\frac{1}{2}$in. Reslosound included in their new products a 4ft model LS.100A and a 6ft model 6LS line source loudspeakers, intended primarily for sound reinforcement and music relay installations.

Aerial Accessories:—As was expected the main developments in this sphere were concerned with u.h.f. television reception. A new coaxial cable based on the "Aeraxial" range of Aerialite is designed to reduce signal loss from aerial to television set. Designated the Cat.500 coaxial cable, it is constructed with a single 0.056in copper conductor surrounded by a 5-cell air space polythene dielectric. The outer braid is constructed from 0.006in copper braid and this is covered with the familiar brown p.v.c. The total diameter is 0.312in as opposed to the usual 0.275. A 75Ω cable, it has a capacitance of 16.5pF per ft and at 850Mc/s the attenuation is given as 5.4dB per 100ft. Antiference of Aylesbury, to reduce matching losses on their u.h.f. aerials, include a balun which is incorporated in the cable junction unit. The praiseworthy feature of this is that the downlead can be fitted to the balun/junction unit on the ground so that once the aerial itself has been sited the cabled unit can then be fixed to the aerial with the minimum of work.

A handy accessory, this time for the "steam" radio manufacturer, was exhibited by Ariel. This was an aerial switch socket, which when fitted to a transistor radio allows a car aerial to be plugged into the set at the same time disconnecting the built-in ferrite rod aerial. Returning to television reception and the problem of greater attenuation with increase in frequency, Arrell demonstrated a new head amplifier which is intended to be built in the insulator of the driven element, thereby dispensing with the need of any conductor from the element to the amplifier. Power supplies for the unit are fed via the feeder cable.

Thoughtfulness towards the erection engineer is further portrayed by the detachable cable junction box of Belling and Lee. Here the cable is attached to the lower half of the box on the ground, this section can then be attached to the aerial without tools, after the aerial has been fixed. Visits to the J-Beam and Telerection demonstrations showed the accent to be on aerial protection. Domestic aerials of the latter firm were shown cocooned in polythene. Professional aerials of J-Beam were shown with protection materials of polythene and glass fibre.

Instruments:—The traditional methods of aerial installation, i.e., a muttered prayer and a wet finger, will be finally abandoned when u.h.f. aerials begin to sprout from the rooftops, and to take the place of the m.p. and w.f. Belling-Lee have brought out their U.H.F. Signal Strength Meter L.1585. This is essentially a tunable valve voltmeter, and covers 100μV to 10mV on a logarithmic scale. The input circuit is tunable from 470 to 860 Mc/s (channels 21 to 68) and bandwidth is 1 Mc/s. A stabilized reference oscillator works at mid-band to maintain calibration accuracy.

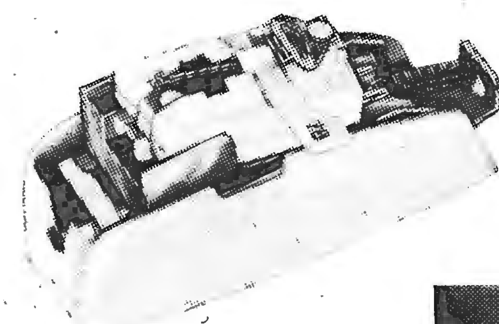
A very sensitive d.c. valve voltmeter shown by Dawe, the Type 611A, has a full-scale deflection of 300μV on its most sensitive range, and an overload capacity of 1.5kV on this range. Ranges are 300μV to 1000V f.s.d. and on the 10mV to 1000V ranges the input impedance is 100MΩ dropping to 10MΩ for 300μV. The accuracy is ±3% over most of the range, this being achieved by the use of a chopper a.c. amplifier/detector technique with a negative feedback amplifier. 50c/s rejection is provided and the amplifier output is brought to the front panel.

G. & E. Bradley were showing their Electronic Multimeter CT471B, a transistor current and voltage meter for a.c. and d.c. measurements. Alternating and direct voltage from 12mV f.s.d. alternating and direct current from 12μA, together with resistance to 1000MΩ are the main functions, while a.c. probes give a response from 10kc/s to 1500Mc/s (2dB down). The instrument is operated by two 1.5V cells.

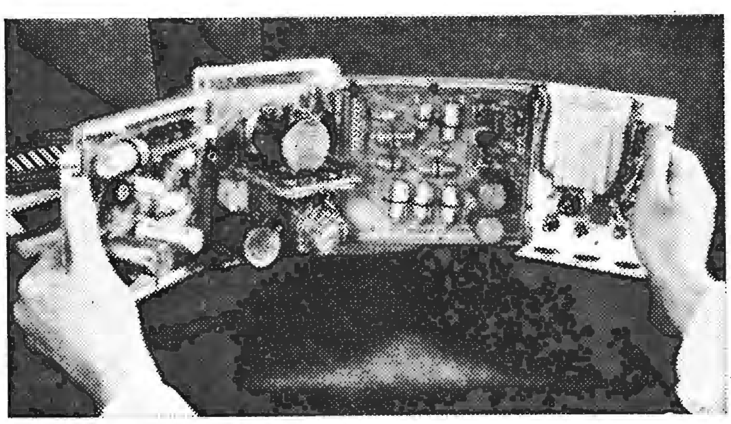
A complete audio and middle range signal source, with monitored attenuators, is provided by Marconi Instruments' new "2000" range of modular units. The "prime movers" are the TF2100 a.f. oscillator and the TF2101 m.f. oscillator which cover 20c/s-20kc/s at 0.5% distortion and 30c/s-550kc/s at 0.5% respectively, and provide 4V and 1V into 600Ω unbalanced. Three types of attenuator are available, two of them monitored, and all the instruments can be used separately or in a side-by-side mounting case.

A new transistor oscilloscope was shown by Marconi Instruments, the TF2202 double beam unit. Two identical y amplifiers are provided, giving a bandwith of 0-6Mc/s with 100mV/division sensitivity, each division being 0.8cm. Built-in preamplifiers can be switched in to increase sensitivity by a factor of 10 or 100 with bandwidths of 0-500kc/s or 20c/s-200kc/s. 350nsec y delay is included, and calibration is by a standard waveform. Timebase delay is variable up to 20nsec after the trigger pulse and the sweep covers 5μsec to 5sec. An internal inverter allows operation from a 24V supply as an alternative to the mains.

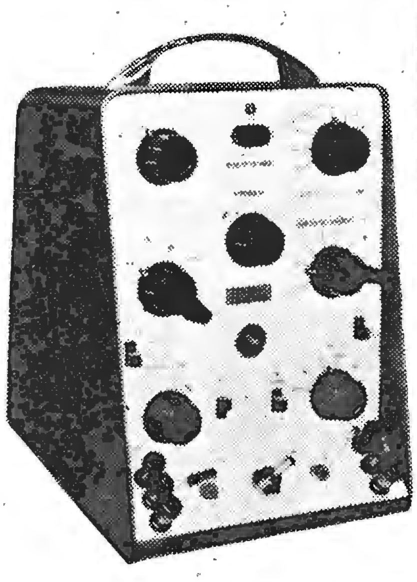
A new double-beam instrument was also on the Telequipment stand, using a double-gun tube. The D43 employs plug-in y amplifiers to ful-



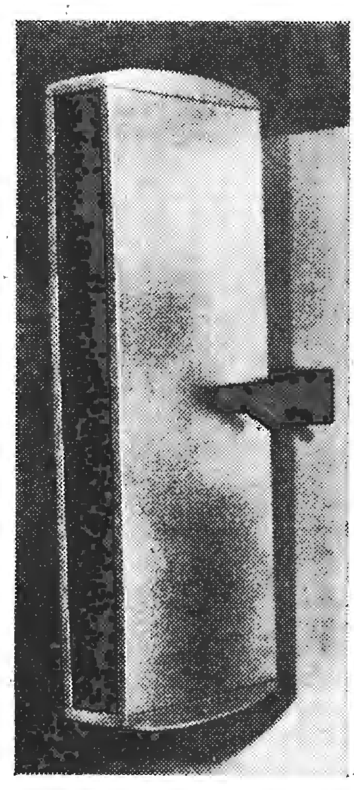
BSR retractable cradle fitted with the CI ceramic cartridge.



Marconi Instruments a.f. oscillator opened for servicing. Instrument still works in this form.



Left: Elliott curve-tracer for transistors, diodes, etc. Families of up to eight curves can be displayed.



Right: Goodmans 100W public address loudspeaker.

fil wide-band, differential and high-gain functions, the maximum banwidth being 0-15Mc/s at 100mV/cm. Maximum sensitivity is 100μV/cm from 3c/s to 75kc/s and as the tube is fitted with an anode modulator, directly-coupled flyback blanking is simply arranged.

For engineers or lecturers already in possession of an oscilloscope, Elliott have produced a curve tracer to display the characteristics, in families of curves or singly, of most types of semiconductors. The 50c/s mains waveform is half-wave rectified and used to provide the collector voltage, the dissipation during this time being low enough to allow the display of avalanche behaviour. Peak voltage and current are 150V and 1A, and output impedance is low enough to display tunnel diode curves.

The laser appear to be escaping from the physics laboratory into industry, one of the first to emerge being the G. & E. Bradley Type 330. Either ruby or neodymium-doped glass elements can be used, and a 10MW peak pulse power is obtained by the use of a "Q-spoiler" to concentrate energy into one long pulse instead of a succession of shorter ones. The maximum p.r.f. is 120 pulses per hour, depending on cooling arrangements, and the pulse length with Q-spoiler is between 0.1μsec and 10μsec. The nonchalance with which a hole was punched in a razor blade in about a millisecond gave one furiously to think.

