Wireless World

ELECTRONICS, RADIO, TELEVISION

JULY/AUGUST 1959

Managing Editor:
HUGH S. POCOCK, M.I.E.E.

Editor:
F. L. DEVEREUX, B.Sc.

Assistant Editors:
H. W. BARNARD
T. E. IVALL

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Introducing an addition to the Mullard Technical Handbook

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VOLUMES I and IA

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VOLUME 2

Data on earlier type Receiving and Amplifying Valves and Cathode Ray Tubes still in limited production for the maintenance of existing equipment.

VOLUME 3

Data on Power Valves for Transmitting and Industrial Equipment. Power Rectifiers. Large Thyratrons. Microwave Devices.

VOLUME 4

Data on Semiconductor Diodes, Transistors, Photoconductive Cells and Photoelectric Cells.

Full details of this service, including subscription rates and application form, will be supplied on request.

Mullard

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JULY/AUGUST 1959
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We Were About to Say

THE hiatus in the publication of this journal caused by the slow-down and eventual stoppage in the printing industry is very much regretted. Although the June issue was eventually dispatched it was very late, and there was no possibility of producing anything in July. However, the present enlarged issue will help to bridge the gap and bring readers up to date with information of some of the interesting things to be seen at the Radio Show at Earls Court.

Throughout the "rest period," as some of our facetious friends have called it, the editorial staff have continued their normal duties, which include the assessment of events at home and abroad, and the present issue contains first-hand reports of the International Transistor Convention and Exhibition at Earls Court, the Brit.I.R.E. Television Convention in Cambridge, the "Automath" Computer Exhibition and Information Processing Conference in Paris and the French Air Show. Another International Congress on Medical Electronics was also held in Paris, but the full report on this will be held over until our next issue as we feel that any attempt at further condensation would do less than justice to its importance.

Our next issue, due for publication in mid-September will contain a full stand-to-stand report of the National Radio Show (for the benefit primarily of those who are unable to see for themselves, but useful also as a record for future reference), while the October issue will carry a technical review of the Show in retrospect which will look more closely at any new developments and assess the general trend of progress. In these issues we hope to give also some first-hand impressions of developments on the Continent as exemplified by the German Radio Show in Frankfurt, the Dutch Firato in Amsterdam and the International Electro-Acoustics Congress in Stuttgart.

The present spate of conventions and exhibitions, interesting as it is, will not be allowed to take more than its fair share of our space, and we shall continue to provide balanced issues with articles catering for a wide variety of interests and at different levels of technical understanding. While maintaining the standard of articles addressed to the professional we hope to extend our service to the student and the amateur experimenter by more articles of an expository and constructional nature. And there will be occasions when we shall take time off to look at ourselves and perhaps discover that there is a less serious side to what must often appear the grim business of radio and electronics.

Finally, a word of reassurance to our subscribers. To compensate for the loss of an issue in July, subscription periods will be extended by one month.

Eurovision—Five Years

ON June 6th the European Broadcasting Union celebrated the fifth anniversary of Eurovision, for it was on that day in 1954 that eight countries collaborated to bring to their viewers the first of a memorable series of live programme exchanges which have set the pattern for subsequent expansion and improvement. True, there had been earlier pioneer work by the B.B.C. and the French R.T.F. but the "Lille Experiment" of June 1954 marked the establishment of a flexible network which superseded what was until then merely a chain.

The history of the technical development of the system is admirably recorded by E. L. E. Pawley (Chairman, E.B.U. Technical Committee) and M. J. L. Pulling (Chairman, E.B.U. Working Party L) in No. 55a of the *E.B.U. Review* (June 1959). At the present time sixteen television services in twelve countries are able to share programmes, and in 1958 no fewer than 233 exchanges were handled by the co-ordination centre in Brussels.

The sole justification of the Eurovision network is immediacy and this has brought many production problems, particularly in arranging multilingual commentaries. Furthermore, the picture itself is not necessarily an international language. As Jean d'Arcy (Vice-chairman, E.B.U. Programme Committee) writing in No. 56b of the *E.B.U. Review* points out, people of different races "simply don't see the same thing when looking at the same picture. . . . A brilliant theme for a broadcast that seems lively and attractive to the Latin is quite unbearable to the English person; a programme that is thought highly of in one place is forbidden in another. Eurovision became a school for us where we learned tolerance and understanding of others."

Looking to the future, world-wide television is already feasible. Using an airborne relay station the French have already linked Europe with Africa. Transatlantic television by such a method or by satellites would be prohibitively expensive, but by exploiting the principle of redundancy and transmitting only new information in each frame it might be possible to reduce bandwidth and so come within the capacity of the transatlantic telephone cable.

National Radio Show

THIS year's National Radio Show opens to the public at Earls Court on August 26th. Last year's innovation of a section devoted exclusively to audio equipment was such a marked success that the area allocated to this section is this year enlarged. There are nearly 150 exhibitors at the show and of this number 38 are in the audio hall; some are in both sections. Seventy-five per cent of the exhibitors are manufacturers of domestic receiving equipment, the remainder being either users (such as the Services, B.B.C. and I.T.A.), publishers and those providing services for the radio and electronics industry. The manufacturing and retailing sides of the industry have joined forces to provide a comprehensive display and information centre (Stand 401) devoted to careers in the radio and electronics industry.

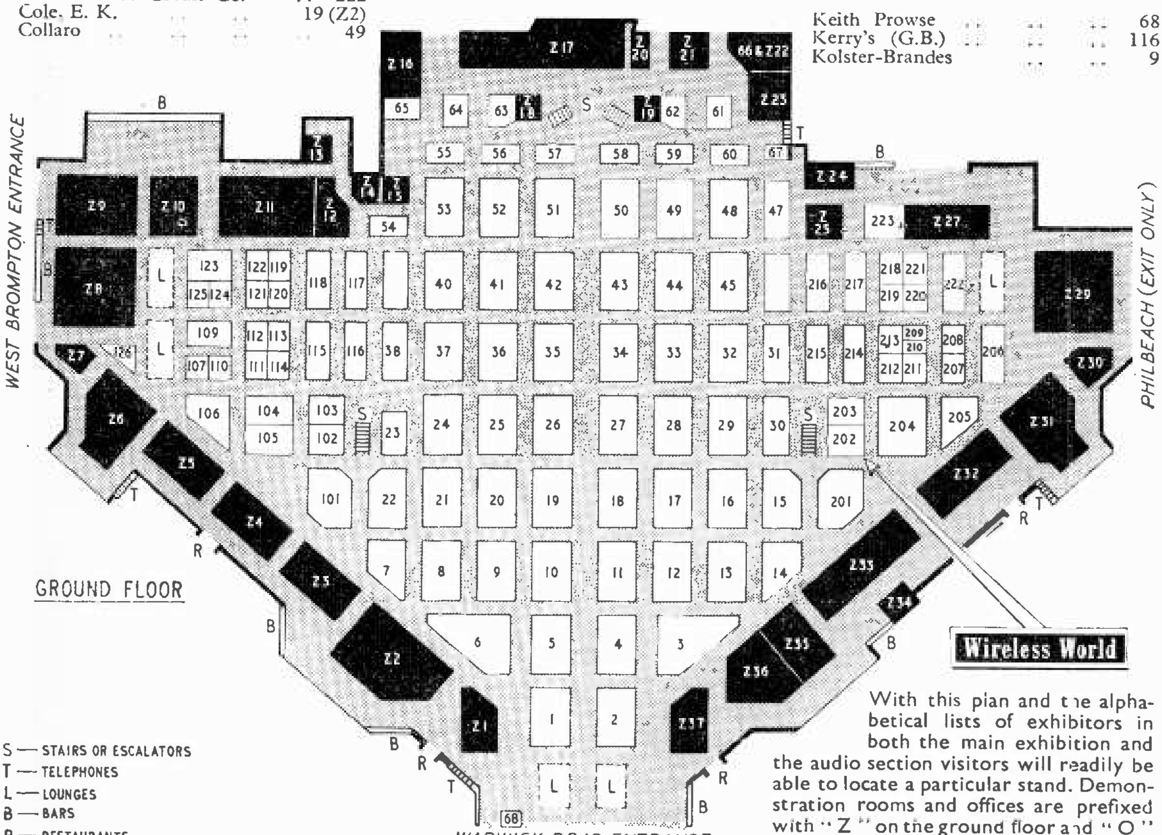
In the following few pages will be found a selection of highlights from the information made available by exhibitors at the time of going to press.

ALPHABETICAL LIST OF EXHIBITORS

Name	Stand
Admiralty	408
Aerialite	22
Air Ministry	409
Airmec	61
Alan-Markovits	109
Alba (Radio & Television)	27
Antiference	15
Barclays Bank	1
Belling & Lee	53 (Z13)
Bernards	126
Bowmaker	208
B.B.C.	410, 411 & 412
British Radio Corporation	214
British Railways	104
Broomhall Joinery	218
Bulgin	59
Bush Radio	6 & 8
"C" Aerials	210
Careers	401
Charterhouse Credit Co.	222
Cole, E. K.	19 (Z2)
Collaro	49

Name	Stand
Co-operative Wholesale Soc.	2
Cossor, A.C.	216
Cossor Radio & Television	50 (Z14)
Daystrom	122
Decca Record Co.	42 (Z6 & Z7)
Design Furniture	103
Domain Products	220
Dubilier Condenser Co.	60
Dynatron Radio	14
E.A.P. (Tape Recorders)	215
E.M.I. Records	55
E.M.I. Sales & Service	52 (Z11 & Z12)
Econasign Co.	209
Electrical & Radio Trading	120
Electronic & Radio Engineer	202
Electrovac Manufacuring Co.	213
Emerson Electronics	32
Ever Ready Co.	28 (Z24)

Name	Stand
Ferguson Radio Corporation	34 (Z5)
Ferranti Radio & Television	36 (Z4)
Fidelity Radio	117
Field & Co.	112
Garrard Engineering	40
General Electric Co.	12 (Z31)
General Post Office	405
Goodmans Industries	23
Greater London Fund for the Blind	404
Grunther Instruments	113
H.M.V. Radio & Television	37 (Z9)
Hobday Bros.	123 (Z10)
Hunt (Capacitors)	54
Independent TV Authority	403
Invicta Radio	48 (Z15)
J-Beam Aerials	7
Johnson Bros.	124
Keith Prowse	68
Kerry's (G.B.)	116
Kolster-Brandes	9



With this plan and the alphabetical lists of exhibitors in both the main exhibition and the audio section visitors will readily be able to locate a particular stand. Demonstration rooms and offices are prefixed with "Z" on the ground floor and "O" in the Audio Hall.

Name	Stand
Labgear	30
Le Grest & Co.	107
Lee Products	118
Linguaphone Institute	219
Lloyds Bank	217
Lugton & Co.	223 (Z27)
McMichael Radio	24
Marconiphone Radio & TV	21
Margolin	45
Martins Bank	106
Mercantile Credit Co.	203
Midland Bank	5
Mullard	43 (Z29, Z30 & Z35)
Multicore Solders	62 (Z19)
Murphy Radio	16 (Z32)
National Inst. for the Deaf	402
National Provincial Bank	204
Pam (Radio & Television)	3 (Z34)
Perdio	47
Perth Radios	207
Peto Scott Electrical Insts.	17
Philco	35
Philips Electrical	18 (Z17 & Z20)
Pilot Radio	20
Pitrie	119
Plessey	66 (Z22)
Portogram Radio	57
Practical Wireless	105
Pye	41 (Z8)
Radio & Allied Industries	26 (Z3)
Radio Gramophone Development Co.	25 (Z36)
Radio Retailing	110
Radio Society of Gt. Britain	407
Radio & TV Retailers' Assoc.	205
Regentone Radio & Television	29
Roberts' Radio Co.	56
Rola Celestion	212
Rose Projects	125
Saga Films	4 (Z37)
Selcol Products	121

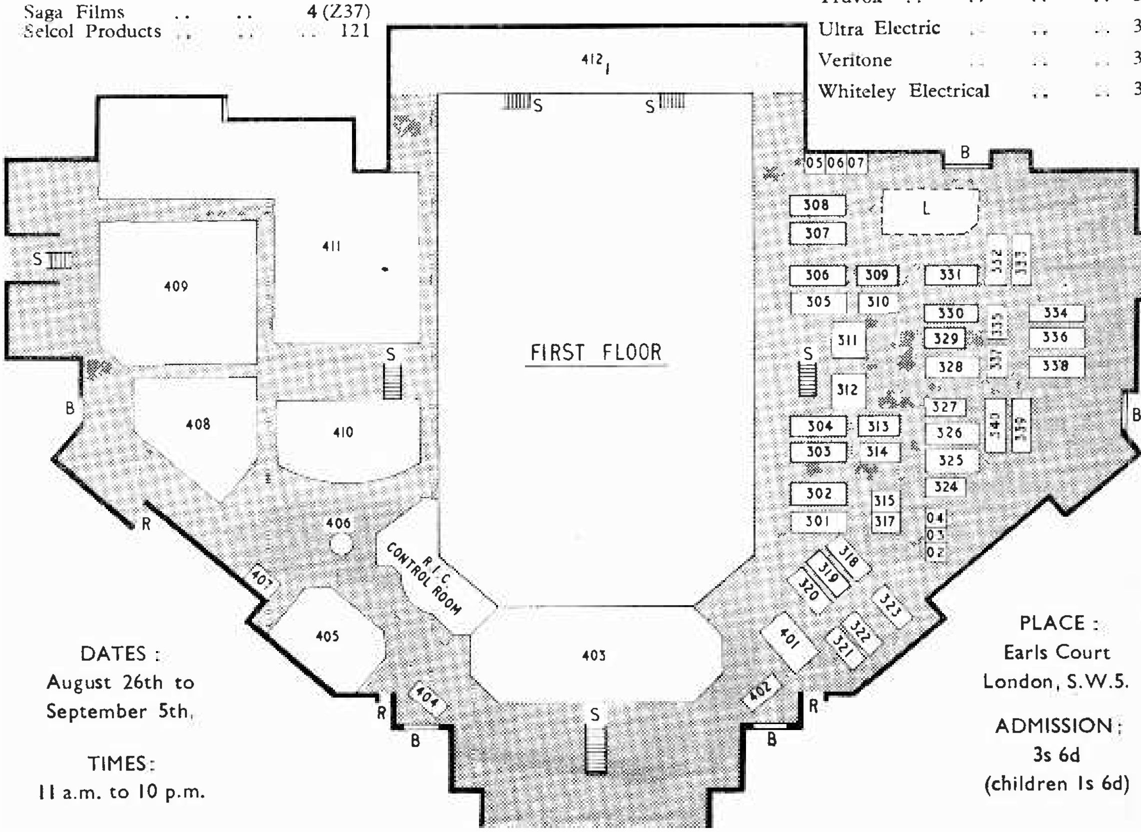
Name	Stand
Siemens Edison Swan	11 (Z33)
Slingsby	115
Spencer-West	114
Standard Telephones & Cables	44 (Z25)
Stella Radio & Television	51
Southgate Tubular Products	111
Tape Recorders (Electronics)	101
Telegraph Condenser Co.	58 (Z23)
Telerection	33
Telesurance	13
The Star	406
Trix Electrical Co.	38

Name	Stand
Ultra Electric	10 (Z1)
Valradio	64
Vulcan Finance Facilities	221
Walter Instruments	206
Waveforms	65
Westinghouse Brake & Signal	102
Westminster Bank	201
Whiteley Electrical	63 (Z18)
Wireless & Electrical Trader	211
Wireless for the Bedridden	67
Wireless World	202
Wolsey Electronics	31

AUDIO HALL (First Floor)

Name	Stand
Alba (Radio & Television)	327
Amplion	338
Associated Electronic Engrs.	309
Ava Sound Enterprises	335
BTH Sound Equipment	307 (05)
Beam-Echo	306 (06)
Brenell Engineering	333
Celestion	305
Cole, E. K.	328
Collaro	330
Cosmocord	304
Decca Record Co.	339 (03)
Dynatron Radio	325
E.A.P. (Tape Recorders)	319
E.M.I Records	323
E.M.I. Sales & Service	303 & 322
Electric Audio Reproducers	320 (02)
Electronic Reproducers	340
Expert Gramophones	329 (07)

Name	Stand
Ferranti Radio & Television	301
Garrard Engineering	336
General Electric Co.	302
Goodmans Industries	334
Hi-Fi News	317
Kolster-Brandes	321
Lustraphone	312
Metro-Sound Mfg. Co.	314
Philips Electrical	331
Portogram Radio	313
Reps (Tape Recorders)	310
Scientific & Technical Dev.	324 (04)
Simon Sound Service	326
Tape Recording	315
Tripletone Mfg. Co.	311
Truvox	332
Ultra Electric	337
Veritone	308
Whiteley Electrical	318



DATES:
August 26th to
September 5th.

TIMES:
11 a.m. to 10 p.m.

PLACE:
Earls Court
London, S.W.5.

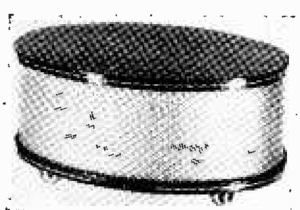
ADMISSION:
3s 6d
(children 1s 6d)

NATIONAL RADIO EXHIBITION

Highlights of the Show

THE innovation of an Audio Hall, combined with the surge of activity in stereophony, made sound, rather than vision, the predominating interest at last year's Radio Show. This year the pattern seems to be repeated, although the following selection of items will show that there has been no lack of development in other branches of the industry.

"Stereo in one Box" is more common than last year. Usually, if desired, one or more extension speakers can be connected so as to extend the overall sound field beyond the cabinet. In the E.A.R. Model 500 single-cabinet reproducer the speaker compartments can be spaced up to 5 feet apart or, if greater separation is required, detached altogether from the main cabinet.



Unusual styling is a feature of the K.B. "Stereovox" extension loudspeaker.

Tape Magazine is provided for the new Garrard "Bichette" deck to make the tape easier to handle. The magazine contains two 4-in diameter spools of double-play tape giving about 35 minutes playing time for each track at the tape speed used ($3\frac{3}{4}$in/sec). The spools are so arranged in the magazine that, when the magazine is slotted into its correct position on the tape deck, the tape is already in the correct position for recording or playback.

Low-tracking Weight crystal pickup heads shown by Cosmocord include a stereo model which will track at about 2gm and, tracking at 0.3gm, an improved version of the single-channel pickup described by J. Walton in our April issue. These pickup heads are fitted to the low-friction vibration-stabilized X286 arm which was described in our June issue. An inexpensive low side-thrust arm designed expressly for use with stereo pickup heads is also on show.

Stereo Balance with dissimilar response loudspeakers is simplified in the Tripletone Stereo 5-5 and 12-12 amplifiers and pre-amplifiers by provision of concentric twin middle-frequency as well as bass and treble controls. Conversion to stereo of the Tripletone "Convertible" single-channel amplifier and pre-amplifier is made easier by extending the control spindles on both sides of the potentiometers so that, if two "Convertibles" are bolted together front-to-back, corresponding controls can be ganged together.

Better Television Sound reproduction is becoming more common. Forward facing speakers appear in many sets—the elliptical type being used to save space—and several models have two speakers, one on each side of the screen. This last trend gives a symmetrical arrangement which is often combined with a bow-fronted cabinet.

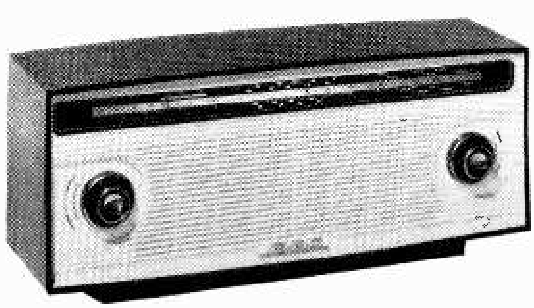
Television and Radio Distribution equipment is shown by Aerialite, Belling & Lee and Wolsey Electronics. The Wolsey Electronics systems can distribute Band-III signals on their own frequencies, or the Band-III programmes can be "translated" to a Band-I channel for distribution over large areas. V.H.F./f.m. can also be distributed on the original frequencies by the system. Another valuable feature is that other programmes, such as Radio Luxembourg, can be translated to a v.h.f./f.m. signal, allowing the use of a combined v.h.f./TV receiver, or a v.h.f.-only receiver instead of an a.m./f.m. set.

"Sounds Fantastic"—a demonstration of sound recording given at frequent intervals by the B.B.C.—includes recorded comparisons of v.h.f. and medium-wave reception and recordings from the B.B.C. archives.

Local Oscillator Stability in f.m. receivers can be assured in two ways—by an a.f.c. system, or by crystal control of the oscillator. As a desirable means of tuning is push-buttons or a switch, crystal control is particularly suitable. S.T.C. are showing among their range of quartz-crystal units a three-crystal assembly on a single B7G valve base.

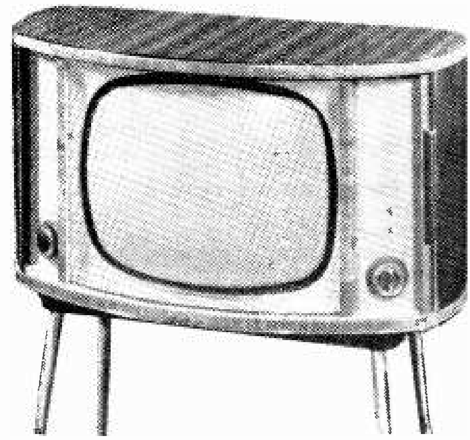
Video-tape recording is being demonstrated by Tyne-Tees Television, the north-eastern programme contractors, on the I.T.A. stand. The equipment used is a mobile version of the standard Ampex video-tape recorder.

Easier Servicing is a major consideration in the design of many television sets. One recent trend is the use of detachable circuit panels. Decca have a hinged chassis on three models which swings out at the back of the set to give easy access. McMichael have a chassis which unclips and can be withdrawn. Alba's



A "long-low" style is being adopted by several manufacturers this year. One example is the Ferguson "Futurist" a.m./f.m. receiver; another is the G.E.C. BC402 a.m./f.m. receiver, shown here.

Tape level indicators using two neon lamps are not very often seen. The neons are arranged to light at different levels so that, by making the loudest sounds light one neon but not the other, the peak recording level can be restricted between two values. Two examples of this type of indicator may be seen in the Alba R59 (shown here) and R.G.D.MK103 recorders.



Slim television receivers, based on the short-necked 110° tube, are displayed by almost all set manufacturers this year. 17-inch and 21-inch screens are the most popular sizes. Advantage is taken of the shape of the 110° tube to produce bow-fronted cabinets which avoid to some extent the "boxy" look of conventional designs. The 17-inch G.E.C. BT304, shown here, has a curved protection glass following the line of the cabinet. Other designs are wedge-shaped, diminishing towards the back.

"packaged service" system, introduced last year, in which 90% of the components are mounted on two replaceable plug-in printed-circuit panels, has been extended to three new models.

Car Aerial Sockets for transistor receivers have already been featured by Perdio and are now provided by many manufacturers. The use of an external aerial in a car avoids changes in the signal input level from the directional internal ferrite-cored aerial as the car moves about. Another new type of socket which is being increasingly provided on all types of receiver is one for feeding the input of a tape recorder.

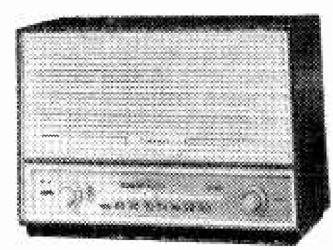
Definition Control by push-buttons in television receivers introduced at a previous Show, is not widely used, but has been continued in two Stella sets, the 21-inch ST. 1001U and the 17-inch ST. 1007U. One button is for "soft" pictures and the other for "crisp" pictures.

Selectivity varying automatically to give the optimum signal-to-noise ratio at various signal input levels (a stronger signal produces a wider bandwidth) is one of the unusual features of the new Perdio "Continental" transistor receiver. Other unusual features of this receiver include an 87-197 metres short-wave band, a loudspeaker as large as 8in by 5in, and fixed bass boost to partially compensate for acoustic losses due to the small cabinet.

In-the-room Aerials are continuing to gain in popularity, due in part to the increasing number of transmitters and improved receiver performances. At last year's show there was a large number of set-top small "V"s. This year Belling-Lee introduce a new V aerial designed for use in areas where the small Vs do not provide enough signal. Called the "Metropolitan," this aerial features elements which extend to about 40in and a tunable matching network in the base pedestal. This network can be adjusted by a "front-panel" control.

Tape Tracking in Both Directions is possible with the new Truvox R7 recorder. Thus both tracks on the tape can be recorded or replayed without having to turn the reels over. Other unusual features of this recorder are a "slide" volume control, and the provision of two alternative fast forward and rewind speeds to permit more accurate selection of a particular position on the tape while fast winding. Two other new tape recorders are also introduced by Truvox.

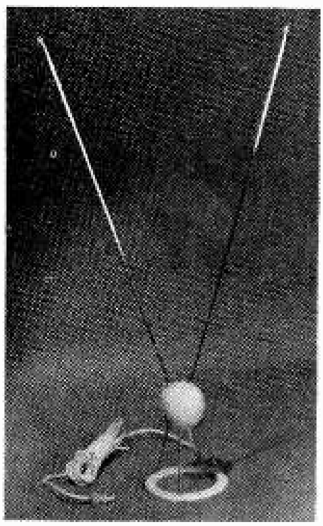
Simplified H.T. Supplies for television sets become possible by the use of silicon junction diode rectifiers. S.T.C. are showing one inexpensive type rated at 400 volts p.i.v. and 500mA up to 50°C ambient temperature. R.G.D. are using them in their latest 17-inch and 21-inch television sets with 110° tubes—the models 610, 611L and 710.



F.M.-only receivers are not very often seen, although their numbers are somewhat increased this year by new models being shown by Ferranti (see photograph), H.M.V. and Ferguson.

Diplexers are usually thought of in connection with television as devices for combining Band-I and Band-III aerial leads, or separating signals in these bands which have been carried on a common lead. Where two Band-III programmes are available, it has hitherto been necessary to change aerial leads when separate directional aerials have been used. Labgear introduce now a diplexer for the combining of Channels 9 and 11 onto one cable. It is claimed to have a negligible insertion loss.

X-Aerial Range of Choice is extended this year. The Wolsey Type X75 is for Band-I stations only, while Labgear have a complete range of combined Band-I/III types. These new aerials feature improved feeder-to-aerial matching. The Labgear series provides not only for independent orientation of the Band-I and Band-III sections, but also for adjustment of the two sections for different linear polarizations of the Band-I and Band-III transmissions.



"Sputnik"-shaped, Labgear's new set-top aerial receives Band-I, -II, and -III stations in areas of good signal strength.

Bass Tone Controls are being increasingly provided in addition to the more usual treble controls even, for example, in relatively inexpensive radio-grams.

Full D.C. Component of the video signal is said to be retained in the Alba 17-inch television receiver, T656. This is an unusual feature not found in the majority of sets nowadays.

Slim Television Trolleys have been introduced for the new slim-cabinet receivers with 110° tubes. As an example one model by Whiteley has a table top measuring 19in × 13in.

Components shown by Dubilier include ganged volume controls for stereo and subminiature electrolytic capacitors for printed circuit and transistor applications. Featured on T.C.C.'s stand is a working model of a rocket-telemetry apparatus illustrating the use of this company's printed-circuit switch panels.

Clock-switched Receiver shown by Ekco, the Radio-Time, incorporates an alarm clock. It can be arranged that, at a predetermined time, the receiver and also a 5-amp mains supply are automatically switched on, and that after any predetermined period up to an hour the receiver is switched off.

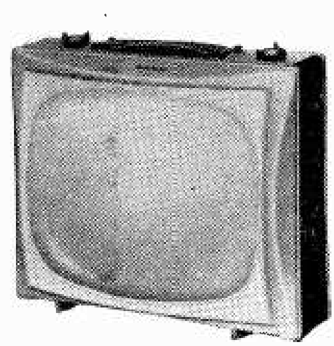
Ipswich is in an area which will receive a reasonably good Band-III signal; but the Band-I transmitter is some distance away. Both Belling-Lee and Antiference introduce new aerials designed for this type of location. The Antiference aerial—Type HL303—has Band-I and Band-III sections of three elements each. The Belling-Lee Type 24A has two Band-I and four Band-III elements, and fits in with the firm's "Unit Plan" system for choosing from a variety of masts and lashing-kits.

Polaroid Television Filters are a new feature to be seen in this year's range of television receivers by Pam. The filters are said to eliminate reflected light completely so that receivers can be viewed with all room lights on or in daylight without darkening the room. In addition the tonal quality of the pictures is said to be improved.

Sound Volume Expansion is an unusual feature of a tape recorder shown by Amplion. From 6 to 8dB can be provided using lamps in a balanced bridge circuit.

Stereo Recording facilities are not very often provided even where stereo playback is possible. Exceptions to this rule are, in the field of tape recorders, the Reflectograph Model 570 and a new Veritone "Venus" model, and, in the field of microphones, the Lustraphone double ribbon model and a new twin crystal microphone shown by Cosmocord.

Revivals of old technical ideas include "variable selectivity" in the Ekco export a.m. receiver Model A733, and "bandspreading" for the short-wave bands in two new Philco receivers. New versions of old ideas in styling include a thermometer-like station indicator on the G.E.C. a.m.



Shorter 110° tube, the 17-inch CME1705, developed by Siemens Edison Swan, is used in this Ekco TP347 receiver to give what is claimed to be the slimmest-ever portable television set. The tube has a new type of electrostatic focusing system, based on a cylinder lens, in which focusing action takes place over a shorter distance than normal. As a result the tube length (11 inches) is about 1¼in shorter than the equivalent 110° 17-inch tube of orthodox gun design.

receiver Model BC401 and, on Ekco and Ferranti receivers, a pair of tuning scales, each of which is printed upside-down relative to the other to allow easy reading of the station names with the receiver at any angle. Another increasingly common styling feature is the employment of edge-on control knobs outside their usual field of television receivers.

Band-III Aerials of high gain, good back-to-front ratio and negligible side-lobe response are often required for "de-ghosting," especially in fringe areas. New eleven-element aerials by Antiference and Labgear feature these characteristics, and aerials by C Aerials, Ltd., have a specially shaped folded dipole to achieve these ends. It is claimed that, with the shaped dipole, side lobes virtually disappear, and a reflector is not necessary. Band-I elements can be fitted to the Band-III arrays and a transparent junction-box cover enables inspection of the connections to be made without unsealing the box.

9x2mm, sub-miniature wire-ended fuses in a range of values between 60 mA and 1A are shown by Bulgin.

New Horizons in Computing

PARIS INFORMATION PROCESSING CONFERENCE AND "AUTOMATH" EXHIBITION

"THE day is rapidly drawing near when digital computers will no longer be made by assembling thousands of individually manufactured parts into plug-in assemblies and then completing their interconnection with back-panel wiring. Instead, an entire computer or a large part of a computer probably will be made in a single process. Vacuum deposition of electrodes on blocks of pure silicon or germanium and the subsequent diffusion of the electrode material into the block to form junctions is a most promising method. The successful development of this method would allow large numbers of transistors and all of their interconnecting wiring to be made in one operation. Vacuum deposition of magnetic materials and conductors to form coincident-current magnetic core memory planes is a second promising method that will allow an entire memory to be made in one operation. The vacuum deposition of superconductive switching and memory circuits is a third method that will make possible the printing of an entire computer."

Advanced Engineering

The above quotation is from a paper by K. R. Shoulders and the late D. A. Buck (inventor of the cryotron) which was read by A. Baker at the International Conference on Information Processing held recently in UNESCO House in Paris. While the Conference was not by any means restricted to the engineering design of computers, but included sessions and symposia on such things as mathematical methods, linear programming and machine translation of languages, it did contain a group of papers of rather special appeal to electronics people. Summed up by the paragraph above, they dealt with the advanced engineering methods of the future which may well become known as "third generation" computing techniques.

At the moment we have the "first generation" of electronic computers, which are thermionic-valve machines. These are already on the market, and we are now rapidly passing into the "second generation" of transistor and magnetic-core machines, which have emerged from the laboratories and are on the point of becoming commercial. Although the conventional transistor seems an ideal component for computers it does not prevent the researchers from developing this "third generation" idea which sees the manufacture of computers more in terms of chemical processing than electronic assembly.

But what is the real need for this new approach? What advantages does it offer? There is, of course, the ever-present drive towards simpler and cheaper methods of fabrication. But the main purpose of the new line of development is the achievement of higher speeds of operation. At present the speed of information transfer in electronic digital computers is in the region of 10^{6} binary digits per second. Advanced transistor techniques are likely to increase this by a factor of 10 quite soon. But many applications are envisaged for which speeds in the region of 10^{9} bits/second are required. This is particularly true of the future class of computers which will have the property of "learning" by trial-and-error methods and will form part of self-adaptive control systems*. An essential feature of their operation is the execution of a great many random trial calculations before the optimum control condition is obtained, and here extremely high speed is required if the computer has to work in the natural time scale of the control system.

With digit pulses of millimicrosecond length the problem arises of time delays in the transfer of information through the computer due to the finite speed of the conduction of electricity. For electrical signals in free space the upper limit is the speed of light. In solid conductors, a signal travelling a mere matter of 6 to 8 inches takes 1 millimicrosecond. One can see, then, that machines with dimensions and wiring lengths of the order of several feet would create difficulties in the precise timing arrangements which are so important to the correct operation of digital computers (because time intervals represent numerical values).

This means, in general, that no computer for this 10^{9} bits/second order of speed can be much more than 2 feet cubed in size. It also means that such a small size places a limit on the allowable power and heat dissipation of the circuitry. Many conventional electronic components are therefore ruled out, not only on the score of size but also because their power consumption is too high.