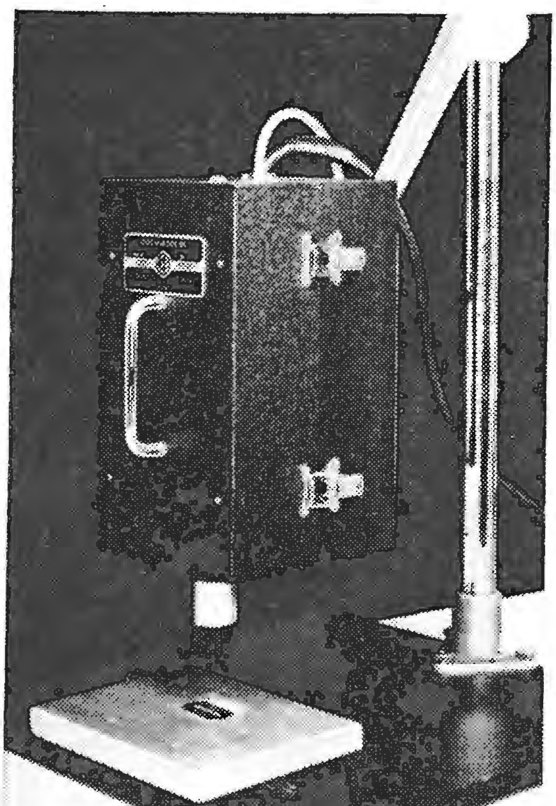
Miniaturization:—Several firms were displaying thin-film networks and assemblies, which now appear to be a commercial proposition. These were of fairly standard form, using borosilicate glass for the substrate, although Welwyn Electric use high-alumina ceramic, claiming better adhesion of the metal films and better thermal conductivity, which eliminates hot spots. Resistors are formed of nickel-chromium alloy to give about 50kΩ maximum on a reasonable area of substrate. Capacitors up to about 10,000 pF/square centimetre can be made by the deposition of successive layers of aluminium, silicon monoxide and aluminium. Working voltage varies between 6V and 100V, depending on capacitance per unit area. Inductors are not often used, and if larger than a few microhenries are made separate wound components. Conductors are of gold (Mullard) chromium-gold alloy (S.T.C.) copper (Welwyn) or aluminium (Morganite), and transistors can be either of ordinary construction or special miniature varieties such as the Mullard ones and the S.T.C. Miniflakes, which can be set into holes drilled in the substrate.

Although not in the same class as thin-film circuitory, the S.T.C. Ministac modulator construction is intended to achieve a similar end, i.e., reduction in volume. Two plastic side mouldings carry a wiring pattern which is cut from standard punched nickel-silver strips. Solder-tags carry components between the two sides, and the wiring pattern makes contact with terminals on two end plates. The complete assembly can be potted for protection.

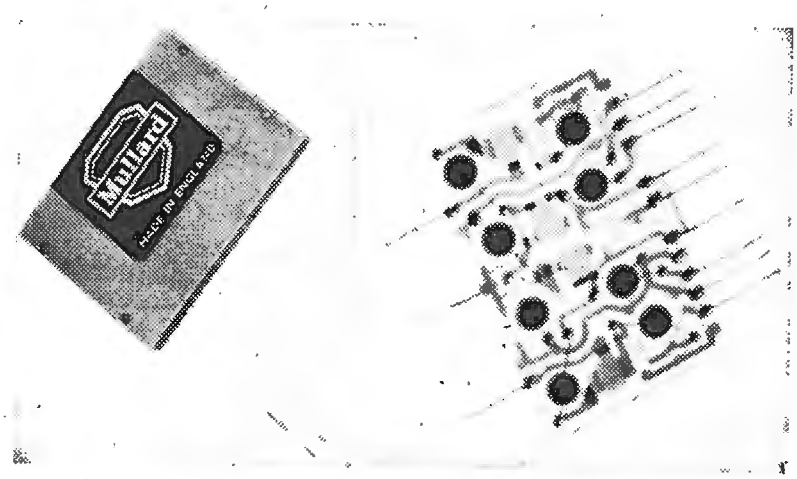
Metalwork:—A new range of sectional chassis were announced by Imhof, known as the Imkit. Standard 19-in panels are used, in depths from 5¼in to 12¼in, and 18 sizes of side frame and eight chassis sizes are produced. The chassis can be mounted horizontally or vertically, or even both in the same unit, and two kinds of rear beam can be supplied to accommodate a variety of plugs and sockets. Nylon rollers are fitted in the chassis.

The standard range of Widney-Dorlec cabinet components are extended by the introduction of a new type with "square" edge and corner fittings. They can be used with the standard parts when stacking is required, or simply for neatness of appearance.

A flexible set of parts for building screened rooms in a variety of sizes is marketed by Belling and Lee. Interchangeable metal units are used, with provision for doors, screened windows, services and lino-tiled floors. The windows are of honeycomb construction and all joints use r.f. mesh gaskets, with the result that attenuation to outside fields, both electric and magnetic, is about 100dB from 1Mc/s to 1000Mc/s. The attenuation to magnetic fields, difficult to provide at low frequencies, is still 60dB at 10kc/s.

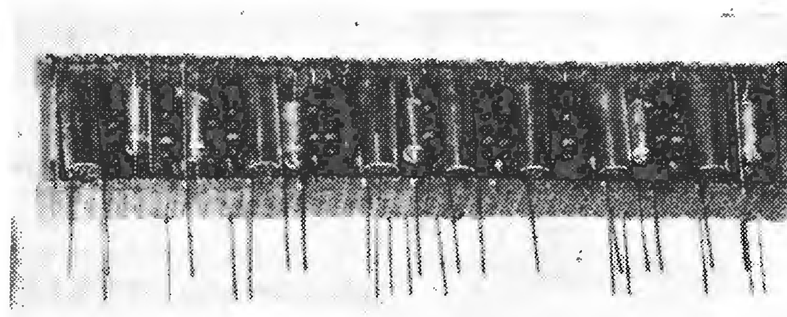


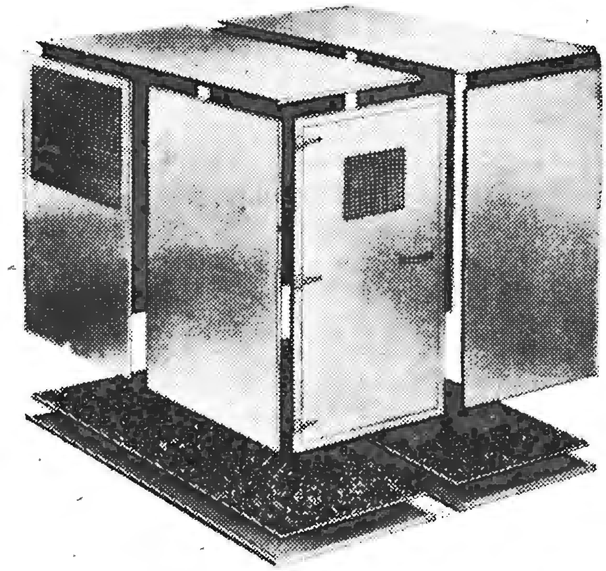
Bradley industrial laser, showing the razor blade being perforated.



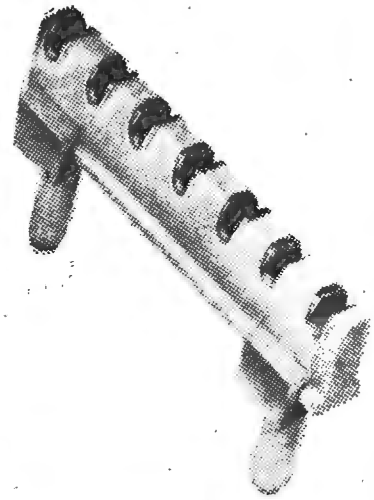
Mullard thin-film circuit. Finished appearance shown on left.

Ministac component wiring module by S.T.C.

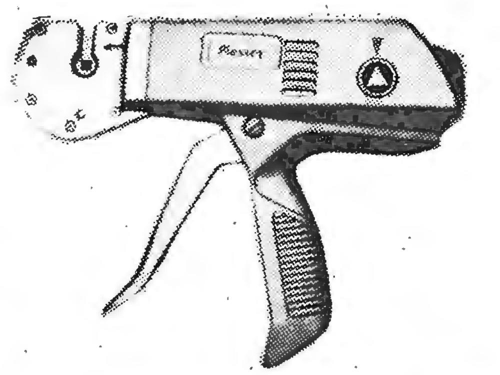




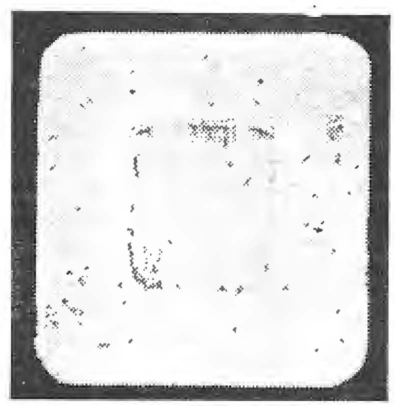
Sectional screened room from Belling and Lee.

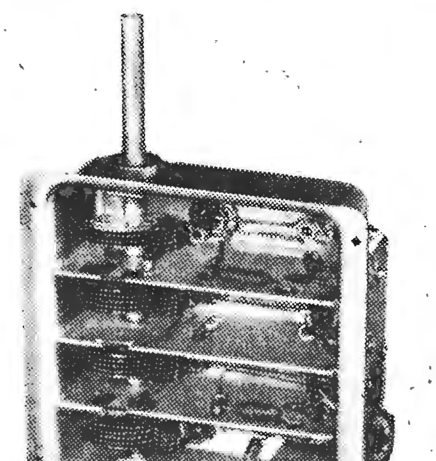


Plessey ceramic terminal strip with nickel soldering surfaces.



Above: Plessey universal crimping tool. Below: Cross-section of finished joint shows wires cold-welded into solid mass





Cyldon u.h.f. transistor tuner for Bands IV and V, using Texas GMO290 transistors.

Chassis fittings:—Ceramic terminal strips from Plessey have been improved by the substitution of nickel for the usual silver-plated soldering areas. Trouble has previously been experienced due to migration of the silver, making soldering difficult. The new strips are mounted by separate nylon or metal feet.

Metal chassis and dip-soldering seem hardly compatible, but Sealectro have now introduced the Cloverleaf chassis receptacle, which holds the leads of up to four wire-ended components in a Teflon bush. Component leads are pushed into these bushes, together with additional central pins, if required, and capillary action is employed to allow dip-soldering. The bush is a press-fit in the chassis.