Superconductive Components

The three main groups of components which are at present being investigated for possible use in these small-size high-speed computers are mentioned in the opening paragraph—semiconductor "solid circuits," magnetic film devices and superconductive components. All lend themselves to the fabrication of circuitry by "printing" methods, and, in fact, the term used by Buck and Shoulders in their paper is "microminiature printed systems."

Actually this paper is concerned more with superconductive (or "cryogenic" as they are sometimes called) components than the others. It describes experimental work which has the ultimate aim of printing cryotrons small enough to fit into 1-micron squares. Conductors will have to be only 0.1 micron in width. The basis of the method is the selective etching away of a deposited metal film, but some very unusual processes are involved. The original metal film (e.g. lead or tantalum) is deposited on an insulating base by vapour plating. A "resist" or protective pattern is then formed on this by electron bombardment in the presence of hydrocarbon or siloxane vapours. The bombardment causes polymerization of the vapour and so produces a deposit

* See "Learning Machines," *Wireless World*, January, 1959, issue.
† "Superconductivity," *Wireless World*, July, 1957.

on the metal film where the electron beam is directed. Finally, the unprotected metal, not covered by the "resist," is etched away by a vapour process, using a suitable gas for the metal concerned (e.g., chlorine for molybdenum films).

The magnetic devices so far investigated for printed computers are based on very thin magnetic films of a few hundred to about a thousand angstrom units. Very little has been done on logical switching elements but considerable experimentation has been devoted to magnetic storage systems. These consist of regular arrays of small circular spots of magnetic material, a few millimetres in diameter, deposited by evaporation on to glass bases. Each spot acts in much the same way as a ferrite toroidal core in the familiar matrix type of magnetic store. The material has a rectangular hysteresis loop and it can be switched from one direction of magnetization to the other by currents passing through adjacent conductors, which can be printed on both sides of the glass base.

Actually the magnetic spots are given a preferred direction of magnetization, or uni-diametrical anisotropy, by evaporating the material (e.g., Permalloy) on to the glass base in the presence of a steady magnetic field. In operation the spots change from one direction of magnetization to the other by a simple rotation of the magnetization. Coincident-current methods can be used for the driving system, as in the present ferrite toroidal-core type of matrix stores.

A paper by J. I. Raffel and D. O. Smith described an experimental magnetic film store for 32 ten-bit words which used 1.6-mm spots centred 2.5mm apart, but it is thought that spot densities of the order of 1,000 per square centimetre should be obtainable. Apart from this possibility of large storage density, the main advantage of the magnetic film is its low switching coefficient—defined as the product of switching time (microseconds) and applied field (oersteds). This is at least ten times smaller than the value for ferrite toroids, so in general one can obtain much faster switching times and use much smaller driving currents. Experiments have indicated, in fact, that switching times in the range 1-10 millimicroseconds are possible.

Parametric Oscillator Devices

The problem of time delays in high-speed computers can, however, be tackled in another way besides that of straightforward size reduction. The technique is to use lengths of conductors which are precisely related to the phases of the signals—in other words, transmission lines. This, in fact, is being done in experiments on a new class of parametric-oscillator‡ computing circuits working at microwave frequencies. A paper by J. Wesley Leas described a parametric oscillator system which can be used to gate, amplify and store binary information expressed in terms of two possible phases of the oscillation (see Fig. 1). The oscillation frequency was 2,000Mc/s and the pump frequency 4,000Mc/s.

It is probably true to say that this work actually stems from the original discovery in 1954 by Eiichi Goto, a Japanese scientist of Tokyo University, that parametric oscillators can be used for binary computing circuits**. The computing elements so formed were named "parametrons" and were ex-

‡ For explanation see "Mavars," *Wireless World*, May, 1959.
** See, for example, British Patent 778,883 (1954).

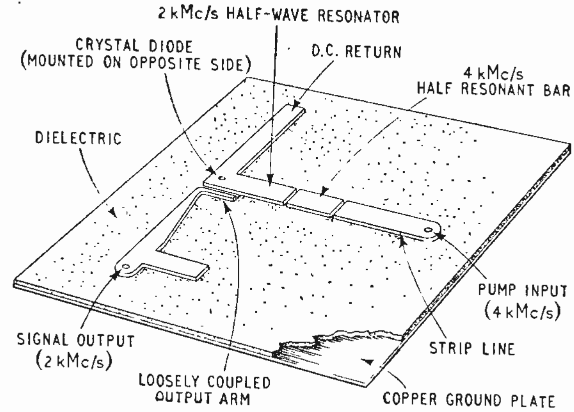


Fig. 1. Construction of microwave parametric-oscillator computing element.

tensively developed in Japan for building digital computers, and now about fifty per cent of the machines in that country make use of them for logical circuitry. It was noticeable in the "Automath" exhibition at the Grand Palais in Paris that, of the 27 exhibitors, four were Japanese firms and all showed parametron computers. (Incidentally, there was only one British stand—Standard Telephones and Cables—and that was present as part of its own international group and displayed a computer designed by a Dutchman.)

As already mentioned, the parametron is basically a parametric oscillator. It has a pump frequency which is twice the oscillating frequency, and the pump signal maintains the parametric oscillation in a resonant circuit by periodically varying the reactance of one tuning element of the circuit. In most of the Japanese machines the variable reactance is a ferrite-cored inductor (see Fig. 2). Because the pump signal is twice the oscillation frequency, it is possible for the oscillation to have either of two phases, 180° apart. These represent the two states, "0" and "1," of the binary circuit. Which state (i.e., phase) the circuit is in at any moment is determined by the forcing or locking effect of the input signal to the parametron. This is a small signal at the oscillation frequency coming from previous parts of the computing system, and it has a phase, representing "0" or "1," which has been determined by previous logical operations.

The linking of parametrons into complete arithmetic circuits is done on the principle of "ballot box" or "majority decision" logic. The outputs of an odd number of parametrons (usually three) converge as primary windings on a transformer whose secondary provides the state-determining signal for the succeeding parametron. If two of the outputs have the "1" phase of signal and the third output has the opposite "0" phase, then by simple cancellation the signal produced at the transformer secondary will have the "1" phase and will trigger the succeeding parametron into the "1" condition.

For "AND" and "OR" gating operations, one of the three inputs to a parametron is arranged to carry a permanent signal, "0" or "1." If a "1" is used for this, a "1" signal applied to either or both of the other two inputs will produce a "1" output at the secondary—that is, an "OR" gate. If a "0" phase is used for the permanent signal input, then a "1" output will be obtained only if a "1" signal is applied to *both* of the other two inputs simultaneously—in other words, an "AND" gate. From such arrangements complete arithmetic circuits can be built up on well-established principles.

Since it is necessary for the parametron to be continually changing its state the oscillation has to be periodically quenched, so that after each quenching it can be started again in a new phase. This is done by a square-wave pulsing system which, in fact, provides the clock pulse or synchronizing signal of the whole computer. Each pulse must, of course, allow several cycles of oscillation to occur in order to establish a binary digit, "0" or "1," on the phase principle, so the clock frequency necessarily has to be somewhat lower than the parametric oscillation frequency. Most of the Japanese machines are restricted by their variable reactors to oscillation frequencies of about 1Mc/s and consequently the clock p.r.f. is limited to the 100kc/s region. This, in fact, is one of the main disadvantages of the existing computers because of the limitation it sets on the speed of the arithmetic circuits.

The obvious way of overcoming this limitation is to use very much higher frequencies of parametric oscillation. This, in fact, is what has been done in the system described by J. Wesley Leas. His 2,000Mc/s oscillator takes the form of a half-wave resonator, constructed on the strip line principle by photographic engraving of a copper-clad insulating board. The variable reactance element in the resonator is a semiconductor diode, and the capacitance of this is varied by the 4,000-Mc/s pump signal delivered through another resonant system. Regarding the device as an amplifier of the small input triggering signals, the gain is about 5 times. With the 4,000-Mc/s pump signal the digit pulse rate can be up to 4×10^{8} pulses per second. Advanced experiments with oscillators using waveguide components and pump frequencies of 10,000Mc/s suggest that digit rates as high as 2×10^{9} pulses per second (2,000Mc/s) might be possible.

A good many sessions at the Conference were devoted to the logical design of computing systems. This subject is nowadays considered more the province of the mathematician or programmer than the electronic engineer, but even so the engineer has to be brought into it eventually. One recent trend in logical design is the speeding up of computation by what amounts to "time and motion study" in the organization of the machine's facilities. Another trend is towards more complete utilization of the computer by systems in which several programmes of calculation can be run at the same time. This idea was exemplified at the "Automath" exhibition by two Continental computers—the French Gamma 60 (Compagnie des Machines Bull) and the German ER56 (Standard Elektrik Lorenz)—both of which were transistor machines.

The basis of the idea is to divide up the computer into a number of autonomous units (for example a storage system can be divided into several sections) which can be used independently instead of acting as a complete interlocking assembly. These units already exist to some extent in conventional computers (e.g., arithmetic unit, store, input equipment, output equipment) but in normal operation are dependent on each other. The calculation proceeds from unit X to unit Y, and while Y is working X is left idle. But in the newer machines, while Y is working X is used for part of another calculation. This system, of course, calls for a central programme control unit for distributing the work (the sections of different calculation programmes) to the units when they become available. It also has to ensure that the several programmes do not become mixed up! In the Gamma 60 machine this programme control unit is called the "central controller"; in the ER56 it is called the "traffic pilot."

"Intelligent Machines"

Other sessions at the Conference dealt with new character recognition schemes based on the morphological rather than the geometrical approach (in which the recognition depends on the positions of "picture elements" relative to the frame of reference). In so far as these morphological methods are able to cope with characters in unfamiliar positions (upside down, say) they might be regarded as more "intelligent" than previous schemes. But perhaps the most advanced sortie into the field of "machine intelligence," as it is called, was a paper delivered by R. Grimsdale of Manchester University which demonstrated the ability of a computer to do crea-

Fig. 2. A unit from a Japanese parametron computer (25 parametrons). The small black semi-circles at the top are the ferrite cores of the variable reactors. Along the bottom are the ferrite cores of the input transformers.

tive thinking. This thinking takes the form of constructing programmes which satisfy certain criteria. The criteria are supplied by human beings, but the human beings have no idea of what form the invented programmes will take. In fact the experimenters admit to being agreeably surprised at the resourcefulness of the machine in producing hitherto unthought-of programmes!

Some degree of randomness is an essential part of creative activity, and in fact the machine operates by generating random sequences of instructions and modifying these by the trial-and-error "learning" process* until the programme conforms to the criteria. For this purpose the programme is performed and tested on a "sub-computer" which is actually the same machine used in a different way. Eventually Dr. Grimsdale and his colleagues hope to devise a thinking machine which will invent its own criteria, based on certain logical concepts. After this, to end with another quotation, "Purposeful thinking to human advantage can only follow if the machine is given contact with the outside world. . . ."

* See "Learning Machines," *Wireless World*, January, 1959, issue.

BOOKS RECEIVED

B.B.C. Engineering Monographs

No. 21 "Two New B.B.C. Transparencies for Testing Television Camera Channels," by G. Hersee, A.M. Brit. I.R.E., and J. R. T. Royle. Pp. 19; Figs. 10.

No. 22 "The Engineering Facilities of the B.B.C. Monitoring Service," by C. J. W. Hill, A.M.I.E.E., A.C.G.I., and H. S. Bishop, Assoc.I.E.E. Pp. 16; Figs. 11. Describes equipment used at the Caversham receiving station.

No. 23 "The Crystal Palace Band I Television Transmitting Aerial," by W. Wharton, A.M.I.E.E., and G. C. Platts, B.Sc. Pp. 15; Figs. 9.

No. 24 "The Measurement of Random Noise in the Presence of a Television Signal," by L. E. Weaver, B.Sc., A.M.I.E.E. Methods based on the sampling of random noise in minimum energy regions of the video spectrum. Pp. 16; Figs. 5.

The price of the above, which are obtainable from B.B.C. Publications, 35 Marylebone High Street, London, W.1, is 5s each.

Metal Industry Handbook and Directory 1959. General properties of non-ferrous metals and alloys, tables of data and lists of suppliers. Pp. 564+XVI. Price 21s. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1.

Radio Engineer's Pocket Book, by F. J. Camm. Twelfth edition of a compendium of useful formulæ and figures. Pp. 178. Price 6s. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2.

British Standard Specifications

3040: 1958. "Radio-frequency Cables for use with Domestic Television and V.H.F. Receiving Aerials." Pp. 15. Price 4s 6d.

3041: 1958. "Television and V.H.F. Broadcast Receiving Aerial Feeder Connectors." Pp. 10; Figs. 3. Price 4s.

3045: 1958. "The Relation Between the Sone Scale of Loudness and the Phon Scale of Loudness Level. Pp. 7. Price 3s.

3081: 1959. "Basic Dimensions for Printed Wiring." Recommendations for rectangular grid dimensions, fixing holes, strip width and minimum spacing, etc. Pp. 6. Price 3s.

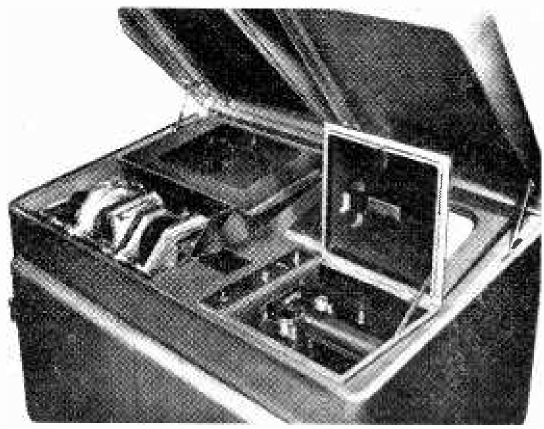
2134: Part I: 1959. "Fixed Electrolytic Capacitors." General requirements and tests. Pp. 15. Price 7s 6d.

The above are obtainable from British Standards Institution, 2 Park Street, London, W.1.

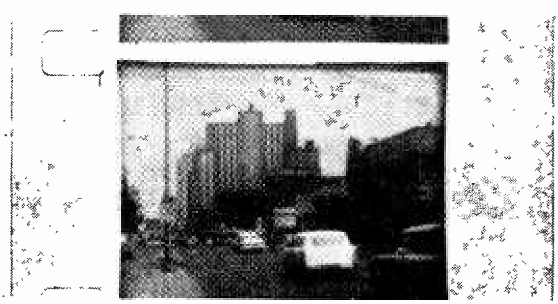
Electronic Apparatus for Biological Research, edited by P. E. K. Donaldson. Contains a great deal of standdard electronics theory and practice, but with some chapters on transducers, electrodes and complete circuits peculiar to biological work. Pp. 730; Figs. 949; Plates 47. Price £6. Butterworths Scientific Publications, 4 and 5 Bell Yard, London, W.C.2.

Noise in Industry. Edited by A. E. Stevens, B.A. (Oxon), B.Sc., F.Inst.P. A review of the effects of noise on hearing and possible methods of amelioration. Pp. 6. Issued for the information of managements by Amplivox, Ltd., 2 Bentinck Street, London, W.1.

High-speed Facsimile



Film scanning unit developed by the B.B.C. for the rapid transmission of motion pictures over the transatlantic cable for subsequent TV broadcasting. A specimen frame of 16 mm film, as received, is shown (below). Some details of the system are given on page 362 of this issue



WORLD OF WIRELESS

International Regulations

AT irregular intervals an international conference is called by the International Telecommunication Union to revise the regulations on which the operation of all radio services is based, and to deal with technical and administrative matters coming within the terms of the International Telecommunication Convention.

The revision of the regulations now in use, which were drawn up at Atlantic City in 1947, is the main task of the conference which opened in Geneva on August 17th. It is at this conference that the block allocation of frequencies to the various radio services (broadcasting, marine, aeronautical, telecommunications, mobile radio, amateurs, etc.) is decided.

A delegation of 45, led by Capt. C. F. Booth of the General Post Office, is representing the U.K. at this conference. The delegation includes representatives of various Government Departments, the Armed Forces, B.B.C. and I.T.A., as well as advisers from operating agencies and other organizations.

The conference is expected to last four months.

"Live" v "Mono" v "Stereo"

AS a result of the interest shown in his Royal Festival Hall demonstrations of mono and stereo sound reproduction, G. A. Briggs has decided to carry the experiment a stage further at a lecture-demonstration to be held at the Colston Hall, Bristol on October 9th. For this purpose he is having special recordings made of solo and concerted items in which all available resources will be employed to obtain the best possible recordings by both mono and stereo techniques. We believe this will be the first occasion on which a comparison between live performances and both monodic and stereophonic reproductions of the same items has been attempted in public.

College of Technologists

LAST November the National Council for Technological Awards announced its proposal to create an award higher than the Diploma in Technology, to be known as the M.C.T. (Membership of the College of Technologists). This college, which is an administrative and not a teaching body, will operate within the framework of the National Council for Technological Awards.

A Board of Scientific and Industrial Studies is to be responsible for the academic and industrial aspects of the administration of the new award and among its fifteen members are:—Dr. R. C. G. Williams (Philips' chief engineer), Dr. G. B. B. M. Sutherland (director, N.P.L.) and Dr. J. S. Tait (principal, Northampton College of Advanced Technology).

The Council's intention is that this award should be a "mark of outstanding distinction granted to a student who has proved his ability by completing a substantial programme of work demanding the application of his knowledge to the solution of a problem of value to industry".

Medical Electronics

AT the second International Conference on Medical Electronics held in Paris at the end of June* a new international organization was formed under the presidency of Dr. V. K. Zworykin. It is to be known as the International Federation for Medical Electronics and its object will be to encourage the dissemination of information on medical electronics.

One of its functions will be to sponsor international congresses at regular intervals and the next will be held in this country in July, 1960. This conference is being organized by the Electronics and Communications Section of the Institution of Electrical Engineers. It is also planned to hold an international scientific exhibition on medical electronics in conjunction with this conference.

British members of the committee of the International Federation for Medical Electronics are Dr. C. N. Smyth, of University College Hospital, who is a vice-president; B. Shackel (E.M.I. Electronics), treasurer; W. J. Perkins, of the National Institute for Medical Research; and Dr. R. C. G. Williams, of Philips Electrical.

*A report on the Conference will be published in our next issue.—ED

B.B.C. Satellites

BY the end of this year the B.B.C. will have 23 television stations in operation and these will serve about 98.7 per cent of the population. There will also be a v.h.f. sound service for about 96.4 per cent of the population from 21 stations. The problem of bringing TV and the v.h.f. sound service to the remaining areas—many of them sparsely populated—is being solved by building a number of low-power satellites. Most of the stations will be unattended "translators" which will pick up signals from an existing B.B.C. station and re-transmit them on a different frequency. Initially there will be 14 TV stations, all in Band I, and eight of them will also be equipped with v.h.f. sound transmitters. V.H.F. sound is also being added to two existing television stations—Londonderry and the Channel Islands.

The new stations will be at Berwick-on-Tweed, Fort William, Galashiels area, Llandrindod Wells area, Loch Leven, Oban, Oxford/Berkshire, West Cornwall, Barrow/Lancaster area, Enniskillen area, Ipswich area, Pembroke/Milford Haven area, Sheffield, and Skegness. The first eight of these stations will be equipped for both TV and v.h.f. sound.

The Radio Industries Club, which now has a membership of nearly 1,000, has elected Dennis Curry, a joint managing director of Currys Ltd., as president in succession to Sir Robert Fraser, Director General of the I.T.A. He is the first "retailer" president. The new chairman in succession to L. A. Sawtell (Mullard) is A. E. Bowyer-Lowe, and the new vice-chairman H. C. Roberts (Cossor). W. E. Miller (Trader Publishing Co.) has relinquished the honorary secretaryship of the club which he had held for 19 years. Harold Curtis, until recently with the Radio and Televsion Retailers' Association, has been appointed secretary.

I.E.E. Council.—The new president of the I.E.E. for 1959-60 is Sir Willis Jackson (Metrovick). The two newly elected vice-presidents are G. S. C. Lucas (B.T.H.), and O. W. Humphreys (G.E.C. Research Laboratories). Among the new ordinary members of the council are Professor H. E. M. Barlow, of University College, London; C. O. Boyse (A.T. & E.); L. Drucquer (B.T.H.); H. G. Nelson (English Electric); and G. A. V. Sowter (Telcon).

I.E.E. Electronics and Communications Section.—The following have been elected to fill the vacancies which will occur on the Committee of the Electronics and Communications Section of the I.E.E. in September:—M. J. L. Pulling (B.B.C.), chairman; J. A. Ratcliffe (Cavendish Laboratory), vice-chairman; P. A. T. Bevan (I.T.A.); Dr. J. Brown (University College, London); L. J. I. Nickels (Standard Telecommunications Laboratories); N. C. Rolfe (Newmarket Transistors and Cathodeon Crystals); and C. Williams (R.A.E.).

Audio Fairs Ltd., the non-profit making organization set up a few years ago by a group of audio equipment manufacturers to sponsor the London and provincial Audio Fairs has moved to 22 Orchard Street, London, W.1. (Tel.: Welbeck 9111.) V. G. P. Weake, director of Pamphonic Reproducers Ltd., and Bryan Savage Ltd., has been elected chairman of the council. M. L. Berry (Trix) is vice-chairman and L. H. Brooks continues as secretary. Other members of the council are:—D. A. Lyons (Trix), J. Maunder (Vitavox), Hector V. Slade (Garrard), G. E. Spark (Garrard) and T. R. B. Threlfall (Pye Records).

The Television Society announces that a new centre is being formed in the Cardiff area and that the Leicester centre is being revived. Readers in these areas can obtain information regarding these sections from the Society's headquarters, 166 Shaftesbury Avenue, London, W.C.2.

A full-time course (October to May) for students wishing to sit for Part III of the I.E.E. examinations is again being organized by the South East London Technical College. Information regarding the course, for which the fee is £17, is obtainable from the Department of Electrical Engineering and Applied Physics, Lewisham Way, London, S.E.4.

Information Engineering.—An advanced 12-month course in information engineering is again being held at the University of Birmingham from October. On the satisfactory completion of the course graduates can qualify for the degree of M.Sc. Subjects available cover communications, radar, computers and control systems with some degree of choice to suit individual requirements. (Fee £81.)

Dip. Tech. Course.—Dr. G. N. Patchett, head of the Department of Electrical Engineering at the Bradford Institute of Technology, has sent us a brochure giving details of the four-year electrical engineering sandwich course for the Diploma in Technology provided at the College. Specialization in electronics with additional physics is provided for in the final years.

A.F.C.E.A.—The new president of the London Chapter of the Armed Forces Communications and Electronics Association is Col. J. A. Plihal of the U.S. Air Force. Being an American organization the officers of the Chapter are Americans but there are also British associate officers. The recently elected associate vice-presidents are:—Sir Harold Bishop (B.B.C.), Henry Chisholm (Cossor), Maj. Gen. E. S. Cole (War Office), Henry G. A. Kay (Benjamin), and Sir Reginald Payne-Gallwey. The associate treasurer is P. D. Canning (Plessey) and the associate secreary L. T. Hinton (S.T.C.).

Society of Relay Engineers.—The offices of the Society have been transferred from Kettering to Obelisk House, Finedon, Northants (Tel.: Finedon 204). The secretary is T. H. Hall.

Computer Development.—The National Research Development Corporation is to give its support to Ferranti and E.M.I. Electronics in further development work on advanced high-speed computers. E.M.I. have been collaborating with the N.R.D.C. for the past four years in the development of large business computing systems which has resulted in the production of the EMIDEC 2400. The new programme will be devoted to the development of the EMIDEC 3400 suitable for large-scale high-speed scientific work. The experience gained from the operation of Ferranti computers has shown the need for the new very powerful high-speed computer now proposed—the ATLAS—for both scientific research and development and for data processing.

Reliability.—The sixth American National Symposium on Reliability and Quality Control in Electronics will be held in Washington, D.C., from January 11th to 13th, next year. Information regarding the submission of papers and attendance at the Symposium may be obtained from R. Brewer, of the Research Laboratories, The General Electric Co., Wembley, Middlesex.

Automatic Control.—The first International Congress for Automatic Control is to be held in Moscow from June 25th to July 5th next year. It is being held under the auspices of the International Federation of Automatic Control, of which the British Conference on Automation and Computation is the U.K. national member. The secretary of the I.F.A.C. is Dr.-Ing. G. Ruppel, Prinz-Georg-Str. 79, Dusseldorf, Germany.

"**Photo-Emission**" is the title of the latest film in the advanced science series for sixth forms and technical colleges which is issued by the Mullard Educational Service. It runs for 18 minutes on 16-mm black and white sound film. It can be hired together with comprehensive teaching notes from the Educational Foundation for Visual Aids, Film Library, Brooklands House, Weybridge, Surrey.

Two new I.T.A. stations are scheduled to come into service in October; the East Anglian station on the 27th and the Northern Ireland transmitter on the 31st. The Mendlesham, Suffolk, station will radiate in channel 11, with an e.r.p. of 200pW, and the Black Mountain, Belfast, station in Channel 9 with an e.r.p. of 100kW. Both stations employ directional aerials with horizontal polarization.

Isle of Man V.H.F.—The B.B.C.'s transmitting station at Douglas, Isle of Man, which has been radiating one v.h.f. sound programme since December, 1957, now broadcasts all three sound programmes. The frequencies are 88.4Mc/s (Light); 90.6Mc/s (Third) and 92.8Mc/s (Home). The mean e.r.p. is 3.3kW.

Brighton.—The B.B.C. has recently brought into service a permanent television transmitter at Whitehawk Hill, near Brighton, to replace the temporary transmitter at Truleigh Hill which has been in use since early 1953. It operates in the same channel (2).

Receiving licences in the U.K. at the end of June totalled 14,847,483. The number of combined television/sound licences increased by over 82,000 to 9,495,183. Sound-only licences were 5,352,295—a decrease of nearly 27,000.

Reunion Dinner of R.A.F. radio ex-apprentices is being organized for September 19th at the Grand Atlantic Hotel, Weston-Super-Mare. Particulars from Flt. Lt. E. C. Hargest, No. 1 Radio School, R.A.F., Locking, Somerset.

Correction.—We have been asked to point out that in the advertisement on p. 104 of the June issue relating to the Mazda 6F23 r.f. pentode, the vertical (anode and screen current) scale of the bottom left-hand set of curves should be doubled, i.e., each division should represent 5 and not 2.5 mA.

Personalities

Rear Admiral K. R. Buckley, M.I.E.E., M.Brit.I.R.E., Director of the Naval Electrical Department, Admiralty, since July 1958, assumes the new title of Chief Naval Electrical Officer under the reorganization of the material and personnel departments of the Admiralty. He also becomes Director of Engineering and Electrical Training. Rear Admiral Buckley commanded H.M.S. *Collingwood*, the naval electrical school at Fareham, Hants., for two years prior to 1957 when he was appointed Command Electrical Officer at Portsmouth.

Sir Willis Jackson, the 1959/60 president of the Institution of Electrical Engineers, has been Director of Research and Education with Metropolitan-Vickers since 1953. For the previous seven years he had occupied the chair of electrical engineering at the Imperial College of Science and Technology. From 1938 to 1946 he was professor of electrotechnics at Manchester University. Sir Willis, who was appointed a Knight Bachelor in last year's Birthday Honours, has served on many advisory councils and committees including the Scientific Advisory Council, Ministry of Supply (1947-1954), and the Research Council of the D.S.I.R. (since 1956).

Sir WILLIS JACKSON

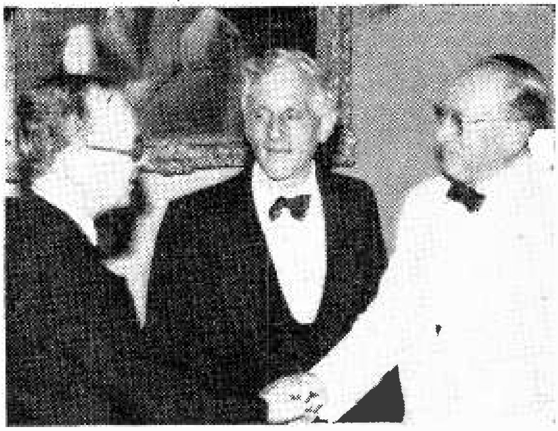
M. J. L. PULLING

M. J. L. Pulling, C.B.E., M.A., who is elected chairman of the Electronics and Communications Section of the I.E.E. for the ensuing year, is Controller, Television Service Engineering, in the B.B.C. He joined the Corporation in 1934 and was superintendent engineer (recording) from 1941 until 1949 when he took charge of the television side of the engineering division. After graduating at King's College, Cambridge, in 1928 and spending a further year in the University radio laboratory he was for five years in the radio industry before he joined the B.B.C.

J. A. Ratcliffe, C.B.E., F.R.S., the new vice-chairman of the I.E.E. Electronics and Communications Section, is reader in physics in the Cavendish Laboratory, Cambridge. He is chairman of the Radar and Signals Advisory Board of the Ministry of Supply Scientific Advisory Council and was appointed to the recently formed National Committee on Space Research.

F. E. Godfrey, assistant secretary of the Radio Industry Council for nearly eleven years, has retired. At the R.I.C., Mr. Godfrey has been concerned with education and training for the industry and administered the R.I.C. training scheme for technicians from its inception in 1952.

N. W. Hunt, chief engineer of Cathodeon Crystals, Ltd., of Linton, Cambridge, since its formation in 1953, has been appointed manager of the crystal division of Pye Proprietary Limited, of Melbourne, Australia.



Honorary Membership of the Brit.I.R.E. was awarded to E. K. Cole (left) and Dr. V. K. Zworykin (right) at the Institution's convention, held at Cambridge University (see page 335). Here they are congratulating each other just after the ceremony in the presence of Professor E. E. Zepler, president of the Institution.

Dr. Henry Boot and **Professor John Randall,** F.R.S., are among this year's recipients of the American John Scott Award for "developing inventions for the benefit of mankind." They will each receive $1,000 for their invention of the cavity magnetron. Dr. Boot, who was at Birmingham University, is now at the Services Electronics Research Laboratory, Baldock, Herts. Professor Randall is Wheatstone Professor of Physics at London University (King's College).

H. Carleton Greene, O.B.E., who is to succeed **Sir Ian Jacob** as Director-General of the B.B.C. at the end of the year, joined the Corporation in 1940 as German editor, in the European Service. For two years immediately after the war he was in charge of broadcasting in the British Zone of Germany. Four years ago Mr. Greene, who is 48, headed the commission set up to advise on the formation of a broadcasting organization in the Federation of Rhodesia and Nyasaland.

Martin Ryle, F.R.S., will be the first to occupy the Chair of Radio Astronomy established at the University of Cambridge. He will take up his appointment on October 1st. Mr. Ryle left Oxford University in 1939 with an M.A. degree and joined the Telecommunications Research Establishment where he worked on radar applications until the end of the war. He then went to Cambridge as lecturer in physics at the Cavendish Laboratory and more recently transferred to the Mullard Radio Astronomy Laboratory at the University.

Paul Adorian, M.I.E.E., M.Brit.I.R.E., managing director of Associated Rediffusion, Ltd., has had the Fellowship of the City and Guilds of London Institute (F.C.G.I.) conferred upon him for his work in the fields of radio relaying, flight simulators and tactical teachers. He studied at the City and Guilds College from 1927 to 1932.

George S. C. Lucas, O.B.E., M.I.E.E., director and chief engineer of B.T.H., has been made an F.C.G.I. "for radar and electronic research and services in technical education." He joined the B.T.H. research laboratories in 1925 and was head of the electrical and development section from 1932 until 1944 when he became head of the electronics engineering department.

Dr Manfred von Ardenne, who is well known for his television research work in the early 1930s, is now actively engaged in the field of medical electronics and read two papers at the recent Paris Medical Electronics Conference. He is now in a research institute in Dresden, East Germany.

Dr. Louis Essen, of the Standards Division of the National Physical Laboratory, which he joined in 1929, has been awarded the A. S. Popov Gold Medal by the Academy of Sciences of the U.S.S.R. This is the first time this medal, awarded for "the most distinguished scientific work in the field of radio-engineering performed during the period 1956-1958," has been given to a scientist outside the Soviet Union. The outstanding achievement which has won Dr. Essen this recognition has been his work leading to the establishment of an atomic frequency standard as a possible basis for the future standard of time.

Dr. L. ESSEN

E. E. ROSEN

Edward E. Rosen, managing director of Ultra Electric, has been elected chairman of the Radio Industry Council in succession to **G. Darnley-Smith** (Bush Radio), who has held the office for the past seven years and one year previously. Mr. Rosen joined Marconi's in 1913 as a pupil and after serving in the 1914-18 war in the Royal Flying Corps, started his own company (Edward E. Rosen & Co.) in 1920 for the manufacture of headphones and loudspeakers. The company became Ultra Electric, Ltd., in 1923. **Hector V. Slade** (Garrard Engineering) is the new vice-chairman of the Council. Mr. Slade is this year's chairman of the Radio and Electronic Component Manufacturers' Federation.

D. Q. Fuller, A.M.I.E.E., who in 1950 was made responsible for the early experimental work on transistors undertaken by the Pye Group, has been appointed director of engineering of Newmarket Transistors, a member of the group. Newmarket Transistors also announce the following appointments: **George Roman,** Dipl.Ing., who joined the company in 1956, becomes chief physicist; **John B. Haggis,** Grad.I.E.E., who has been with the Pye Group since 1945 and was working on television camera tube development with Cathodeon until 1954 when he transferred to Newmarket Transistors, is appointed chief production engineer; **T. D. Towers,** M.B.E., M.A., Grad.Brit.I.R.E., who joined the company as a circuit applications engineer early last year, becomes chief development engineer.

C. Ross, Grad.Brit.I.R.E., whose article on magnetic heads is on page 321, has been working on professional 16-mm magnetic recording equipment in the research and development laboratory of Kelvin & Hughes at Hillington, Glasgow, since 1957. After serving an apprenticeship with E.M.I. Engineering Development, Ltd., he worked as a technical assistant in the company's magnetic recording development laboratory specializing in magnetic heads until 1957, when, for a short while before joining Kelvin & Hughes, he was attached to E.M.I. Studios.