One has seen the insertion of metal bushes and terminals into plastic and even metal sheets, but until now, holes have been required for relatively soft materials fitted to metal. J & S engineers have introduced their Jasflo process which is capable, at its most impressive, of inserting in a 1-in diameter Perspex window into a $\frac{1}{8}$-in mild steel plate by means of a punch. Nylon bushes are fairly run-of-the-mill to this machine, "spread" of the soft material being avoided by the use of a hollow cylinder to contain it during the punching operation.

Heat sinks for semiconductor devices have taken many different forms, the latest being made by Alexander Orba and shown by Vero Electronics. It consists of a slab of aluminium honeycomb with aluminium block embedded in it to take the semiconductor. The honeycomb can be tailored to fit a convenient piece of chassis space.

Crimped contacts for wire terminations are held to be time-saving and reliable, but if a number of contacts of different sizes are to be attached the first of these advantages tends to be reduced. Accordingly, Plessey have designed a crimping tool which is truly universal, in that it will deal with a large variety of contact sizes with no other accessories. The aperture is a "diminishing square," which grips the contact, and pressure is built up by a few squeezes of a trigger. The pressure is self-setting, and as soon as the crimp is completed, the jaws release and operate a counter to record the number of operations.

Assemblies:—Several new Cyldon v.h.f. and u.h.f. television tuners were on the Sydney S. Bird stand, one of them being a transistorized unit. A common-base r.f. amplifier and common-base self-oscillating mixer are used to give coverage on the band 470-854 Mc/s. A three lecher-line input circuit is used to match 50Ω into the base of the r.f. amplifier. The band-pass filter is continuously tuned for a bandwith of 5-7 Mc/s over the range, coupling between primary and secondary being via slots in the screening partition. Power gain, on the average, is 15 dB, with an average noise level of less than 10 dB. I.f. and second channel rejection are at least 50 dB and 55 dB respectively.

For those applications where a standard cell cannot be used because of its low voltage and negligible current, International Electronics have designed a reference power unit, using transistors. In its standard form the modular unit ($6\frac{3}{4}\times4\frac{1}{4}\times$14in) provides a 100V, 100mA output with an output resistance of less than 100mΩ. Stability with input variation is 7,500:1 for $\pm10\%$ and the temperature coefficient is 0.0004% per degree centigrade. Setting accuracy over ±5V of nominal is better than 1mV.

Meters:—Moving-coil indicators in new styles by Taylor and by Sifam are designed with the same philosophy in mind and coincidentally bear the same name "Clarity." The Taylor range have square, transparent cases, the clear plastic material, avoiding shadows. The most sensitive movements are 10μA, and self-contained direct and alternating voltage and current indicators are made. Sifam meters are roughly similar, advantage being taken of the case shape to obtain large scale lengths. The most sensitive movement is 25μA. Scale markings are to the new British Standard recommendations, and a fairly thick pointer with a sharp tip is used to provide readability at a distance combined with accuracy at short range.

I.E.E. CONVENTION ON H.F. COMMUNICATION

THAT the h.f. band should have ever-increasing demands made upon it, and that in fact renewed interest has built up in it, could not have been prophesied a few years ago. Yet this was one of the main conclusions which stemmed from this Convention, held from 25th to 27th March, at which 53 papers were presented, and, in the associated Exhibition, a large number of new developments were assembled and demonstrated.

For a considerable time to come it is likely that maximum utilization of the h.f. band (3-30 Mc/s approx.) will be sought because the properties of the ionosphere make possible long-range communication round the world with a relatively low transmitted power. This has special application for "mobile" radio services but the propagation characteristics of the ionosphere have also been fully exploited for point-to-point communication links. The price to be paid for these advantages lies in the possibility of disturbance in the propagation medium causing interruption to the links. There are two ways in which interruption can be caused—either by a "sudden ionospheric disturbance" (s.i.d.) or by an "ionospheric storm." These phenomena and the long-term effects due to sunspot activity and to the fluctuations in the earth's magnetic field have been the subject of investigation for many years. As a result it has been possible to set up a prediction service for the United Kingdom radio links on the h.f. band.

Apart from the short-term interruptions, a general pattern is known to exist for h.f. ionospheric propagation in which stable conditions can be expected during the day- and night-time hours, with deterioration during the transition periods of sunrise and sunset. Also improvement takes place with increased sunspot activity in that the extent of the available frequencies lying between the m.u.f. (maximum usable frequency) and l.u.f. (lowest usable frequency) is at a maximum. In contrast, however, the incidence of s.i.ds. is greatest when sunspot activity is at its highest, resulting in loss of circuit time during the hours of daylight. (It has been established that s.i.ds. occur only when the radio path lies on the sunlit side of the earth.)

Thus it will be appreciated that long-term predictions do not always give the most accurate forecast for the optimum working frequency when propagation conditions are fluctuating violently. An alternative which suggests itself is to make measurements over the radio path to be used, preferably for the whole gamut of the frequencies which have been allocated to the link. Such a method is afforded by "ionospheric sounding", which has been in use for some years as one of the sources of data on the behaviour of the ionosphere as a radio propagation medium. In dealing with "synchronized oblique ionosphere sounding," Dr. R. D. Egan, of Granger Associates, Palo Alto, described equipment and techniques which have been employed under service conditions for sounder frequency control for communication links.

The basis of the method is to transmit pulses over the communication path for which immediate propagation data is required and to display on an "ionogram" the percentage distortion at the receiving end for the whole frequency band. To achieve this the band is scanned in a series of steps, transmitter and receiver being accurately synchronized (within 1 msec) during the scanning process. The ionogram may be produced (either by electrostatic printer or storage-type oscilloscope, depending on whether or not a permanent record is required) with the ordinates representing relative time delay, expressed as percentage distortion, shown against a frequency scale. Thus a form of histogram is produced from which m.u.f., l.u.f., and total multipath distortion can be determined. In the examples which were quoted, pulse lengths of up to 500 μsec were employed and the distortion scale was derived for 100 word per minute (75 baud) teleprinter working.

Aerials: The Convention brought out clearly the pronounced difference in size and complexity which exists between h.f. aerials used for point-to-point working and those developed for mobile services. With so much dependence on propagation conditions the aerial system must obviously be designed to exploit to the full, and to be compatible with, these conditions.

This approach is probably taken furthest with the multiple unit steerable arrays which began with the classic MUSA, and find their latest expression in the G.P.O. experimental MEDUSA* receiving system which has been installed at Cooling in Kent. This site is particularly suitable for such an installation in consisting of flat salt marshes. These give the uniform "ground constants" which are necessary for such spaced aerial systems, and the high ground conductivity required for satisfactory low-angle reception.

The inverted-cone monopole aerials are arranged in two circular groups, each 300 m in diameter and containing some 40 aerials. Their received signals are fed over coaxial cables of equal electrical length (to $\pm 1°$) to phasing and combining units after individual amplification in single grounded-grid triode stages. The phasing and combining units have several components including the r.f. diode switches which produce the steering effect. These switches operate in accordance with "phasing instructions" which are calculated by a small special-purpose digital computer for a specific steering programme. The resultant variation in signal strength associated with this scanning action is monitored on a c.r.t. display from which the optimum direction in which the aerial system should be steered is determined.

Another similar type of monopole aerial—the biconical—due to the Admiralty Surface Weapons Establishment, was quoted as having a bandwidth of the order of 2.6:1 over which a standing wave ratio no worse than 0.5 (max:min 2:1) was maintained with a 50/75 ohm coaxial feed and no additional matching and tuning circuits.

For both G.P.O. and A.S.W.E. designs a "ground plane" is provided by a radial wire system, totals of 16 and 36 equally spaced wires being used in the G.P.O. and A.S.W.E. cases respectively.

These aerials represent an example of design to give broad-band characteristics—an approach adopted for most equipment and particularly for the other aerials and associated systems described at the Convention. The demand for this broad-band capability stems from the

* Multiple-direction universally steerable aerial.

requirement to cover the full h.f. band without difficulty and without equipment having to be changed. In turn this arises from the need to vary the operational frequency for changing propagation conditions.

Thus the tendency has been to move away from resonant aerials, e.g., the Franklin type, and to go to the rhombic configuration. It appears that rhombic aerials will continue to be employed for both transmitting and receiving in the h.f. band, and that they will be mounted at more than one height at a given site to deal with a selection of different "arrival angles." (Extended tests on long-distance h.f. circuits have indicated that maximum response in the vertical plane should be at about 8° angle of elevation, this requires that rhombic aerials for 8 Mc/s should be 75 m. high.)

Another method of obtaining broad-band characteristics is used in logarithmic aerials. Sometimes referred to as "frequency independent," they are given their wide frequency response by being made of a series of active elements with their resonant frequencies in geometrical progression. Thus only the elements which are at or near resonance contribute to the array taken as a whole, which, as a result, has a relatively small effective aperture. It is obviously desirable to make each element give the maximum efficiency over the widest possible band, and this is most easily realized either with the folded dipole or the "skeleton broad dipole." The latter is a corollary of the broad dipole array in which the wide dipole limbs are replaced by wire loops which take their outline trapezium form. It is of interest to note that single-strand cadmium copper was found to give increased fatigue resistance and freedom from twisting.

There is some physical similarity between these aerial assemblies and the Yagi array, spacing and element length are tapered, however, in the former. Another point of similarity is the difficulty of analysing them mathematically to give a basis for design. Because of this difficulty Marconi have used u.h.f. scale models to determine by experiment the optimum design parameters. (One of the main problems in the mathematical approach is to assess mutual interactions along the array.) The u.h.f. models themselves are built up from fine wire on Perspex.

A type of aerial which may find increasing favour, at least for reception, is the "sloping vee." Reminiscent of the much longer Beverage aerial, its open ends are each terminated to ground through 800 ohm resistors, the feed point at the elevated end of the vee being from a tapered (600 to 800 ohm) balanced transmission line. Design has much in common with the rhombic aerial, but, as a travelling-wave device, the dependence of the sloping vee on the ground plane reflection process is much greater.