A. N. Thomas, who, as reported in our May issue, recently retired from the B.B.C., has joined Pye Ltd., as overseas consultant in the sales department of the Television Transmission Division.

F. Duerden, B.Sc.(Hons.), A.M.I.E.E., has been appointed manager of the electronics department of Bruce Peebles and Co. Ltd., of Edinburgh, in succession to **J. W. Haig Ferguson,** M.A.(Cantab.), A.M.I.E.E., who has become divisional director. Mr. Duerden graduated at Manchester University and started his professional career in Marconi's research and development department. He then served as a radar officer in the R.A.F. and after the war joined Ferranti's, where he remained until joining Bruce Peebles as chief electronic engineer in 1956.

BIRTHDAY HONOURS

Among the recipients of honours in the Queen's Birthday List are several who took a leading part in the organization of the International Geophysical Year. They include **Professor Sir David Brunt** (K.B.E.), **Professor W. J. G. Beynon** (C.B.E.), and **J. MacDowall** (O.B.E.).

Leslie C. Gamage, chairman and managing director of the General Electric Company, receives a knighthood; **A. V-M. Leslie Dalton-Morris,** who became Air Officer Commanding on the formation of the R.A.F. Signals Command, is promoted to K.B.E.; and **Group Captain G. R. Scott-Farnie,** managing director of International Aeradio Ltd., becomes a C.B.E.

Among the new O.B.E.s are: **Commander K. B. Best,** R.N.(Retd.), director of communications at the Home Office; **A. M. Beresford-Cooke,** head of planning and construction, Engineering Department, I.T.A.; **M. Davenport,** principal, London Communications Electronic Security Agency; **R. C. Harman,** head of operations and maintenance, Engineering Department, I.T.A.; **C. J. V. Lawson,** engineer-in-chief, Cable & Wireless; **H. O'Neill,** general secretary and treasurer, Radio Officers' Union; **C. J. Strother,** assistant to chief engineer, B.B.C.; and **W. A. J. Thorn,** deputy director (telecommunications), Ministry of Transport and Civil Aviation.

New M.B.E.s include: **A. L. Budd,** chief telecommunications superintendent, Air Ministry; **I. Davies,** lately communication officer, H.M. Embassy, Djakarta; **S. F. Hodge,** manager, International Aeradio Ltd., Sharjah; **W. H. Mitchell,** experimental officer, Royal Radar Establishment; **G. W. R. Robinson,** communications officer, H.M. Embassy, Washington; **R. E. G. Trembath,** International Aeradio's representative at Hargeisa, Somaliland; **N. Walker,** senior executive engineer, Engineer-in-Chief's office, G.P.O.; and **E. F. Woods,** assistant to superintendent engineer, lines, B.B.C.

Recipients of the British Empire Medal include: **A. L. Adams,** chargehand, Marconi's W.T. Co.; and **R. A. Grace,** instrument maker, E.M.I. Electronics.

OBITUARY

William Theodore Ditcham, A.M.I.E.E., who was associated with Capt. H. J. Round at Marconi's in the early development of direction finders during the first world war and with the experimental broadcasts from Chelmsford in 1920, has died in his 79th year. From 1925 to 1944 Mr. Ditcham was in charge of the development of Marconi's broadcasting transmitters, and was assistant engineer-in-chief when he retired in 1949 after 34 years with the company.

Geoffrey Bennett, manager of the Liverpool factories of Automatic Telephone & Electric Co. Ltd., died on April 27th aged 45. He started his career in telecommunications with the British Post Office and joined A.T.E. in 1945 after leaving the Royal Corps of Signals, in which he held the rank of Lieutenant Colonel.

Eric Frederick Kerridge, who was in charge of the technical publications department of Ferguson Radio Corporation, has died at the age of 45. He joined the company in 1942.

News from the Industry

Wharfedale Wireless Works, Ltd., the loudspeaker manufacturers of Idle, Bradford, Yorks, have been acquired by the Rank Organization. G. A. Briggs, the founder and managing director, who is well known also for his books and lecture-demonstrations, has agreed to remain in active management as have all the other executive directors.

Avo.—Changes are announced in the board of Avo, Ltd., which recently became a member of the Metal Industries Group. Sir Charles Westlake, chairman of Metal Industries, becomes chairman of the board of Avo with J. H. Rawlings, Avo's managing director, as deputy chairman. Other new directors are John Black, a director of M.I., and H. O. Houchen, managing director of Brookhirst Igranic, another M.I. subsidiary, recently formed to merge the interests of Brookhirst Switchgear, Ltd., and Igranic Electric Co. Mr. Rawlings is to be appointed to the board of Brookhirst Igranic.

The Plessey Company has concluded an agreement with Elettronica Metal Lux s.p.a., of Milan, Italy, providing for the manufacture of Metallux resistors in the U.K. Plessey, who for the past 18 months have been U.K. agents for these metal film resistors, will hold, in addition to sole manufacturing rights in this country, selling rights for both the U.K. and all Commonwealth countries.

Bendix Aviation Corporation, of America, has concluded an agreement with Cossor Radar & Electronics, Ltd., whereby it obtains from Cossor know-how and patent licences for the manufacture of secondary radar airborne transponders.

P.A.M. Ltd., of Merrow, Guildford, manufacturers of Nera large-screen television equipment, have been absorbed by Tyer and Co., of Dalston, who are moving to the Guildford factory where they will continue the work previously undertaken by P.A.M. Both companies are subsidiaries of the Southern Areas Electric Corporation.

Anglo-French Collaboration.—In October, 1957, Marconi's W/T Co. and Compagnie Générale de T.S.F. agreed to collaborate in certain aspects of N.A.T.O. work. Their proposals for the provision and installation of equipment for all stations in the Early Warning radar chain have now been accepted and contracts totalling nearly £7M are being placed by the governments concerned.

Ferranti, Ltd., have received an order from Bruce Peebles & Co., of Edinburgh, for a £60,000 Pegasus digital computer. Initially, the computer, which will be installed next year, will be used for fundamental research and design calculations, and although priority will be given to Bruce Peebles' own work, the machine will be made available to other firms or organizations wishing to make use of it.

E.M.I. Electronics Ltd., are to supply a large EMIAC II computer to de Havilland Propellers Ltd., Hatfield, as an additional aid to research into guided missiles and other problems associated with high-speed flight. The installation will consist of twenty-two modules and cost £52,000.

Electrode Welding Co., Ltd., of Cobbold Road, London, N.W.10, has been appointed sole representative in the United Kingdom for electron gun mounts manufactured by Superior Electronics Corporation, of Clifton, New Jersey, U.S.A.

Decca Navigator, Mk. 10, receiver has been re-engineered to the ARINC (Aeronautical Radio Inc.) specification to fit American aircraft racking. The new receiver will be known as the Mk. 10A (Type 900).

Armstrong Whitworth Aircraft Ltd., of Coventry, have taken over the Technical Developments Division of Gloster Aircraft Company. Both are members of Hawker Siddeley Aviation Limited. The merger brings together two departments producing a complementary range of equipment with a wide application in the fields of instrumentation, automation and radio communication as well as aircraft and guided missile systems as a whole. E. W. Absolon, who has been chief engineer at T.D.D., has been appointed manager of the new division and A. E. Martin, who has been in charge of A.W.A. Commercial Electronics Department, moves to Gloucester as deputy divisional manager.

Standard Telephones and Cables have received an order from Cable & Wireless for the supply of 92 submerged two-way repeaters and eleven equalizers for the Scotland-Newfoundland section of the proposed Commonwealth round-the-world telephone cable. The repeaters, each containing duplicate three-valve amplifiers, will be inserted in the cable at intervals of about 23 nautical miles. The equalizers, for correcting inequalities of signal strength at different frequencies, will be inserted in the cable at intervals of some 200 miles. The order is valued at about £1.8M.

COMPANY REPORTS

Ekco.—The Ekco group of companies, which includes E. K. Cole, Ltd., Ferranti Radio and Television, Dynatron, and Egen Electric, had a net profit after taxation of £459,225 in the year ended in March, an increase of £142,474 on the previous year.

Thorn Electrical Industries.—Group trading profits for the year ended last March amounted to £2,953,536. After deducting all charges, including taxation at £927,257, the net profit was £979,371 compared with £681,832 in the previous year.

Vickers, Ltd.—Reference is made in the annual review of Vickers to the Hollerith-Powers Samas merger in which the company now has a holding of 38 per cent of the equity in International Computers and Tabulators, Ltd., the new title of the merged companies.

Ferranti Ltd.—Consolidated profit for the year to March 31st was £2,419,865 compared with £1,252,971 for the previous year. After provision for tax the net profit was £1,104,572 against £575,971 last year.

Rediffusion, Ltd., which holds a 37½% interest in the television programme contractors, Associated-Rediffusion, reports a group trading profit of £4.29M for 1958/59 which was £280,000 more than in the previous year. The group also includes Redifon, Ltd., and Rediweld, Ltd.

Elliott-Automation.—The accounts for the first full financial year of the Elliott-Automation Group show a net profit after taxation of £458,628. The Group was formed in August, 1957, with the merging of Elliott-Brothers (London), Ltd. and Associated Automation, Ltd.

Garrard.—Profit for the year ended in January was £545,590 of which £264,462 will be absorbed by taxation.

International Aeradio, Ltd., in which 17 international airline operators are shareholders, had a gross group turnover during 1958 of just over £2M, an increase of £200,000 on the previous year.

Ever Ready Company (Great Britain), Ltd., announce a consolidated net profit (after allowing over £1M for taxation) of £1,262,856 for the year ended in February. This was an increase of £342,757 on the previous year.

OVERSEAS TRADE

Radio link between Newfoundland and the Canadian mainland, used initially for television during the Queen's recent Canadian tour, includes the world's longest microwave over-water path. Standard Telephones and Cables' s.h.f. automatic space diversity equipment is used for the 70-mile relay across the Cabot Straits in order to combat the difficult transmission conditions caused by the rise and fall of tidal waters. In all, twenty-three S.T.C. relay stations are used to cover the 524 miles between St. Johns, Newfoundland, and Sydney, Nova Scotia. The link provides for 600 two-way telephone circuits in addition to a television link in either direction.

Facsimile equipment, valued at over £85,000 and supplied by Muirhead, has been installed by a Japanese newspaper publisher. The equipment is used to transmit by radio from Tokyo complete pages of the newspaper which when received at Sapporo, on the island of Hokkaido, 500 miles away, are used for off-set printing, so that the paper is available almost simultaneously in both places—the actual delay is said to be 75 minutes.

Autosonic inspection equipment to the value of £10,000 has been ordered from Kelvin Hughes for the Chomutov steel works in Czechoslovakia. The equipment will facilitate the automatic scanning of rolled mild steel bars of up to 7.9in diameter and will mark and reject any material containing internal defects in excess of a predetermined degree.

Sound and vision transmitters, combining filters and programme input and ancillary equipment for five new Band III television stations under construction in Sweden are to be supplied by Marconi's. One of the stations, at Borlänge, will have two sets of transmitters operating in parallel, and will have a vision e.r.p. of 60kW. The remaining four stations will each have single transmitters feeding into a directional aerial. These will have different gain factors, so that the respective e.r.p.s will range from 10kW to 60kW.

Communication Receivers.—A contract for the supply of 350 radio-telephone receivers to the Canadian Department of Transport has been secured by Plessey International Ltd. The receivers, which will be used in aeronautical and other services, are designated PR51c and form part of the Plessey PR51 range of single-channel h.f. receivers.

Weather Radar.—Two international Swiss airports, near Geneva and Zurich, are to be equipped with Decca weather radar. Both installations will be on high ground some distance from the airfields, with radio links to relay the radar information to the airfield meteorological offices.

Closed circuit television equipment is being supplied by E.M.I. Electronics for installation in a large gold mine in Ghana. Three cameras, mounted at vantage points to scan the working area and linked to receivers in the offices of the security officer, are being installed as an added security measure against pilfering.

Airborne ILS/VOR equipment, for installation in the Soviet Aeroflot TU104 jets used on the Moscow-London route, has been ordered by the Russian Purchasing Authority from Standard Telephones and Cables.

I.L.S.—Two Pye instrument landing systems are to be installed at Moscow airport. The contract is worth about £100,000.

Radar for the double-ended ferries on the Manhattan-Staten Island service, New York, is to be supplied by Decca. This order, valued at over $106,000, is for twenty-three sets and brings the total to 37 supplied by Decca for the New York Ferry Services.

Communications equipment valued at £73,000 has been supplied by Racal Engineering Ltd., for the Canadian Government. The consignment includes over 100 RA.17 communication receivers and ancillary equipment.

Iran.—The representation in Iran of a British manufacturer of sound radio and television receivers is sought by Sherkat Nesbi Bafandegi Baradaran Jurabchi, near Saray Haj Hassan Bazar, Teheran. They ask for a descriptive catalogue and wholesale export prices.

Canada.—Ray Hamerton Ltd., of 317 Fort Street, Winnipeg 1, Manitoba, wishes to take up the agency for British-made loudspeakers, amplifiers and turntables which are not already represented in the province.

NEW ADDRESSES

Kelvin House, Wembley, Middx., is the new headquarters of the Aviation, Marine and Industrial Divisions of S. Smith and Sons, which includes Kelvin-Hughes and Smith's Aircraft Instruments.

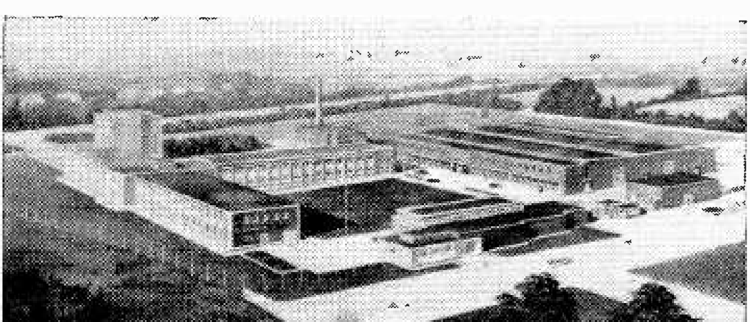
Technograph.—The new London office of Technograph Printed Circuits, Ltd., and Technograph Electronic Products, Ltd., is at Eros House, 29-31, Regent Street, S.W.1. (Tel.: Regent 5273.)

Siemens Edison Swan's London district office has been transferred to Crown House, Aldwych, W.C.2 (Tel.: Temple Bar 8040). The stores will remain at Tyssen Street, Dalston, E.8.

Telerection Limited, aerial manufacturers, have opened a new factory in Weymouth and closed their Cheltenham plant. The address is Antenna Works, Lynch Lane, Weymouth (Tel.: Weymouth 2140).

Decca Radio and Television Ltd., have moved their offices and factory from Brixton Road, London, S.W.9, to Ingate Place, Queenstown Road, London, S.W.8. (Tel.: Macaulay 6677.) The spares and service department is still at Brixton Road (Tel.: Reliance 6011).

CQ Audio, Ltd., manufacturers of sound reproducing equipment, whose premises in Sarnesfield Road, Enfield, were severely damaged by fire some months ago, have taken possession of a new factory at Bush Fair, Tye Green, Harlow, Essex (Tel.: Harlow 24566).



Headquarters of A.E.I. Electronics Apparatus Division (incorborating BTH and M-V) at New Parks, Leicester, opened by Rt. Hon. Aubrey Jones, M.P., Minister of Supply, at the end of June. With a total floor space of 180,000 sq ft, the new building comprising factory (right), offices and laboratories (T-shaped block, left and rear-centre) and canteen (front centre).

Magnetic Tape Heads

Factors Influencing Their Design and Construction

By C. ROSS, *Grad. Brit. I.R.E.*

MAGNETIC recording has a wide variety of applications, and the magnetic head can be considered the "heart" of the machine, for its performance governs to a high degree the capabilities of the recording machine. The advent of ferrites has made high-frequency recording possible, and improved the performance of the audio range recorders also. In general, the highest frequency that it is desired to reproduce governs the speed of the magnetic tape across the magnetic heads. Tape speeds for instance, of the order of 0.25 in/sec may be used for very low frequency recording or conversely, speeds of 200 in/sec and above are used for high-frequency work. For high quality sound recording, which this article is based upon, speeds of 7.5 to 30 in/sec are in common use. The replay head provides a limitation to the maximum number of cycles of magnetic signal per inch of recording media which can be resolved satisfactorily.

There are three main factors to be considered when dealing with tape heads and associated circuits. They are frequency response, distortion and signal to noise ratio. Good quality magnetic heads are now commercially available and with suitable circuits will perform satisfactorily up to a frequency limit of 1800—2000 cycles per inch per second.

Almost without exception in the high-quality professional field, the recording machine has three heads mounted on an easily detachable rigid plate. The tape is first demagnetized by the erase head. Saturation of the tape takes place at its gap, which is large in relation to the record and replay gaps, and the tape is taken through many cycles of magnetization which gradually decrease due to the motion of the tape past the head. The record head has two magnetizing components, one the signal and the other consisting of a high-frequency "bias" to reduce distortion. The signal produced on the tape is then reproduced by the replay head and fed into suitable frequency-corrected amplifier stages. This process is relatively well known.

The various types of magnetic head will now be discussed in detail, and the importance of various mechanical relationships illustrated; the three types are assumed to take the general form shown in Fig. 1.

Erase Heads.—The impedance of the erase head is chosen so that the voltage developed across it is not excessive when operating normally. The high frequency current required is usually derived from a tuned power amplifier stage driven by an oscillator of low distortion. The frequency of the oscillator is often 7-10 times the highest audio frequency which is to be recorded, the danger being heterodyne interference between a harmonic of the signal and the oscillator frequency. Harmonic distortion of the erase current (and bias current) waveforms should be kept as low as possible. Distortion causes noise to be kept on the tape; this is mainly due to the presence of even-order harmonics producing an unsymmetrical waveshape, hence leaving the tape polarized to a small extent. This noise is very pronounced when the tape has been erased using a plain permanent magnet in place of h.f. erasure. A figure of less than 0.5% total harmonic distortion is usually required in practice to give a clean, low noise tape background. Core losses can be minimized by using a ferrite material in conjunction with a non-conducting gap spacer. In practice it has been found that although a better flux distribution about the working gap is possible with a conducting gap spacer (phosphor-bronze, etc.), the heat generated due to eddy currents is excessive in "full track" erase heads and the insulator type is superior. The metal spacer tends to "throw out" the flux, whilst the poorer flux distribution about the non-conducting gap spacer is approximately balanced by the lower losses, and the heat generated is negligible. The gap length of the erase head is not critical, and a

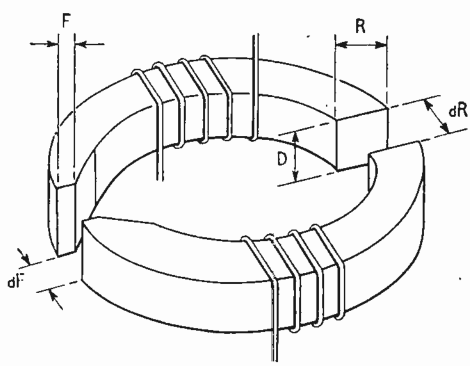


Fig. 1. Generalized sketch of a magnetic head with relevant dimensions

length of 0.012in to 0.020in is satisfactory for tape velocities of 7.5 and 15 in/sec.

Record Heads.—The basic requirements of a record head are a low reluctance magnetic circuit with small hysteresis and eddy-current losses, and a well-defined straight-edged front gap, its length being relatively unimportant compared with the replay head front gap. Ferrite material is inherently granular and unsuitable for the gap portion of the record head, although successful heads have been made by using pole shoes of high-permeability metal to form a clean straight gap.

The C.C.I.R. recording standard is widely adopted now. This means that the tape has been recorded to a definite induction/frequency characteristic. Taking the characteristic adopted for the tape speed of $7\frac{1}{2}$ in/sec as equivalent to that of a circuit with a time constant of 100 microseconds and providing that the replay amplifier has the

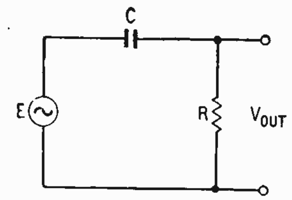


Fig. 2. Circuit with response equivalent to the C.C.I.R. recording standard

inverse of this response of 100 microseconds, the output would be constant over the band of frequencies recorded on the tape. This is only true if the replay head has no losses whatsoever and is in fact "ideal".

The response is conveniently described in microseconds, for it is the response of a simple R-C combination shown in Fig. 2. V_{out} represents the voltage across an "ideal" replay head winding when a tape is reproduced having the C.C.I.R. induction/frequency characteristic of 100 microseconds.

To produce a recording which has the required C.C.I.R. characteristic, a certain amount of high frequency pre-emphasis or "equalization" is incorporated in the recording amplifier to overcome losses in the tape magnetizing process and the record head. For a tape velocity of 7.5 in/sec approxmately +11dB of equalization is required at 10kc/s

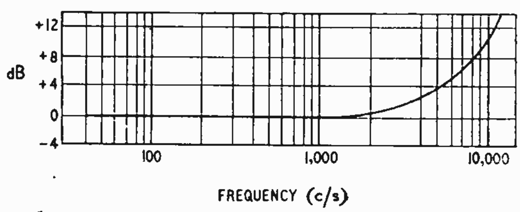


Fig. 3. Typical recording pre-emphasis circuit

(reference 1kc/s=0) to produce a recording which has the C.C.I.R. characteristic, given a good-quality record head. A typical current *versus* frequency curve is shown in Fig. 3, the record head working at peak optimum bias for a signal frequency of 1kc/s.

The efficiency of a record head largely depends on the front-to-back depth (F in Fig. 1) of the working gap and the type of tape used, but it is difficult to calculate accurately because it depends upon the leakage and fringing across the gap to some extent. In general, the back-to-front depth is made as small as possible consistent with reasonable working life of the head. This also applies to erase and replay heads.

The optimum bias required is governed by three major factors: high-frequency losses in the head itself, the nature of the tape coating and the signal frequency. Fig. 4 shows how the recorded signal varies when the bias current is altered from a low value to a high value and the dotted line indicates the recorded signal harmonic distortion (for a given signal level). This peak in the tape signal recorded is shown occurring at a bias current of 8mA, but this condition exists only at a certain signal frequency, i.e. 1kc/s. Inspection of the graph in Fig. 5 will show how this peak varies with signal frequency. Therefore it can be seen that the bias current governs to a large degree the performance of the record head. Operation of the record head with insufficient bias current can cause distortion and an accentuated high-frequency response. However, it has been found that it is advantageous to over-bias the record head so that the tape signal at 1kc/s drops by 2dB (from the peak value obtained using 8mA bias current as shown in Fig. 4). This ensures that the effects of any discontinuities in the tape coating, contact variation between head and tape, etc., are kept to a minimum. This necessarily affects the h.f. pre-emphasis required by the record head to produce a recording conforming to the C.C.I.R. specification, assuming the head was originally operated at peak optimum bias. The extra pre-emphasis required can be obtained by adjustment of the record amplifier characteristic, which is made variable in professional machines. Distortion of the signal on the tape can be caused also by an excessive magnetization level. The maximum signal level allowed in practice is one which produces 2% to 3% total harmonic content. The main component is usually the third harmonic due to the tape coating magnetization characteristic. Some types of tape can accept a higher level of magnetization than others for a given distortion, and if the signal-to-noise ratio of the system is to be as high as possible, the tape which can accept the maximum magnetization level for this given distortion level should be chosen.

Replay Heads.—The losses in a replay head can be split into two groups: frequency-dependent losses and wavelength-dependent losses.

Other factors to be considered are sensitivity, e.g. the voltage output should be as high as possible from a given signal level on the tape, and the voltage waveform an exact replica of the magnetic signal on the tape. There is a limitation to the number of turns of wire wound on the magnetic core, for high-frequency resonance with the self-capacitance of the winding is undesirable. High-frequency resonance is an extreme condition usually, although transformer coupling of a replay head to the input of the amplifier requires careful design of the transformer to avoid this condition.

The front-to-back depth F of the gap directly affects the sensitivity, because the shunting effect

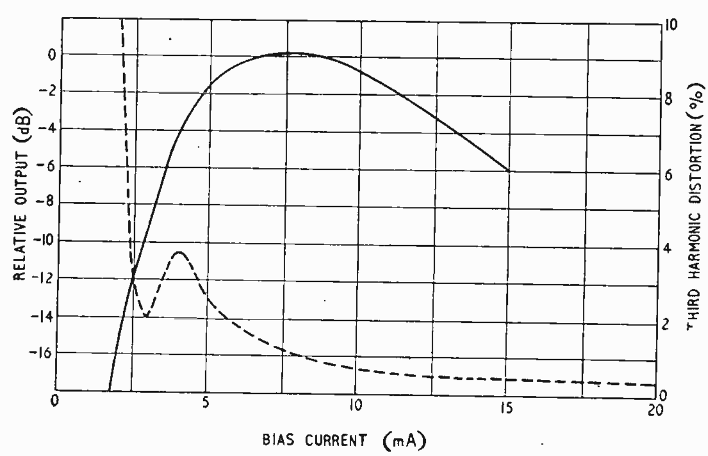


Fig. 4. Effect of bias current on the level and distortion of the recorded signal

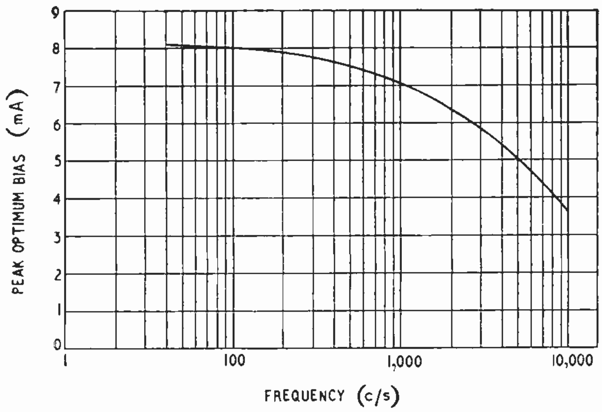


Fig. 5. Variation of optimum bias with signal frequency

is greater when the gap depth is large. This dimension is a compromise, the back-to-front depth being made as small as possible consistent with an allowance made for head wear during service. A figure of between 0.007in and 0.010in is commonly used in practice.

Effect of Front-to-back Depth on Sensitivity. A simplified equivalent circuit of a typical magnetic head is shown in Fig. 6.

Referring to Fig. 6.

E = magnetomotive force.
R_1 = reluctance of tape and tape contact with head.
R_2 = front gap reluctance.
R_3 = core plus rear gap reluctance.
i = flux entering poles from tape.
I = flux through core (and hence coil).
μ = mean permeability.
l = mean length of magnetic path.

$$\text{Now } i = \frac{V}{R_1 + \frac{R_2 R_3}{R_2 + R_3}}$$

$$\therefore I = \frac{V}{R_1 + \frac{R_2 . R_3}{R_2 + R_3}} \cdot \frac{R_2 R_3}{R_2 + R_3} \cdot \frac{1}{R_3}$$

$$= \frac{VR_2}{R_1 (R_2 + R_3) + R_2 R_3}$$

$$\text{From Fig. 1, } R_2 \propto \frac{dF}{D \times F}$$

$$R_3 \propto \frac{dR}{D \times R} + \frac{1}{D \times R \times \mu} = \frac{dR}{D \times R}$$

$$\left(\text{if } \frac{1}{D \times R \times \mu} \ll \frac{dR}{d \times R}\right)$$

Solving for I using two values for R_2, the change in output voltage of the winding can be found, due to the front-to-back depth being altered, say, from a small to a large dimension. The object is to make the magnetic flux mainly traverse the magnetic circuit around which the coils are placed, rather than taking the short-cut presented by the front gap reluctance R_2.

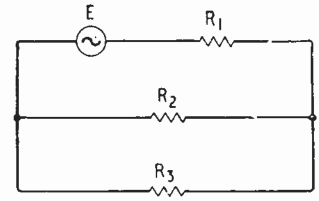


Fig. 6. Simplified analogue circuit of a typical magnetic head

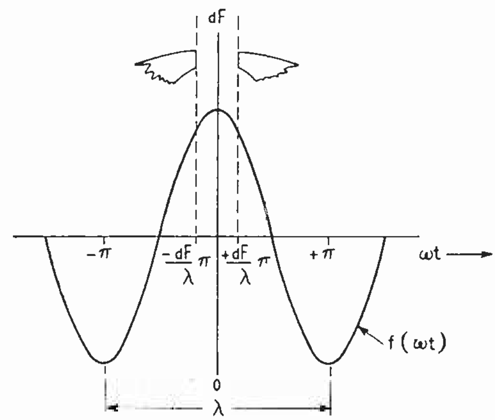


Fig. 7. Method of calculating gap loss

Effect of Gap Length dF on Sensitivity. This can be calculated in a similar manner to the previous example, thus using two values for R_2 again but incorporating different values for dF, the result is an increase of output when dF is changed from a small to a large dimension $\left(R_2 \propto \frac{dF}{D \times F}\right)$.

Summarizing: Output $\propto \frac{1}{F} \propto dF$.

Frequency Response—The gap length dF is the most important dimension. The gap loss can be calculated by simple integration. From Fig. 7, dF represents the effective magnetic gap which is usually 20% greater than the actual mechanical gap, due to "end effect," etc. The gap loss at

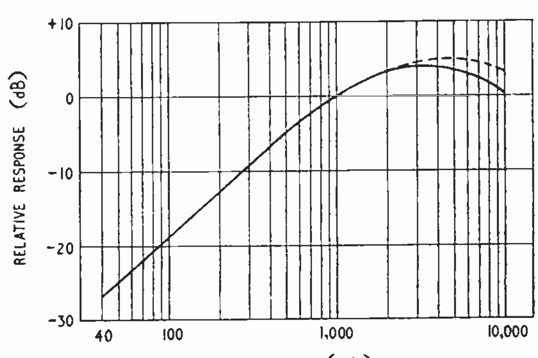


Fig. 8. Output from a good quality reply head with theoretical response from a C.C.I.R. recording at 7.5 in/sec

any given wavelength λ may be represented by the average value of the sinusoidal signal illustrated, between the limits set by the length of the effective magnetic gap dF. It can be seen that when this gap equals the wavelength λ the output will be zero, for the poles will have a similar polarity at any point along the curve. By taking the average value of the curve $f(\omega t)$ between the points $-dF/2$ to $+dF/2$ in terms of 2π a general expression is obtained. The reference axis " O " is placed where $f(\omega t)$ is a maximum, therefore $f(\omega t)$ becomes $\cos \omega t$. The average value is thus:

$$\frac{\lambda}{2\pi dF}\int_{-\pi dF/\lambda}^{+\pi dF/\lambda}\cos \omega t \, d(\omega t)$$

$$=\frac{\lambda}{2\pi dF}\Big[\sin \omega t\Big]_{-\pi dF/\lambda}^{+\pi dF/\lambda}$$

$$=\frac{\sin(\pi dF/\lambda)}{\pi dF/\lambda}$$

$$\therefore \text{Gap loss} = 20 \log_{10} \frac{\sin \pi dF/\lambda}{\pi dF/\lambda} \text{ dB}$$

The output of a good quality replay head from

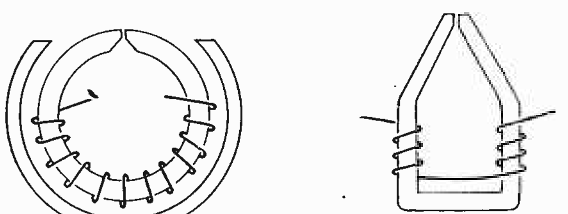


Fig. 9. Screening and poles with short tape contact affect the low-frequency response of replay heads.

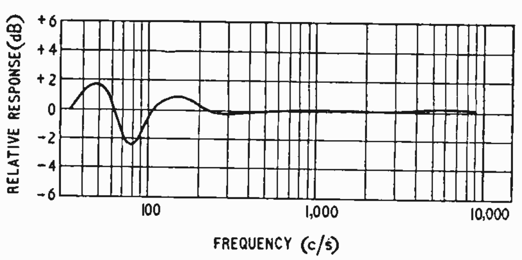


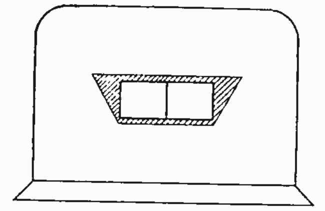
Fig. 10. Typical response irregularity at low frequencies.

a C.C.I.R. recording at 7.5 in/sec is indicated in Fig. 8, whilst the theoretical output is shown by the dotted line, the difference between the two curves represent the eddy and hysteresis losses, etc., of the particular head.

Effect of Screening Can and Pole Shape upon Low Frequency Response. The replay head is usually screened magnetically against hum pick-up from nearby motors, etc., in the machine, and also erase and bias pick-up from the erase and record heads, assuming in the latter case that the signal is being monitored by the replay head.

When the screening can is in close proximity to the tape and pole-pieces it can act as a secondary pole-piece and has the effect of increasing or decreasing the field from the tape according to the length of the tape embraced, and the signal wavelength.

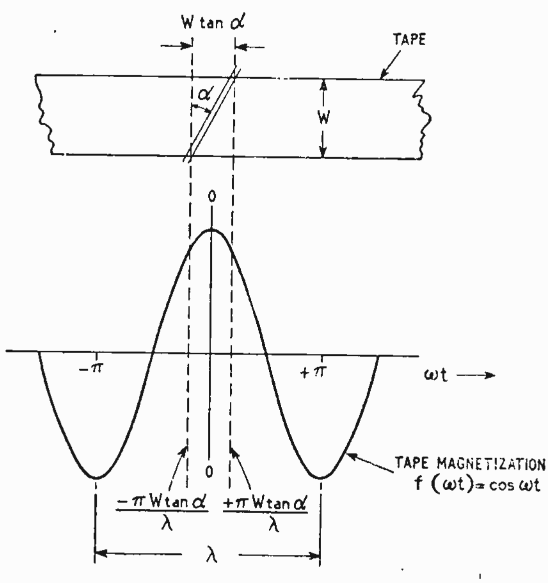
Fig. 11. Screening-can aperture shaped to reduce low-frequency response irregularities.