It will be appreciated that ground reflection effect will always be present with the limited directivity of the vertical apertures which are practicable at h.f. (taking the high frequency end of the band, $\lambda=33$ ft or 10 m at 30 Mc/s). An aspect of the aerial/earth combination which does not usually have significance in the United Kingdom—that of the effective earth resistance of frozen snow—was therefore of particular interest when discussed at the Convention. In the case quoted, that of a mobile set under development for the Army, serious deterioration in performance was cured by the substitution of a counterpoise system for a conventional earth connection with its "megohms per inch" resistance through the frozen soil.

An area in which considerable development work has been expended, largely to meet operational requirements, is that of the "aerial exchange." In general these take a matrix form in which provision is made to interconnect a number of transmitters or receivers with various different aerials in selected combinations. The switches themselves are arranged to possess within close limits the characteristics of the feeder system into which they are inserted, and to have low contact resistance. Thus the switch links for a high-power coaxial system are themselves of similar coaxial construction, while in an open-wire balanced layout the mechanical arrangement is continued in the switch unit—mercury switches with tungsten electrodes being used as the contact elements.

The Telegraph Aspect: Statistics given for growth of traffic over the whole of the Cable and Wireless overseas communication network showed a rate of increase of 60 per cent per annum for the telex and "leased" channels. In contrast the number of radiotelephone channels in the h.f. band is contracting because it is becoming more and more difficult to find room for the much wider band required for the transmission of the nominal 3 kc/s telephone spectrum.

As a result, the majority of the channels in the h.f. band are becoming of the telegraph type. Also, because of its relatively narrow width and the demands being put upon the h.f. band, the conservation of bandwidth within it is becoming increasingly important. Thus, even for the comparatively small spread of say a telex channel, it is clearly worth while to do all that is possible to effect the maximum economy in the use of bandwidth.

These considerations have led to a great deal of development work being done on the encoding of telegraph messages and the modulation processes associated with them, particularly on the production of highly accurate and stable r.f. sources. The inter-relation of these and other apparently dissociated fields is extensive, e.g. modulation rates for telegraph working have usually to be fixed at a value below 200 bauds because of radio link multi-path effects. (Changes of 2 msec. or more have been observed in arrival times when multi-path propagation was taking place.)

In this connection the "Piccolo" system due to the Diplomatic Wireless Service of the Foreign Office was noteworthy because it was an example of telegraph techniques being developed and extended into the field of radio circuit design. This system was of special interest on several counts, particularly with regard to the use of resonators to integrate signal energy and hence to improve error rate at low signal/noise ratios. By allocating an individual resonator to each of 32 tones associated with a specific character in the teleprinter alphabet, a given character is passed through its particular resonator circuit to appear at its output with a much improved signal/noise ratio, whereas other characters (frequencies) are, in effect, rejected. The Piccolo system depends for its efficacy on the resonators being "lossless" (infinite Q), which is achieved by applying positive feedback to each of the tuned circuit (LC) resonators. Under these conditions the resonators behave as oscillators which are quiescent until energized, at which point they maintain oscillation at that level.

Each resonator feeds into a detector, and 100 msec. after the reception of a character tone burst, the outputs of all the detectors are examined in a voltage comparator unit. This unit identifies the output with the highest amplitude, generates a pulse corresponding with it, and sends it out on the appropriate wire. After the selection operation has been completed, the resonators are immediately "quenched" and the detector outputs brought to zero in readiness for the next character.

Since the discrimination in the comparator is better than 0.2V over a range of 0.3 to 10V, this circuit can deal with the corresponding amount of selective fading.

The system operating speed was given as 100 words per min. (10 characters/sec.) with an occupied bandwidth of 470 c/s—the character frequencies extend at 10 c/s spacing from A=330 c/s, to letter shift=630 c/s and blank=640 c/s.

The improvement produced by the system is claimed to be such that errors can be kept below 0.2% when the signal is 4dB below the noise level, and operating conditions are as quoted.

The other, and more conventional, approach to the error problem is based on the principle of automatic demand for, and repetition of, distorted signals immediately following the recognition of their faulty nature. This original method, due to Dr. Van Duuren of the Netherlands Post Office, and using a 7-element code of the R.C.A. (Moore) type, has been under continuous development since its introduction over ten years ago.

In practical terms, the system operates by stopping the teleprinter and sending back a "repeat" (RQ) order to the transmitting end whenever a distorted character is detected. The original character is extracted from a temporary store (usually holding at any instant the last three characters in the message train to cover the system delay) and repeated, if necessary a number of times, until a correct signal is received and printing is resumed.

Thus actual "start-stop" signals are not transmitted, but their equivalent is derived by a decoding process from the intelligence signals. Consequently traffic capacity is established at a high level in relation to the frequency band taken up.

The system employs time-division multiplexing with close synchronization of transmitting and receiving "distributors"—sampling switches or commutators. The distributors are locked to crystal controlled oscillators, and with one as master the slave oscillator is brought into synchronism—"phased"—by reference to signal transitions. One main division of development has been to replace electromechanical devices by transistors, particularly for the synchronizing and phasing processes. It has been found that several advantages have accrued, not only in terms of performance and reliability, but also from the point of view of maintenance and general economy.

Although not strictly in the telegraph context, it seems relevant to note in this section the developments in privacy equipment demonstrated by Standard Telephones and Cables, and the electromechanical filters which were employed in the gear.

The latter consisted of a coupled mechanical system of cylinders and small-diameter rods vibrating in the torsional mode, and embodying the transducer as one of the resonant elements of the filter. The nickel-zinc ferrite used as the magnetostrictive material gives a Q (mechanical) of between 1,000 and 3,000 at 100 kc/s. For applications such as i.f. filters the electromechanical filter offers a number of advantages including small physical size. For instance a 7 kc/s i.f. filter operating at 465 kc/s (skirts of curve 60 dB down within approx. 4 kc/s) had the dimensions $2 \times \frac{1}{2} \times \frac{1}{2}$ in.

The privacy equipment itself was a good example of the miniaturization which can be achieved with modern techniques. Thus it has been possible to compress this 5 band speech scrambler providing 4 privacy channels into a volume of 4 cu ft.

Equipment Design: A pronounced trend in detailed design became evident at the Convention which can be seen in other fields of electronics, viz. the use of solid-state printed-circuit type cards as modular units. With the exception of transmitter output valves, transistors appear to be replacing the valve for all stages in h.f. receiving and transmitting equipment.

Among the many pieces of gear described during the Convention, a transistorized frequency synthesizer by S.T.C. may be taken as typical. (A frequency synthesizer is an extremely stable control source which is arranged to make available for selection a large number of accurately determined frequencies. It is used as a transmitter drive and as a receiver local oscillator control.)

In this case, although light alloy castings were used to provide screening between various sub-units, the whole unit had a volume of only 1 cu. ft. With a complement of some 130 transistors the power consumption is 12W, so that temperature effect may be regarded as negligible.

The synthesizer provides a range of frequencies adjustable in steps of 125 c/s between 3.0 Mc/s and a nominal 7 Mc/s—actually 7 Mc/s less a final step of 125 c/s. This range is obtained by mixing 5 fundamental signals in a mixer and filter chain, and extracting the various outputs from dividing and gating stages.

A somewhat broader design requirement arises from the ever-increasing pressure, common to all users, for economy in the use of manpower. This demand for unattended operation brings with it a number of problems, particularly on the transmitter side.

The solution of the overall problem, that of reconciling flexibility of working, i.e. rapid change of frequency over a wide band, with high equipment working efficiency, has been tackled in two ways. One is to make all the equipment units broad-band in themselves, the other is to adopt "self-tuning" or frequency following techniques.

The former was exemplified by the system, described by B. M. Sosin of Marconi, which utilized broad-band power amplifiers, mixers and ferrite core r.f. transformers. The first of these major components had been made a distributed rather than a pure wide-band amplifier in order to obtain the best working conditions with the varying load presented by an aerial system over a wide frequency range.

Another Marconi paper gave details of medium- and high-power automatically tuned linear amplifiers ($7\frac{1}{2}$ and 30 kW p.e.p.* respectively) in which tuning is effected by taking advantage of the 180° phase difference which should exist between grid and anode r.f. voltages in a correctly tuned amplifier. The two voltages are compared in a phase discriminator and the error signal is used to drive a tuning servo-motor in a relatively conventional loop, feedback being taken, from a generator coupled mechanically to the tuning motor, back to the input of the servo amplifier.

Finally mention must be made of the large number of papers devoted to the "mobile" group of users, largely composed of the armed and public services. Much the same considerations apply to design and policy as for point-to-point communication, especially in terms of flexibility of working and maintenance of emitted frequencies to a high degree of accuracy. The emphasis on compactness is, however, even greater for mobile equipment, and transistorized modular equipment is becoming practically universal in this field.—R. E. Y.

*P.e.p.=peak envelope power.

Non-linear Inductance

By "CATHODE RAY"

LAST month we faced the fact that whereas everything sheltering under the vast umbrella called electronics involves non-linear circuits, virtually all the elementary books and most of the advanced ones dodge the issue by assuming linearity. We have, for example, valve and transistor parameters referred to as "constants" when they are not. So general is the assumption of linearity that when we put it aside we feel quite lost without our Ohm's law, the principle of superposition, r.m.s. values, and other trusted concepts. Therefore we introduced ourselves to non-linearity by considering it in one of its simplest manifestations—non-linear resistance. We get this in valves, transistors, thermistors, varistors, etc.

Two guiding principles we relied on are (1) that the average value of any complete cycle of pure sinusoidal waveform (sin or cos) is zero—obvious, of course—and (2) the product of any two such waveforms is also zero unless they have the same frequency. The rule for finding the total of a number of alternating currents in a circuit by taking the square root of the sum of the squares of their separate r.m.s. values seemed to contradict (1) until we remembered that it is special to linear circuits, where the existence of harmonic currents necessitates corresponding voltages, so the equal-frequency exception in (2) applies. The whole idea of r.m.s. values is founded on linearity.

In non-linear circuits a sinusoidal e.m.f. produces harmonic currents, but in accordance with (2) these have no wattage. Here we had to beware of confusing the index of the non-linearity with that of the harmonics produced thereby. Whereas square-law and all other even-index non-linearity produces second and other even harmonics only, so no power is involved and therefore no influence on effective resistance, all odd non-linearity brings in fundamental as well as odd harmonics, and therefore affects the resistance.