Any sharp discontinuity in the profile of the pole-pieces adjacent to the tape surface can also produce similar effects. Generally, these undesirable conditions can be reduced to negligible proportions by making any such discontinuity at least 5λ (max.) away from the gap, where λ (max.) is the longest wavelength that it is desired to reproduce. Typical examples of replay head are shown in Fig. 9 whilst the effect upon low frequency equalized replay response is indicated in Fig. 10. To completely overcome this type of poor low frequency response it is advisable therefore to make the pole-pieces of the replay head a smooth curve up to, and away from, the tape surface. Where a screening can is used, the edges of the aperture through which the pole-pieces protrude should be far enough away from the tape to prevent its influence upon the magnetic field of the tape, alternatively an angled aperture may be used (Fig. 11).

Alignment of Replay Head Gap to Recorded Signal Azimuth. Correct azimuth alignment is very important where good overall high-frequency performance is required. This is obtained by rotating the replay head about an axis, preferably located at the mid point of the gap width, normal to the tape surface. This mid-point location ensures that the lateral movement of the head during adjustment is kept to a minimum. The replay head is rotated until its gap is exactly parallel with the azimuth of the recorded signal on the standard tape. Adjustment is made at the high-frequency end of the audio-frequency band covered by the recording machine, i.e. where the wavelength of the signal

Fig. 12. Calculation of loss due to vertical misalignment of gap.



is approximately twice the length of the effective magnetic gap of the replay head. For example, alignment procedure can be outlined as follows. The machine (assuming a single-channel type with three heads), is set to "replay," loaded with the standard C.C.I.R. tape for the relevant tape velocity. The replay head is adjusted to give the maximum peak in output from the high-frequency azimuth band on the standard tape. Then with the standard tape removed and replaced with "clean" tape, the machine is switched to record and a tone of similar frequency recorded. The azimuth of the record head is then adjusted to give the maximum peak output from the replay head which is monitoring this signal. On a machine with two heads, e.g. erase and record/replay the latter test does not apply, but correct alignment is important where pre-recorded tapes are to be used and interchange of tapes from machine to machine is required.

The effect of azimuth misalignment can be calculated in a similar manner to the gap loss, given the angle of tilt away from correct azimuth, the width of the replay track and the signal wavelength. Referring to Fig. 12, the loss is given by:—

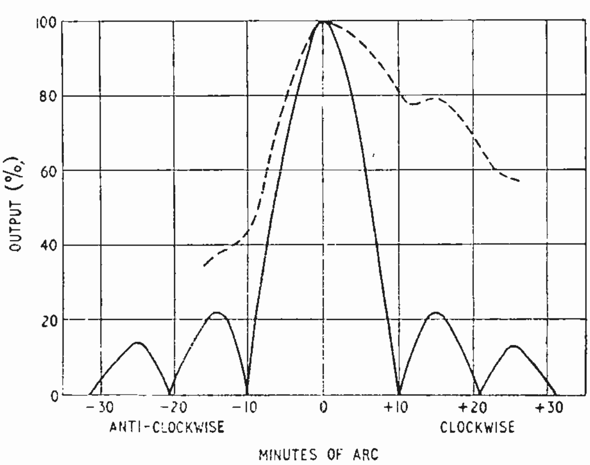
$$\frac{\lambda}{2\pi W\tan\alpha}\int_{-\frac{\pi W\tan\alpha}{\lambda}}^{+\frac{\pi W\tan\alpha}{\lambda}}\cos\omega t.d(\omega t)$$

$$=\frac{\lambda}{2\pi W\tan\alpha}\Big[\sin\omega t\Big]_{-\frac{\pi W\tan\alpha}{\lambda}}^{+\frac{\pi W\tan\alpha}{\lambda}}$$

$$=\frac{\sin\frac{\pi W\tan\alpha}{\lambda}}{\frac{\pi W\tan\alpha}{\lambda}}$$

therefore loss in dB $= 20\log_{10}\frac{\sin\pi W\tan\alpha/\lambda}{\frac{\pi W\tan\alpha}{\lambda}}$

Fig. 13. Variation of output with deviation of gap from the vertical. Solid cure "ideal", dotted curve typical measured response where the gap is not straight and varies in length across the track.



It can be said that any misalignment of this nature has the effect of increasing the replay head gap to the amount W tanα which of course is quite an additional effect to the actual gap itself, previously calculated.

For the machine running at 7.5 in/sec, a misalignment of only two minutes of arc at a recorded frequency of 10 kc/s will cause a reduction of output of 0.6db, assuming a full width recording on standard ¼in tape.

Using the above formula to display graphically the relation between head rotation and replay output for a given wavelength and track width, it can be seen from Fig. 13 that a number of peaks in output can be obtained, of differing amplitudes, the main peak accurring at the true azimuth. The solid line represents the ideal case, where the gap is perfect in every respect. In practice, however, various curve shapes are obtained, depending upon gap straightness, and variations in the gap length along the track width, etc. The dotted curve indicates a typical case in practice. In some cases, one of the secondary peaks may be quite large in amplitude compared with those illustrated in the ideal case, and may be mistaken for the true azimuth peak. Providing the magnetic head is rotated over a fair range, from about −2 deg to +2 deg (taking true azimuth to be 0 deg), selection of the major peak is not difficult.

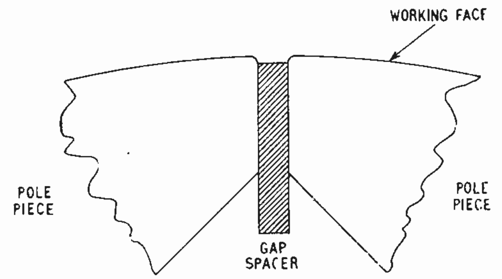


Fig. 14. "Dig-out" wear of the gap spacer.

Effects of Wear.—The performance of a magnetic head which is essentially in contact during its working life, for a.f. application, is subject to gradual change. The relationship of the various mechanical surfaces, gaps, etc., to performance have been discussed, and the back-to-front depth F is the main factor to be considered. This dimension gradually decreases with wear, until it may become zero, which is the end of the working life of the head. It was found that this dimension was inversely proportional to the sensitivity of the head, e.g., lower bias and signal currents required for a given tape level for a record head and higher output voltage from a replay head for a given tape induction (and frequency in both cases). Therefore, a magnetic head has its peak performance and efficiency just before the end of its useful life.

Spurious Effects.—Soft gap spacer material can cause a falling off in high-frequency response and, in some cases, azimuth change. The characteristic "dig-out" wear is illustrated in Fig. 14 representing a much enlarged view looking along the gap. Copper, aluminium and similar materials used as gap spacer shim exhibit this effect, for they are soft compared with the laminated pole-pieces. Beryllium copper, phosphor-bronze, etc., have been found suitable.

The pole-piece material governs the rate of wear to a large extent, and, in general, three types of alloy are in common use: "Radiometal," "Mumetal" and "Supermumetal." "Radiometal" has the greatest resistance to wear, for it is mechanically harder than the latter two alloys. It is also magnetically "harder," which reduces the sensitivity of the head to a small extent (compared with using Mumetal or "Supermumetal"), depending on the reluctances of the air gaps in the magnetic circuit. Pressure pads in many cases cause uneven head wear, and shorten the life of the head, and should be unnecessary for tape work providing the tensions are correct.

Poor finishing of the working gap face causing burring over of the pole-piece material which may bridge the non-magnetic gap spacer can cause rapid changes of response during the first few hours of operation.

Some types of magnetic head have a working face dimension which is greater than the tape width, and after some hundreds of hours use, a shallow channel of tape width is worn therein, which may cause amplitude flutter of high frequencies and in some cases frequency flutter or wow. Regrinding during the working life of the head is then desirable. At all events, it can be recommended that any new magnetic head should be "run-in" before tests are made, by passing a few thousand feet of tape across them.

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FERROELECTRICS

2.—DOMAINS: AND SOME APPLICATIONS OF CERAMICS

By *J. C. BURFOOT*,* Ph.D.

THE first article described the spontaneous polarisation P of a single domain of a ferroelectric, and its hysteresis loop, and showed that although ordinary ferromagnetism is due to *permanent* dipoles, in ferroelectricity *induced* dipoles can also be involved. The ferroelectricity disappears above a transition temperature T_0, and near that temperature, the dielectric constant ϵ and some of the piezoelectric and elastic coefficients show anomalously large values which can be related to the polarisability α. The dipoles and the large polarisabilities occur for different reasons in different materials; we cannot generalise.

Materials.—The earliest material known to be ferroelectric (1921) was the tartrate named Rochelle salt ($NaKC_4H_4O_6 . 4H_2O$); potassium dihydrogen phosphate (KH_2PO_4) followed in 1935, barium titanate ($BaTiO_3$) in 1944, and guanidine aluminium sulphate hexahydrate, familiarly known from its initial letters as gash, in 1955, and some alums. It will suffice to study the first three and allied chemicals, but ferroelectricity has also been found in ammonium sulphate and fluoberyllate, thiourea, colemanite, glycine sulphate, and others. The T_0 values range from $-260°C$ to about 600°C. Some values are given in Table I. Other members of some of these groups are anti-ferroelectric; that is, their individual dipoles are arranged in ways which produce zero overall polarisation, though dielectric anomalies remain.

In applications of ferroelectrics it is inconvenient to have to keep the *temperature* T such as to give particular values of the properties being used. So it is important to be able to select a *material* with which room temperature (or working temperature) is suitable. Similarly the values available for the given property should cover as wide a range as possible, and if the anomalies can be made either very peaky (against T) or flat, as required, there will be more applications. As one example of such versatility, here in single domain properties, consider replacing some of the barium in barium titanate crystals by lead. It happens that in this case all compositions of this solid solution are possible, and all are ferroelectric, and T_0 increases continuously from 120°C to

* Queen Mary College, London University.

490°C as the percentage of lead increases. Iron impurity deliberately introduced into barium titanate lowers T_0; 5% of iron lowers it 100°C; the resistivity is also altered. There are other possibilities when we consider polycrystalline forms.

The crystal structure of barium titanate and lead titanate ($PbTiO_3$) is shown in Fig. 7(a). Above T_0, the lattice cell is cubic, 4Å in size (254 million Å = one inch), and the titanium ion is at the centre. Below T_0 it is displaced by an amount x, equal to 7% of the cell-side, relative to the octahedron of oxygen ions (in $PbTiO_3$); the A ions are displaced 11% in the same direction. In barium titanate, the corresponding figures are 3% and 1½%, but in this case, the octahedron is also distorted, the ions marked I being displaced 1% in the opposite direction. It would not be correct to assume a dipole strength made up of terms like (4e times x) for the titanium for two reasons: (i) the crystal bonding is not all "ionic," so the effective charge on the titanium is less than 4e, (ii) each off-centred ion is in a local field which must distort the electron cloud surrounding it, because of *electronic* polarisability, so that each ion becomes itself a dipole at its displaced position, and of unknown strength. Notice that the extent of off-centring quoted is that which is observed; it gives no indication whether or not it is induced (by co-operative effects). Also below T_0, because of the spontaneous polarisation P now developed, the electrostriction discussed in the previous article in relation to Fig. 6(b) causes a spontaneous strain $S \propto P^2$; actually the cell becomes about 1% elongated in the direction of P, with very little change of volume. This elongation is many orders larger than similar effects in ferromagnetics.

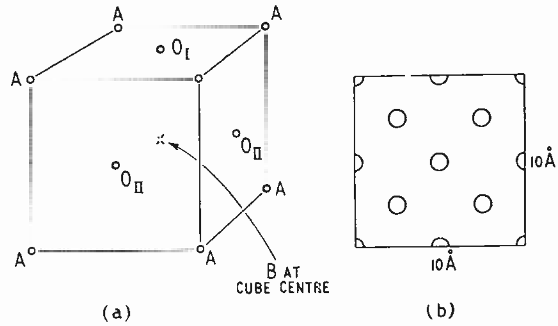


Fig. 7. (a) Perovskite cell ABO_3. $A = Ba^{++}$ or Pb^{++} etc., $B = Ti^{++++}$ etc., O^{--}. (b) Centres of PO_4 groups in KH_2PO_4, projected on horizontal plane.

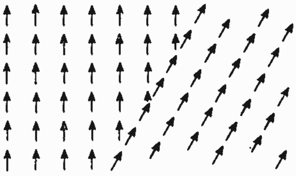
TABLE I

Material	T_0 (°C)	Max. P (μ coul. cm^{-2})	Material	T_0 (°C)	Max. P (μ coul. cm^{-2})
$BaTiO_3$	120	26	KH_2PO_4	−151	4.8
$KNbO_3$	415	30	KH_2AsO_4	−177	5
$PbTiO_3$	490	~100?	RbH_2PO_4	127	5.7
$KTaO_3$	−260		RbH_2AsO_4	−162	
$NaTaO_3$	475		CsH_2PO_4	−114	
$LiNbO_3$	>450		CsH_2AsO_4	−130	
$LiTaO_3$	>450				
$CdNb_2O_7$	−88	~10	Gash	—	0.6 at −180°C
$PbNb_2O_6$	570	~10?	Methyl ammonium aluminum alum	−96	0.6 at −107°C
Rochelle salt	24	0.25	Ammonium sulphate	−49	0.25 at −58°C
Lithium ammonium tartrate	−170	0.22	Ammonium fluoberyllate	97	0.19 at −110°C
Lithium thallium tartrate	−260	0.14	Thiourea	−105	3.1 at −110°C
			Colemanite	−2	0.5 at −38°C
			Glycine sulphate	47	2.2 at 15°C
			Glycine selenate	22	

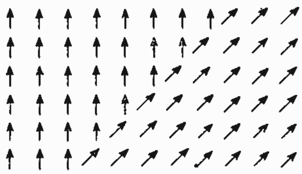
Rochelle salt is unusual in that it also has a lower transition temperature, below which the ferroelectricity disappears. This will not be discussed in these articles. Gash decomposes before reaching T_0.

In Rochelle salt, the unit cell contains 4 each of the atoms given in the chemical formula, and is a very complicated structure. In KH_2PO_4, the cell containing 8 each of the formulae is about 10Å, 10Å, 7Å. The K atoms and PO_4 groups are centred 3½Å vertically apart, if we describe the 7Å cell dimension (the ferroelectric axis) as "vertical." But those PO_4 groups whose *projections* in Fig. 7(b) are neighbours are only separated vertically by half of 3½Å, so that the top of one PO_4 group is level with the bottom of a neighbour. Then in a PO_4 group each top O is only 2½Å from an O belonging to the bottom of another PO_4 group, the line of separation being almost horizontal. Midway between each of these close oxygen atom pairs is a hydrogen atom; its position has been discovered by neutron diffraction experiments. Below T_0, the hydrogen atoms move along the O-O line, 0.20Å from the midway position, in such a way that each PO_4 group finds two of the four hydrogen atoms closer than before; the P atom, in that PO_4 group which is approached, moves vertically away from that O atom by 0.05Å; the K atoms move 0.06Å vertically the other way. Thus the hydrogen displacements cannot cause the polarisation, because they are across the ferroelectric axis. But apparently their charge causes the necessary polarisation vertically in the PO_4 groups. Also below T_0, the spontaneous P together with the piezoelectric effect causes a distortion of the 10Å × 10Å base so that its angles are now ½° different from right-angles.

These structures are relatively simple, and indicate the very different natures of the dipoles in different ferroelectrics. The ferroelectricity of gash and others with H_2O groups could be associated with H situated between O-O as in KH_2PO_4. But there may also be effects due to N-H-O combinations, and in ammonium sulphate, for example, only the latter is possible. Ammonium fluoberyllate ($(NH_4)_2BeF_4$) shows the O is not essential. In non-ionic thiourea (NH_2CSNH_2), the responsible structure is N-H-N or N-H-S. Notice that in KH_2PO_4 there is one unique crystal direction for the ferroelectric axis, whereas in the barium titanate type, there are three equivalent directions (six senses) and the co-operative



(a)



(b)

Fig. 8. (a) A crystallite boundary, (b) A domain wall.

effects select one, either at random or under pressure of the piezoelectricity. These "easy" directions are determined by the forces controlling the crystal structure as we have now seen, and by the piezoelectric effects. We saw one example of this "anisotropy" in the previous article when discussing the values of the dielectric constant ϵ in different directions.

Domains.—We have so far discussed the ferroelectric material as though it were a perfect crystal lattice, with aligned dipoles, extending in all directions. But in fact many of its most interesting properties occur because this is not true. Just as in magnetics, the material contains domains, i.e., regions defined by the dipole alignment; in each domain the alignment is different. You must distinguish carefully between a domain and a crystallite (in polycrystalline material). Crystallites are differentiated by a break in the lattice, domains by a "break" in the direction of alignment. The distinction is shown schematically in Fig. 8. Usually domains are the smaller entity. Ferromagnetic properties are largely determined by the domain structure. We shall see that there is special interest in materials in which the grains are so small that separate domains cannot form in them.