Now that we come to non-linear inductance, which we don't have to go far to find since every iron-cored coil has it, we encounter some extra complications:

(a) Inductance is a less simple relationship between current and voltage. Instead of $E = IR$ we have $E = L\, dI/dt$ or, because current and voltage in this case are normally variables, $e = L di/dt$ where di/dt is the usual shorthand for "the time rate-of-change of current".

(b) Whereas there are at least parts of circuits where $E = IR$ is sufficient, because they are nearly-enough purely resistive, inductance necessarily involves appreciable resistance (except, sometimes, within a few degrees of the absolute zero of temperature) and often capacitance, so $e = L\, di/dt$ is only part of the story. Non-linear (i.e., iron-core) inductance additionally involves a more complicated form of resistance—core losses (hysteresis).

(c) Quite often the non-linearity of resistance can be expressed as a reasonably simple equation, but this is unlikely with inductance, especially as

(d) the curve of non-linearity itself varies with the amplitude of the current, and is affected by the past history of magnetization of the iron.

Basically it is the material of which the core is made that is responsible for most of these peculiarities, because, when magnetized by current flowing around it, it increases—usually very greatly—the amount of voltage-generating magnetic flux therein. Inductance being proportional to the amount of flux created by a given current, this is the essential property. It can be depicted in the most generally applicable form as curves of B (flux density) against H (magnetizing force). Because B is flux per unit area of core and H is ampere-turns per unit length of core, such curves enable (at least in theory) the effect of a core of any size and shape made of the material to which they relate to be calculated. So

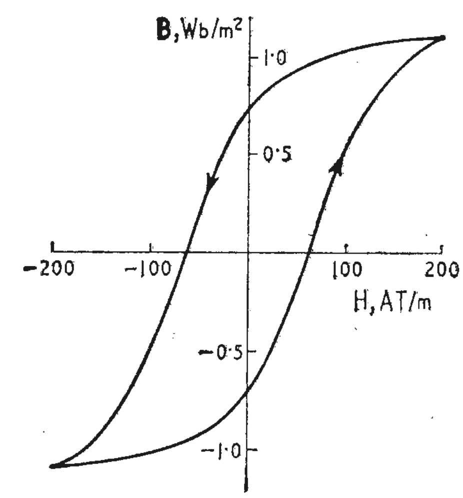


Fig. 1. Typical B/H curve, with scales in m.k.s. units.

their appearance is familiar to anyone likely to be reading this.

Fig. 1 is an example. A curious thing, incidentally, is that the one major pocket of resistance to m.k.s. units is the magnetic materials trade, yet here the m.k.s. system is not least advantageous. Instead of oersteds (which I get mixed up with gilberts) there is a meaningful unit of H:—ampere turns per metre (of core length). And the 4π and $10/4\pi$ drop out altogether, so that the energy stored per cubic metre is simply BH, not $BH/4\pi$. And the unit of flux is such that e.m.f. in volts is equal to its rate of change instead of being 10^{-8} times as much. I suppose it is the metres that people dislike, applied to cores that are usually in the centimetre range. I can only say that since I adopted the m.k.s. system I more often get my sums right, and with far less thought and reference to books. So much for the alleged inability of old dogs to learn new tricks—when the tricks are sensible ones. But that is by the way.

The most striking feature of this sort of curve is that it is like a one-way traffic system. Consequently

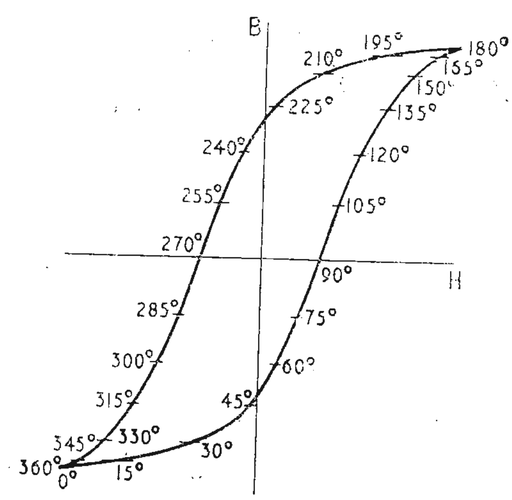


Fig. 2. Hysteresis curve as in Fig. 1, marked with phases of a sinusoidal applied e.m.f.

the value of B depends not only on H but on whether it is coming or going. In fact, this particular material retains about half its maximum flux when there is no magnetizing force at all, and the polarity can be either way, depending on what it was before. That is what I meant by the influence of history. Obviously this curve applies only after H has been varied through at least one whole cycle; it doesn't show what must have happened some time previously when the iron was unmagnetized, as represented by a point at the origin. And, as also stated under heading (d), this curve holds good only for the particular amplitude of H for which it is drawn; increasing or reducing the amplitude would make it trace out a different curve—no part of the one shown would remain. This is obviously a serious inconvenience, though one can get along fairly well by interpolation if a family of curves is available.

As I mentioned earlier, but will not stop to prove because it is in all the relevant books, the energy stored in the material is equal to BH. When an a.c. is sweeping it through the cycles represented, the fact that the up and down curves are different, and enclose an area, means that the energy restored to the circuit is less than that put into it electrically. The difference, represented by the area within the loop, is the energy lost in the core.

The relationship between H and current through the coil is revealed by its unit—the ampere-turn per metre (along the path of the flux). And the voltage generated *per turn* in any coil around the core is equal to dB/dt multiplied by the cross-sectional area of the core.

All this is elementary electrical engineering stuff, in preparation for the first job in hand: to inquire what "inductance" means in this context.

The inductance in henries is commonly defined as equal to the e.m.f. induced when the current is varying at the rate of one ampere per second. That the inductance in a circuit is assumed normally to be constant is shown by the form of the equation almost invariably quoted:

$$e = L\frac{di}{dt}$$

Here the current (i) and e.m.f. induced when it varies (e) are clearly variables, otherwise the equation is not worth writing—to say nothing of the convention that reserves small letters for variables. But where, as in every iron-cored coil, the inductance depends on the amount of current flowing, the equation doesn't tell the whole truth. One would have to write

$$e = f(i)\frac{di}{dt}$$

where $f(i)$ is a probably unspecifiable function of i, and that is a very different matter.

Continuing to assume that we have the relevant information in the form of a B/H curve, such as Fig. 1, how can we use it?

That depends on whether we know i and want to find e, or vice versa. Suppose we apply a known voltage waveform across an iron-cored coil and want to find the waveform of the current. We have already noted that the voltage induced per turn is (in m.k.s. units) equal to the rate of change of flux linked with the turns. And flux is BA, where A is the cross-sectional area of the core, assumed the same all round the core. (If it isn't, the calculation has to be done piecemeal and is much more like work.) So:

$$\frac{e}{N} = \frac{AdB}{dt} \quad \cdots \quad \cdots \quad (1)$$

Given e, A and the number of turns N, we can find dB/dt. But what do we do with it when we have found it? Nothing very useful so far as I can see.

It would, on the other hand, be most helpful if we knew B corresponding to each phase of e, because the B/H curve would translate this for us into H, from which we could (knowing the number of turns and length of core) find i.

That problem can soon be solved by integrating equation (1) with respect to t:

$$\int e\, dt = ANB + C$$

where C is the usual constant of integration. The waveform of e will either be pure sine or a Fourier combination thereof, and the integral of $\sin\theta$ is

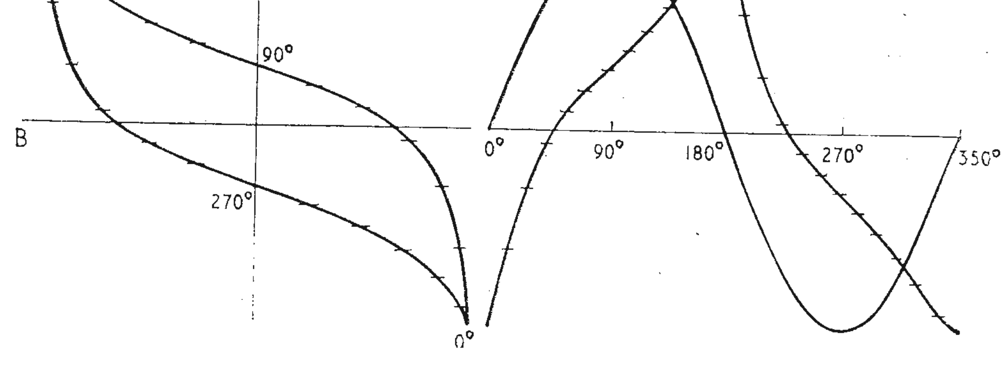
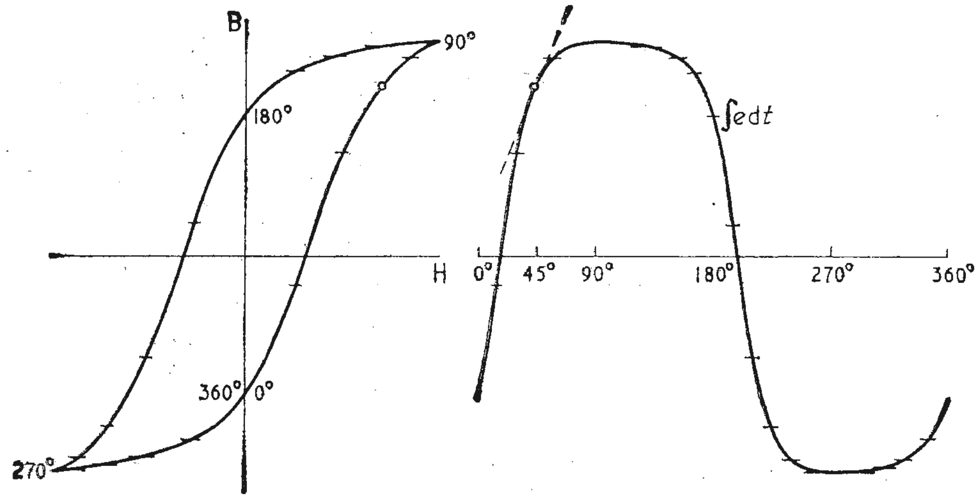


Fig. 3. Diagram of Fig. 2 turned through a right angle for conveniently drawing a H/θ curve, which has the same waveform as the current, i. The e.m.f. e is shown for comparison.

Fig. 4. Reverse process, for deriving voltage wave across the iron-cored inductor when a sinusoidal current is maintained through it. The curve shown on the right is actually a voltage integral curve, which has to be differentiated to get the voltage waveform, by measuring its slope at each point as shown.



well known to be $-\cos\theta$. θ in this case will of course be ωt, where ω is, as usual, 2π times the frequency in c/s. This slight complication is taken care of by dividing the $-\cos\omega t$ by ω.

So: $$\mathrm{ANB} + \mathrm{C} = \int e\,dt = \int \mathrm{E}_{max}\sin\omega t\,dt = -\frac{\mathrm{E}_{max}}{\omega}\cos\omega t \quad \ldots \quad \ldots \quad (2)$$

The first thing is to make sure that we have an appropriate B/H curve, which means one having the correct maximum value of B. Now the values of $\cos\omega t$ range between $+1$ and -1, so (ANB + C) ranges between $-\mathrm{E}_{max}/\omega$ and $+\mathrm{E}_{max}/\omega$. B/H curves are what is called skew-symmetrical—the left-hand half is a negative mirror image of the right-hand—so provided that the current is purely alternating, which it will be if there is no rectifier in the circuit, the peak negative values of B and H will be numerically equal to the peak positive values, as in Fig. 1. This can only be so if C is zero. That, then, is one complication out of the way:

$$\pm \mathrm{B}_{max} = \mp \frac{\mathrm{E}_{max}}{\mathrm{AN}\omega}$$

This reveals the size in B/H curves we need. If we haven't got it we shall have to sketch one, guided if possible by the next larger and smaller sizes.

Next, we want to find the values of B corresponding to sufficient other phases in the voltage cycle. I suggest every 15°. The numbers by which to multiply B_{max} are $-\cos 0°$ $(= -1)$, $-\cos 15°$ (-0.966), etc. Fig. 2 shows the diagram at this stage.

This, of course, indicates the values of H at these phases. The relationship between them and the current is, as we have already noted,

$$\mathrm{H} = \frac{i\mathrm{N}}{l} \quad \ldots \quad \ldots \quad (3)$$

where l is the length of the core (again, assumed to have constant cross-section). Current being directly proportional to H, we can plot its curve from Fig. 2 and use equation (3) if we want to provide it with a scale in amps. The easiest way of transferring the plots is to turn Fig. 2 on its side, as in Fig. 3. A sine wave is plotted too, to represent e for comparison. The shape of the i curve will be familiar to anyone who has used an oscilloscope on iron-cored coils. But we can take a more intelligent interest in it by tracing its generation as suggested.

Sometimes, as for example when an iron-cored coil is in series with a pentode, a more or less sinusoidal current is passed through it, and one is interested in the shape of the resulting voltage across it. The quickest and most reliable means of satisfying one's curiosity is again an oscilloscope, but again there is something to be said for tracing it out from basic principles.

It might be thought that this can be done simply by following the same procedure in reverse. And it can be done that way, but not quite so simply. It is easy to mark the phases on the B/H curve—in the direction of the H axis this time—and transfer the corresponding B values to get the waveform of $\int e\,dt$. All one has to do now is to differentiate it to get e; but this time we don't have a simple mathematical curve, with a standard differential. There is nothing for it but to measure its slope from point to point and plot that. Fig. 4 shows the procedure.

If all you want is the waveform, you can plot it to a scale of so many divisions up for each division along. An actual scale of e in volts can be found by referring to the scales of B and θ; the latter is also a scale of t if the frequency is known. For example, if f is 50 c/s, then 15° is $15/360 \times 1/50 = 0.00083$ sec.; in that period the slope at 45° rises 0.2 weber/m². According to eqn. (1), then,

$$e = \mathrm{AN}\frac{d\mathrm{B}}{dt} = \mathrm{AN} \times \frac{0.2}{0.00083} = 240\ \mathrm{AN}$$

Fig. 5 shows the resulting voltage waveform, with the current for comparison. The voltage due to a sinusoidal current is notably more peaked than the current due to a sinusoidal voltage (Fig. 3). Note too that in Fig. 5 the voltage peak is rather less than 90° ahead of the current, indicating resistance (i.e., core loss) as well as inductance. In Fig. 3 the peaks are actually 90° out of phase, but the asymmetrical shape of the current waveform shows that its *fundamental* component lags less than 90°.

That reminds me that our main object was not to trace out rather laboriously what an oscilloscope can do f times per second, instructive though that may be, but to inquire into the meaning of inductance in such cases.

Last month we saw that because resistance is a measure of the electrical-energy-dissipating character of a circuit, its assessment should be based on that property. With simple d.c., the rate of energy dissipation (i.e., power, P) is EI. The alternative

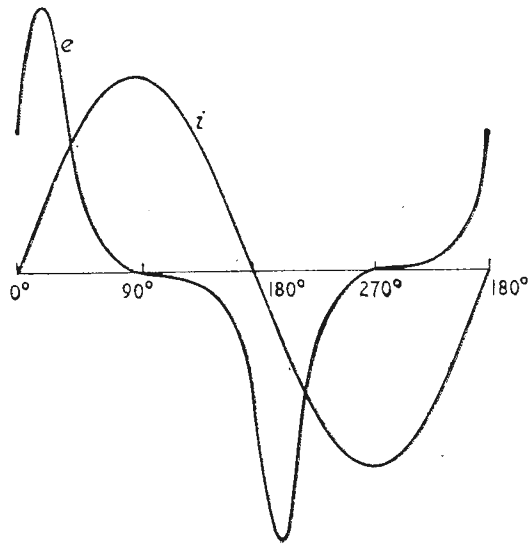


Fig. 5. Waveform of voltage e *corresponding to sinusoidal current,* i, *obtained as in Fig. 4.*

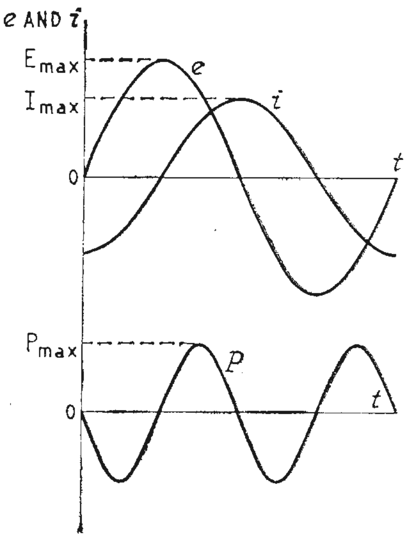


Fig. 6. Sinusoidal voltage and current curves relating to pure inductance, and the corresponding power curve, showing equal energy loan and repayment twice per cycle.

formulae for resistance are P/I^2 and E^2/P, and substituting EI for P in either of these gives us the familiar

$$R = \frac{E}{I} \qquad .. \qquad .. \qquad (4)$$

If anyone objects that I have got it all back to front, because (4) is the definition of resistance, my reply is that this may be so for d.c., but it doesn't answer in more complicated cases, where we have to fall back on the fundamental basis of power dissipation. With a.c., for example, E and I are changing all the time. So the dissipation has to be averaged over a whole cycle. Provided that the circuit is purely resistive and linear, P is again equal to EI, where this time E and I are r.m.s. values, and we again get (4). With pure sine waveform, E and I are $1/\sqrt{2}$ times the peak values, E_{max} and I_{max}. If there is reactance in series with the resistance, it causes a phase difference (ϕ) between E and I, and only the in-phase component of E counts. So $P = EI \cos \phi$. Dividing this by I^2 we get

$$R = \frac{E \cos \phi}{I} \qquad .. \qquad .. \qquad (5)$$

This is valid only for pure sine waves, but one can analyse any other waveform into component sine waves and *in a linear circuit* deal with each separately.

With non-linear resistance, as we have already recalled, a pure E gives rise to harmonic currents as well as fundamental, but as these are not associated with voltages of the same frequencies they can be ignored when calculating the power dissipated. (The same is true if E and I are interchanged). One is then dealing with fundamentals only, as before, and the only complication is calculating the fundamental current due to E (or vice versa). Fortunately one can ignore even-power terms in the current/voltage or transfer characteristic, because they generate harmonics only—no fundamental. So if, for example,

$i = ae + be^2 + ce^3$, where $e = E_{max} \cos\theta$,

for the purpose in view we can ignore be^2:

$$i = a\,E_{max} \cos\theta + cE^3_{max} \cos^3\theta$$
$$= aE_{max} \cos\theta + cE^3_{max} \tfrac{1}{4} (\cos 3\theta + 3 \cos\theta)$$

The $\cos 3\theta$ can also be ignored because it is 3rd harmonic, so the fundamental current is

$$i = E_{max} \cos\theta \,(a + \tfrac{3}{4}\, C\, E^2_{max})$$
$$\therefore I = E\,(a + \tfrac{3}{4}\, c\, E^2_{max})$$
$$\text{and } R = \frac{E}{I} = \frac{1}{a\frac{3}{4}cE^2_{max}}$$

Note that the resistance depends on the square of the peak voltage.

If neither voltage nor current is pure and the resistance is non-linear, then there will be power dissipation at other than fundamental frequency, and this must be included when reckoning the resistance—*at the specified amplitude, frequency and waveform.* Not only will there be harmonics of both voltage and current but also intermodulation. So things can get quite complicated.

I have reviewed the theory of non-linear resistance fairly fully because most of it can be used again, with appropriate modifications, for non-linear inductance. The basic difference is that inductance is a measure of energy storage rather than energy dissipation. For comparison with a similar diagram last time, Fig. 6 shows a sinusoidal e.m.f., the resulting current (or, in a non-linear circuit, the fundamental part of it only), and the power p—equal to ei at every instant. For simplicity the inductance is assumed to be free from resistance—impossible, really. So the current lags by exactly a quarter of a cycle.

Now the magnetic energy stored in an inductor depends only on the current. It is shown in elementary books to be equal to $\frac{1}{2}i^2L$. The maximum storage occurs, of course, at the peak current; so is I^2_{max} L, twice per cycle. Because the current is sinusoidal, this is equal to I^2L, which reminds us of I^2R—the average rate of energy dissipation is resistance R.

However, this line of thought is not so very fruitful, because there is no means of measuring or calculating the amount of energy stored. But we can make use of our meditations on resistance to the extent that they showed that even in non-linear circuits we had only sinusoidal current and voltage to deal with, provided that one or other of them was pure. And with pure waveform there is ωL, the reactance, equal to the ratio of voltage and current components 90° apart, just as R is the ratio of in-phase voltage to current. So corresponding to (5) for resistance we have

$$\omega L = \frac{E \sin \phi}{I} \qquad .. \qquad .. \qquad (6)$$

Because of the nature of hysteresis curves it is not, in general, practicable to *calculate* the fundamental current due to a sinusoidal voltage (or vice versa), as in the resistance example given; the best one can do in that line is to find the complete waveform graphically as described and use any of the standard methods to analyse it into fundamental etc.

But in practice one would use measuring instruments. The first thing would be to decide whether sinusoidal voltage or current was nearer the working conditions of the inductor in question. Then one would apply the said voltage or current, with amplitude as nearly as possible equal to working conditions; and, of course, the working frequency. The meter for reading the distorted current (or voltage) would have to be of a type, or provided with a suitable filter, to read the fundamental only. And it would be necessary to measure the phase difference, ϕ, between it and the driving voltage (or current), by an oscilloscope or otherwise.

Most often, measurements on inductors are done by specially designed bridges. To get a true result, the generator has to have an internal impedance practically equal to zero (for voltage) or infinity (for current); negative feedback is a great help here. And the detector must reject the harmonics and respond to the fundamental. And there must be provision for measuring the fundamental current amplitude. Then the answer will mean something. Whether it is worth the trouble is another matter.

BOOKS RECEIVED

Fundamentals of Modern Semiconductors by Barron Kemp and R. H. McDonald is a book written for the uninitiated in transistor techniques. Beginning with semiconductotr physics the reader is presented with design manufacture, and applications of most transistor and semiconductor types in use at present. Thin film technology, microcircuits, photo-transistors and parametric amplifiers are among the subjects dealt with. Throughout the book mathematics and formulæ are kept to a minimum. Pp. 160. Howard W. Sams & Co. Inc., 4300, West 62nd St., Indianapolis 6, Indiana.

Electromagnetic Theory by Prof. Erik Hallén. This book is based mainly on the lectures given by the author and his colleagues at Uppsala University and the Royal College of Technology, Stockholm. The work is conveniently divided into six sections, namely electrostatics, direct current, "stationary" electromagnetism, electromagnetic induction, alternating current and electromagnetic field theory. The m.k.s. system is used throughout. A set of problems followed by answers and suggestions is found at the end of the book. Pp. 621. Chapman and Hall Ltd., 37, Essex Street, London, W.C.2. Price 126/-.

Environmental Testing Techniques for Electronics and Materials by Geoffrey W. A. Dummer and Norman B. Griffin. This book, one of an international series of monographs on electronics and instrumentation, surveys this field and most aspects of environmental testing are examined, including a detailed account of the experience in military fields of vibration, shock and satellite environments. As well as dealing with the more general environmental hazards of galvanic corrosion, temperature, vibration and transport, nuclear radiation and acoustic noise hazards are also considered. Pp. 444. Pergamon Press, 4 and 5 Fitzroy Square, London, W.1. Price £5.

Television Deflection Systems, by A. Boekhurst and J. Stolle. One of the Philips Technical Library series this book deals with the problems related to the deflection of the electron beam in the television picture tube. The book is divided into two parts. The first investigates the tube and its associated deflection devices; the second considers external circuits related to deflection techniques. The requirements imposed on valves by these circuits are extensively discussed as are design problems associated with line and field output transformers. Pp. 218. Cleaver-Hume Press Ltd., 31 Wrights Lane, Kensington, London, W.8. Price 42s.

Variable Resistors, by G. W. A. Dummer, M.B.E., M.I.E.E. (second edition). Written to help the user to choose the best component for a particular requirement, special attention has been paid to precision variable resistors. Specialized and experimental types are covered. In this, the second edition, the text has been revised to include data on new commercial types. Pp. 228. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 45s.

International Code Training System, by International Teaching Systems, Inc. A book with three 7-in $33\frac{1}{3}$ r.p.m. records giving textual, diagrammatic and aural aids to learning the morse code, with practice recordings for speeds from three to 22 words per minute. Pp. 96. Howard W. Sams & Co., Inc., 4300, West 62nd St., Indianapolis 6, Indiana. $6.95.

Introduction to Electron Beam Technology, edited by Robert Bakish. Deals primarily with the use of high-intensity electron beams in metallurgy, e.g., melting, welding and evaporation. The design of electron guns is covered in detail and many examples of commercial application are described. Other applications of electron beams included in this symposium by 18 specialist contributors are electron microscopes, microanalysis and the irradiation of materials. Pp. 452. John Wiley & Sons, Ltd., Gordon House, Greencoat Place, London, S.W.1.

INFORMATION SERVICE FOR PROFESSIONAL READERS

Judging by the number of reply-paid forms returned to us each month, this *Wireless World* information service is proving to be very helpful to our professional readers and is therefore being continued.

The forms are on the last two pages of the issue, inside the back cover, and are designed so that information about advertised products can be readily obtained merely by ringing the appropriate code numbers. Code numbers are also provided for requesting more particulars about products mentioned editorially.

By the use of these forms professional readers can obtain the additional information they require quickly and easily.

UNBIASED

By "FREE GRID"

A Procuratorial Clangtron

IN the June issue, under the title of Etymological Exactitude, I suggested the setting up of a commission charged with the task of bringing cosmos out of the chaos of misused and misspelt words which we find despoiling electronics and kindred branches of science. The members of such a commission would have to be not only learned in language and literature, but also masters of mathematics and experienced in engineering as well as being skilled scientists.

By a piece of good luck the Editor has received a letter from a man who would make the ideal Chairman of the commission, for in addition to the qualifications mentioned above he is obviously also a legal luminary because he signs his letter with the pen name of "Procurator," well known in Scottish legal circles but usually Anglicized into Proctor south of the border to describe the man who acts for the Queen in divorce cases.

Unlike the best known of all bearers of this title of Procurator, namely Pontius Pilate, he has no desire to wash his hands of all responsibility, but, on the contrary, has anticipated his future duties as Chairman by accepting my invitation to sit upon one or two rough suggestions I made.

The Editor tells me that he is a very exalted personage in the engineering hierarchy of the B.B.C. who is as familiar with the Olynthiacs of Demosthenes as with the relativity hypotheses of Einstein. He criticizes my neglect of the rule about the use of the supine of the Latin verb when attaching the suffix "or" to certain English words derived from the Roman tongue, and to this charge I would reply: *Peccavi; me pænitet.*

But, *mirabile dictu* (no neglect of the supine there!), he falls into error himself by saying that what I wrote was "a clanger." The O.E.D. knows not "clanger" but speaks of "clangor," and Dr. Johnson of "clangour." They are, of course, referring to the noise produced by something and not to the actual thing itself; but just as armour is made by an armourer, so, surely, is a clangour made by a clangourer? However the word "clang" is actually an onomatopœic word of Greek origin, and so the correct word for the agency which produces this cacophony is surely clangtron?

For reasons other than that of etymological exactitude the word "clanger" is one which, in the past, I would have hesitated to use. Connotations change with time, and I feel that if "Procurator" had, in his younger days, been heard using it in the streets of one of our two most ancient university cities, the proctor's bulldogs would soon have been asking him politely, as they always used to do, for his full name and college; maybe they would have been a little incredulous when he gave the former, and so possibly have booked him twice.

Exhibition Catalogues

IN the course of the year I usually go to all the exhibitions of a radio or electronics nature and I have noticed that all possess the irritating defect that there is always a very expensively produced catalogue on sale. In this catalogue, sandwiched in among a plethora of advertisements, there is a list of stands with a brief résumé of the exhibits to be found there, and also, of course, a plan showing where to find them.

These catalogues cost 2s 6d or, in the case of the Radio & Electronic Components one, 3s 6d. Surely a much better idea would be that, in return for his 2s 6d the visitor received an inexpensive list of stands and a plan *plus* a strong paper bag containing all the pamphlets that are available in the show.

Now I am fully aware that obstructionists will say that nobody wants a copy of every pamphlet on the stands. This is true, of course, and yet one constantly sees people collecting whole armfuls of pamphlets including many they discard immediately they study them at home. Another argument which will be raised against my idea is that the present style catalogue is heavily loaded with advertisements which help to pay for its costly production, and may even add a bit to the revenue of the exhibition organization.

Now I know nothing of the economics of running an exhibition, but if the revenue from the catalogue advertisements is so necessary, surely every exhibitor could pay so much for having his pamphlets in the bags sold to visitors. A manufacturer could say a lot more in a pamphlet than in a catalogue advertisement.

Speaking from the point of view of the exhibition visitor, I always dislike the way I have to go from stand to stand collecting these wretched pamphlets with the bag getting heavier and heavier all the time. I should like to be able to go from stand to stand with my hands free of all pamphlets and bags, and so indeed I could if my idea were put into practice, for the great beauty of it is that the visitor would not be handed his bagful of pamphlets until he departed from the exhibition; only the simple list of exhibitors and plan of stands would be given him on entry.

Next year the National Radio Show will resume its annual run at Earl's Court. Would it not be possible to start putting my idea into practice then?

Electronic Therapeutics

A VISIT to the Hospital Equipment and Medical Services Exhibition at Olympia a few weeks ago made me realize what wonderful advances electronic therapeutics—if I may coin a phrase—has been making in recent years. Every doctor knows that differential diagnosis is one of the most difficult things in medicine, but so far nobody has produced a computer whereby a doctor could, after "binarising" the symptoms (which is itself an impossible task at present), just shove them into a computer and get the correct diagnosis and treatment.

One of the most interesting electronic exhibits of a non-medical nature was the elaborate communication system whereby a patient can, by means of closed-circuit TV, see and talk with somebody elsewhere in the hospital. This apparatus would be particularly useful for visitors to a patient in an isolation hospital.

I was particularly interested in the microwave hospital cooker. There is nothing new in the principle of this, of course, and it is used by many restaurants, especially quick-service ones of the gulp-it-as-you-go type, which serves hot dogs and suchlike things. I was told on the exhibitor's stand that small items could be cooked in a trice, however long that may be, and a family joint took only a few minutes, but domestic models are not yet available. The frequency used in the model I saw was 2,450 Mc/s, which, to save you getting out your slide rules, is roughly a wavelength of 0.122 metre, i.e., a little short of 5 inches.

"Wire-less"

IN the issue of *Wireless World* for November, 1961, I mentioned that, during the preceding summer I had been to a first-class entertainment in the pierhead theatre of a well-known seaside resort but felt irritated by the trailing cable of the microphone used by a ventriloquist as he moved about the stage and among the audience. I suggested that instead of the cable there should be a microwave link.

Owing to the high praise I bestowed on the quality of the entertainment, the entertainments manager of Southend-on-Sea had little difficulty in realizing that I must be speaking of this famous Essex resort, as indeed I was. The upshot of the whole matter was that he made a few enquiries and came up against various difficulties including the insuperable barrier of the fact that the Post Office was not prepared to allocate a frequency for this service.

There the matter has rested for 18 months, but now the picture has changed entirely. The P.M.G. has allocated a frequency (174.6-175 Mc/s, as mentioned in the May issue of *Wireless World*) and British type-approved apparatus was shown at the Audio Fair in April and also at the Radio & Electronic Component Show in May. On both these occasions I had a very good look at these radio mikes. A power of 10 milliwatts is the limit set by the P.M.G. but the open-air range is several hundred yards which is all that can be desired. The tiny transmitter is small and light enough to be concealed on even a child performer.

I have naturally been wondering if there are likely to be any snags. I think it very unlikely that any practical joker would think it worth his while to invest in duplicate apparatus which might enable him to interpolate into the programme disconcerting remarks of his own.

I still think, as I mentioned in November, 1961, that by its use a ventriloquist would be able to extend his scope very greatly if a very compact receiver and loudspeaker as well as a telearchic lip and eyebrow operator were fitted into his dummy. He would be able to cause it to chatter and gesticulate even when he was a considerable distance from it, such as the full length of the auditorium.

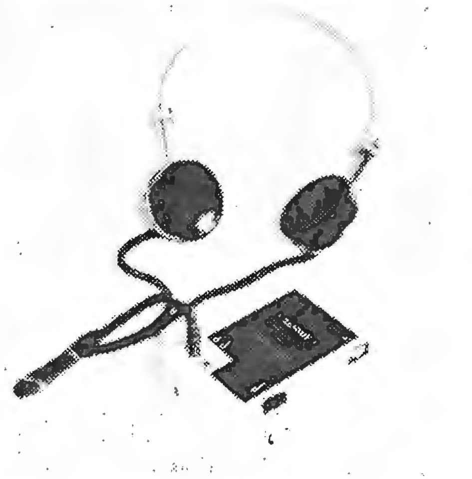
Sexagesimal System

SOME months ago I asked in these columns if any of you could tell me why there are 360 degrees in a circle and also 60 seconds in a minute and minutes in an hour. Some of you blamed the Babylonians, although nobody suggested why they did it.

I find it is dealt with by Dr. A. C. Aitken, in his book "The Case Against Decimalization" to which I referred last December. Dr. Aitken tells us that in 2,000 B.C. the Sumerians used not only decimals but also the sexagesimal system, and that a few centuries later, the Babylonians took both over from them. While the ordinary folk continued to use decimals, the mathematicians and technologists used the sexagesimal system because 60 had more factors than any number less than it. It was these people who have left their stamp on our divisions of time and of the circle.

INDUCTION LOOP INTERPRETATION SYSTEM

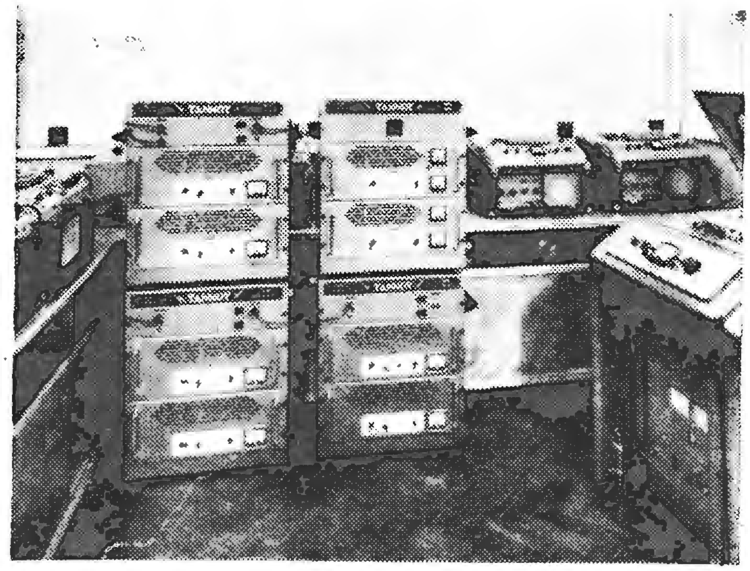
IN addition to the permanently-wired installations which have been provided for debating chambers and conference halls in all parts of the world (e.g., the United Nations in New York and Geneva, and Church House, Westminster) Tannoy have now developed a mobile radio (inductive) system together with comprehensive facilities not only for multi-lingual translation but also for verbatim recording. These facilities can be provided at comparatively short notice, and subsequently



Delegate's receiver unit tunable to six channels.

tape copies of speeches can be provided if required through Sound Recording Ltd., a new company in the Tannoy group.

The new loop system provides 6 channels with carrier frequencies of the order of 100kc/s, each channel being crystal controlled. Microphone outputs go through a volume compression voltage amplifier before being applied to the modulator, giving a change of only 2dB for a 20dB change of input level.



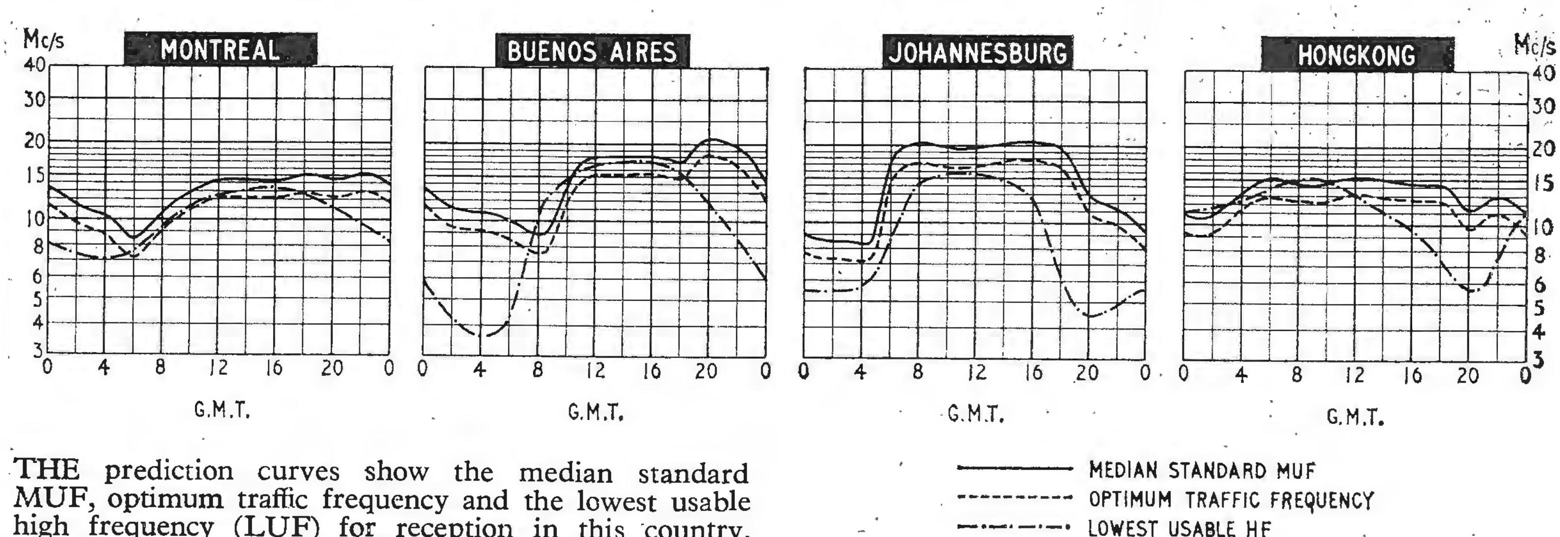
Transmitting amplifiers and recording equipment forming part of the Tannoy radio-inductive simultaneous translation system.

The receivers are superheterodynes housed in high impact plastic cases measuring $4\frac{3}{4}$in $\times$ $3\frac{1}{4}$in $\times$ $1\frac{5}{8}$in. A ferrite rod high-Q tuned input circuit precedes the mixer which is followed by one i.f. stage with a.g.c. and reflexed for a.f. amplification, a diode detector and an output stage, transformer coupled to the headphones. A socket in the base accepts a jack for charging the sealed nickel-cadmium battery, and combined storage and charging racks, each holding 60 units, have been designed for ease of transport.

Channel selection is by means of an edgewise control switch with a small degree of movement on each position for fine tuning of the carrier frequency. A second control is a combined on/off switch and volume control.

The Tannoy Company of Norwood Road, London, S.E.27, is prepared to undertake the complete simultaneous translation services for conferences of up to 2,500 delegates.

H. F. PREDICTIONS—JULY



THE prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable high frequency (LUF) for reception in this country. Unlike the standard MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, local noise level and the type of modulation: it should generally be regarded with more diffidence than the MUF. The LUF curves shown are those drawn by Cable and Wireless, Ltd., for commercial telegraphy and they serve to give some idea of the period of the day for which communication can be expected. The LUF curve for Montreal takes account of auroral absorption.

During the summer months in the minimum of the solar cycle past experience has shown that frequencies considerably higher than the predicted standard MUF can at times be received. This effect is mainly confined to daytime on the radio path and has been especially noted on reception in the U.K. from the Far East. The cause is thought to be associated with sporadic-E ionization.