In Fig. 9(a) the field E shown will bodily reverse the polarisation in the domain Y. The simple theory which disregarded domains, will show how large E must be to do it, and this field value (which is often enormous) would be the coercive field. But if domain walls are present, they can move, and in Fig. 9(a), E will tend to cause the wall to move to the right, till the whole crystal is one domain instead

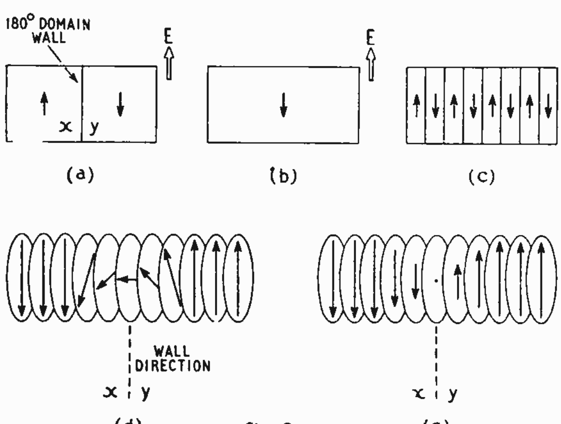


Fig. 9.

of two. This may be a much easier way to do it than the other, so that the measured coercive field is very much smaller than the value from the simple theory. If a wall is not present (Fig. 9(b)), one may nevertheless form, say at the left edge, if this "nucleation" of a wall happens to be easier than reversal. The wall shown is a "180° wall"; more complicated structures usually occur.

A wall between domains may not be a happy thing, in spite of there being (Fig. 8(b)) no lattice misfit there. (For the moment I ignore the differences of cell size in neighbouring domains due to polarisation.) It depends on the details of the way P changes over its direction and magnitude from the one domain to the other. In addition, the changes of cell size due to polarisation may be different in neighbouring domains, so that some lattice misfit does after all occur. There must be some distortion of the ideal lattice near the boundary to conform with this, and since this may extend some distance from the boundary, the wall must be regarded as having a thickness. In magnetics this may be a hundred lattice cells; in some ferroelectrics, less than one.

The interplay of these factors affects the polarisation "in" the wall thickness, either in direction or magnitude, in a complicated way. Figs. 9(d),(e) show details of two of the possibilities in the simple case Fig. 9(a). Here I have supposed there are only two easy directions of polarisation: up and down; if this anisotrophy is strong the detail suggested in Fig. 9(d) is a strong violation, and the material may prefer 9(e). But the cell sizes change with polarisation, and 9(e) may involve more elastic "discomfort."

These microscopic details of the wall are usually summarised by a single number, calculated if possible from the detailed knowledge above, and called the wall energy per unit area of wall, e.g., in cobalt the wall energy is $\sigma = 8$ ergs./sq. cm. The purpose of this is to be able to discuss domain changes on a relatively large (macroscopic) scale, temporarily forgetting the microscopic detail. σ is defined as the work that would have to be done if we could form the *wall** deliberately, and it is used, for prediction of domain behaviour, by the well-tried principle that the total work done must be as small as possible (principle of minimum energy). However, the figure used can be different for a wall in different situations, so that σ must be used with caution. Often in practice, σ is deduced from experiment, rather than calculated, and is then used to predict the results of of other experiments.

Wall Movements.—The work done (hypothetically) in forming an imagined *domain structure* (compare above*) differs according to where any particular wall is supposed to be. This is partly because the wall area may differ, partly because impurities and local imperfections of the lattice may alter σ, and partly because the bulk of the material would be harder to force into state y than into state x (Fig. 9(a)) when E is present. Also because of the polarisation, there may be "free pole" at the crystal faces, and in some cases also at domain walls; this may be regarded as the source of disturbing fields which affect the work necessary. Ferroelectrics differ from ferromagnetics in this respect because, since they are not perfect insulators, charge carriers can migrate through the material to compensate any free pole if given sufficient time; this

(*Continued on page 329*)

does not occur in ferromagnetics, because carriers of single magnetic poles do not exist. The wall position adopted is the one (A) needing minimum work, but there may also be positions (B) corresponding to local minima, i.e., neighbouring positions to (B) may be less favourable than (B), but position (A) would be better. A wall may become trapped at (B), unable to reach (A) because intervening positions correspond to higher energies. Nucleation of a new wall may be easier than intrinsic reversal, but more difficult than moving an existing wall. Here also we can regard nucleation as being difficult because there is a high-energy situation intermediate between the states " before " and " after."

When a field causes an existing wall to begin to move, it does so at a measurable rate, and the account may be made simpler by using an effective " mass " for the wall, to describe this sluggishness or inertia. Other macroscopic concepts are adopted also, such as an " elastic " binding to position (B). This can be broken and there may be " frictional " and "viscous" oppositions when the wall is moving.

Much of the modern mastery of magnetic materials in production is through techniques to control these factors influencing the wall motions, for example by controlling the nature and distribution of the impurities. Above the coercive field, the viscous impedance to wall motion controls the rate at which the walls move. For magnetic walls it is due to eddy current damping, magnetic relaxations, or other effects, and is rather imperfectly understood; in ferroelectrics it has as yet hardly even been measured.

The coercive field is that field which only just provides sufficient drive to move the walls across material containing traps. Until that occurs, the viscous impedance cannot operate. To account for the coercive field, however, it is not knowledge of the viscous impedance which is needed but an evaluation of that factor which makes the driving field H inoperative below a certain value. This is explained for magnetics in terms of the local trapping already described; we saw that the external field affects the energy functions which control the wall; when H is as great as H_c, the neighbouring positions are no longer energetically unfavourable and the escape is made. Control of the impurities therefore controls H_c. At smaller fields, the wall may still move slightly, while remaining bound, and will return to (B) when the field is removed. This gives the bottom part of the hysteresis loop.

If the traps are not all equally deep, the escape may allow the wall to move only to a neighbouring trap, unless a slightly larger H is applied; thus the steep side of the hysteresis loop is not usually vertical. But if a barrier against nucleation must be overcome first, and is a higher barrier than any trap barriers, the loop side becomes vertical. This is seen in some ferroelectrics. If in addition the only P directions involved are those parallel and antiparallel to E, then higher E cannot cause further slight increases of the overall P by turning it from the easy direction towards E, as happens in magnetics. So no rounding of the loop corners occurs—the loop is " square."

There is another point to consider, however, *viz.* that thermal random motions may overcome barriers without such large applied fields. This becomes *very* rapidly impossible as we consider higher barriers, but in any case when the barrier (against escape from a trap, or against nucleation) is low enough for this possibility to be worth considering, we have to recognise the fact that it leads to results whose characteristics are quite different. For when thermal activation is a possibility, the passage from (B) to (A) will always occur, given only sufficient time. This appears to be the case in some ferroelectrics, and we shall see later that it leads to important restrictions on the use to which we can put the material.

We have seen that the breadth $2E_c$ of the hysteresis loop is not a simple intrinsic property of the crystal lattice, but is strongly influenced by the domain structure. So are many of the other properties previously discussed in terms of single-domain theory. For example, in Fig. 9(c), the overall P may be very small, although P for each layer is large. The dielectric constant ϵ, which measures changes of P in response to changing E, would be unaltered in such a structure; it may even be a little increased if the walls are free to move sideways so that in a given field the favoured layers increase in size at the expense of the alternate ones. (This contribution of wall motions to the dielectric constant would disappear at higher frequencies because of the inertial property of the wall.) However, the piezoelectric effect of E is opposite in alternate layers, so that they impede one another's changes of shape and the P changes are reduced; this reduction in ϵ is a clamping effect additional to that which occurs even in a single domain if the frequency used is above the mechanical resonance frequency of the piece of material. Clearly the apparent piezoelectric coefficient of such a structure is also less than the intrinsic one and this decrease will be greater the thinner the layers are.

Domain Structures.—The domain structures in ferromagnetics may be very different from those in ferroelectrics. For we saw that the spontaneous distortions are very much less in magnetics. Also because carriers of free pole do not exist, ferromagnetics often have " closure domains," which are domains in the crystal surface oriented to avoid free pole at the surface. Similarly, powdered materials in which the particles are too small to break up into domains (because the wall energy would form too large a proportion of the total energy) are unable to become polarised spontaneously, and so always retain the cell sizes typical of temperatures above T_0. This is because of the self-depolarising effect at the surfaces of the particles, an effect which is 1000 times bigger than in magnetics. This " unnatural " cell size is observed for KH_2PO_4 particles smaller than six-millionths of an inch. But in a conducting liquid, even particles as small as two-millionths have the normal cell size, because the surface polarisation can be neutralised by charges migrating through the liquid. KH_2PO_4 is a very good insulator, so that migration through itself is relatively slow.

Magnetic domains can be made visible because suitable tiny magnetic particles floated on to the surface will move into the fields at the domain interfaces and a similar technique has recently been reported for ferroelectrics. Most investigations have made use of the fact that plane-polarised light, sent through ferroelectric material in a direction across the ferroelectric axis, travels differently according to the orientation of its polarisation, so that a polarising microscope will show up domains differently. This method will not distinguish domains with antiparallel polarisation, and for these it is usual to etch the crystal faces; a suitable etchant will attack the positive ends of domains more than negative ends and the resulting pits can be seen in an ordinary

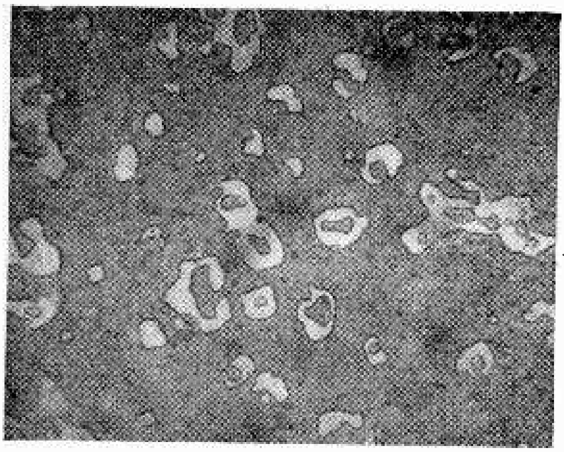


Fig. 10. 180° domain walls in a barium titanate crystal.

microscope (Fig. 10). None of these methods will display rapid alterations of domain structure.

Ceramics.—Ferroelectric devices have mostly used barium titanate, with or without additives, because of the high values of its various coefficients (ϵ, d, . . .) though Rochelle salt has been used a good deal for transducers. A few words about crystal material will serve to show why ceramic forms are often used instead.

Crystals of barium titanate are grown by crystallisation from potassium fluoride flux, a highly unpleasant material, in platinum crucibles, with the addition of tungsten trioxide or perhaps iron to obtain large crystals, that is, up to 1 cm across. The process depends on the correct thermal gradients and concentration gradients, and often only a small proportion of the extract consists of good crystals. Sodium carbonate and barium chloride fluxes have also been used, in carbon crucibles, and in inert atmospheres, and crystals have been grown also by special techniques from the pure liquid, but a hexagonal or cubic lattice which is not ferroelectric readily results instead. When successful, the crystals are about a tenth of a millimetre thick and exceedingly fragile. A good crystal should have the ferroelectric axis everywhere directed through its thickness. There are unwanted " twinning " domains for which this is not so. These can usually be removed by " poling" with a temporary d.c. field, for a small voltage applied between the faces of these crystals gives a field of several kilovolts per centimetre. But even this process can easily fracture the crystal, because of the high stresses set up by the piezoelectric effect at the edges of these twinned areas. The geometry is such that these stresses do not occur at the 180° walls discussed earlier.

The ceramics are made by grinding barium titanate (or its components) and any additives, and by extrusion or pressing with or without a binder, and sintering at high temperature, say 1200–1400°C, to make a glassy product. The result may be regarded as a very complicated polycrystalline material, with the crystallites randomly directed, unless the manufacture included the application of special fields. Many of the crystallites will have grown into one another at their corners by a diffusion process. In general, each crystallite contains several domains, and the domain walls can move under electrical or mechanical stimulus in ways similar to those for single crystals. The one-directional properties discussed earlier will be " averaged out " in the virgin material and though this may be altered by applying fields, it is clearly not so easy to explain simply the properties of such materials. But the ceramics are hard and resistant and can be made any reasonable size or shape. Solid electrodes can be fixed on to them in a number of ways, including evaporation, printing, or the firing-on of metallic pastes. Finally they may be given protective coatings, especially if they are at all porous.

Each crystallite is in a polarised state and may be highly stressed because of its surroundings. Without electrical treatment, the polarisation will average out to zero. A small field will lengthen some grains and shorten others during the time it is applied, so that the apparent piezoelectric coefficients (d, etc.) will also be small or zero. But the effect of that field on the intrinsic polarisation of the various parts, is to increase it where it is positive (say) and decrease it where it is negative. Thus *these* effects do not average out, so that the dielectric constant ϵ can be measured and used as an index of the extent to which the ceramic properties approach those of the single-crystal material. Usually more intense sintering makes for higher ϵ, an improvement which can also be followed by watching the density of the ceramic. The crystal density is 6.0 gm/cc. and ceramic densities about 5.7 cm/cc. are common.

" Poling " the virgin ceramic causes some degree of alignment, so that hysteresis loops and the other properties we have discussed can now be observed. The polarisation now lies, not all parallel as in a single crystal but along the nearest easy direction (to the poling) in each crystallite. It can be shown that the maximum P possible should then be 86.6% of the single-crystal value (26 microcoulomb/cm² in barium titanate). But the high d together with stresses left in manufacture and stresses introduced by poling, and the gaps between crystallites, means that only about 7 microcoulombs/cm² is achieved as retentivity. The saturation value may be twice as much, so it is clear that the loop no longer has the " good " square shape.

Similarly, the piezoelectric coefficients are, say, a quarter of the single-crystal values. It is interesting too that when the applied field causes thickness expansion of a disc of the material, the accompanying radial contraction, quoted as a fraction, is often *less* than half the fractional thickness change, because thickness expansion of the crystallites shows up as an expansion of the disc, whereas to some extent radial contraction of the crystallites can occur without full corresponding contraction of the disc. In a crystal, the contraction in each of two directions is half the expansion in the third, so there is no volume change; in the ceramic there is an *apparent* change of volume.

As in the crystalline forms, T_0 and the other properties can be altered by suitable additives, and now the state of sub-division and the nature of the annealing provide further controls since they alter the internal stresses. In this way one can make the curves of the various anomalies (against T) less peaky for applications where this is desirable; usually the maximum value will then be less. If the internal stresses are not very uniform throughout the material, there will be a spread of T_0 values, and the flattening may be thought of as due to the superposition of these. In barium titanate ceramics ϵ

increases as grain-size decreases. Added calcium titanate lowers P and raises the coercive field E_c; 10% raises it from 2½ to 5 kV/cm. Admixtures of strontium titanate give values of T_0 which differ under different heat treatment during preparation, as the barium and strontium ions rearrange themselves; the strontium ion is 11% smaller than the barium ion so that certain special regularities of arrangement will occur if temperature conditions allow. Addition of antimonates is said to reduce ϵ at T_0. It would be impossible to summarise all the possibilities. I shall merely quote arbitrarily some of the many materials which have been used.

Applications.—Some uses of ferroelectrics depend on the large values of some of their properties near T_0; others depend rather on the non-linearities, e.g., P plotted against E is not a straight line as in ordinary dielectrics, and the small-signal ϵ is not constant against signal size and bias. In general, the first group has been well developed over a number of years so that devices are commercially available, while the second group is largely represented by development work, and "one-off" models to be found in various laboratories.

In the first group the non-linearities are usually a nuisance to be minimised if possible, and the valuable high coefficients, as we have seen, depend strongly on temperature. The hysteresis loop in particular, for applied voltages large enough to traverse it, causes losses due to the energy dissipated as heat, and this in turn is likely to cause drifts in the coefficient being exploited (ϵ, d, etc.), due to the temperature changes. Questions of temperature stability therefore become important. Many well-known electro-mechanical transducers use ferroelectrics because of the large values of d available, and miniature capacitors may use ferroelectric dielectrics because of the high ϵ.

The second group *depends on* the non-linearities, and here there is one large subgroup which does not use the hysteresis and another which does. Each covers a range of possibilities, but for the first we may use the envelope name "dielectric amplifiers," and the hysteresis uses are largely of interest in digital computers, either as memory devices or for switching purposes.

Transducers.—Devices which convert small mechanical oscillations or impulsive motions into electrical signals include microphones, gramophone pickups, vibration detectors, accelerometers, detectors for ultrasonic waves, strain-gauges, and detectors for small displacements. Those which convert electrical signals into mechanical motions include vibrators, loudspeakers, sonic pulse generators in delay lines, and generators of ultrasonics for non-destructive probing of solids, for determinations of physical properties, for cleaning of surfaces during various processes, and for cutting difficult materials. We must consider also the use of piezoelectric crystals to determine and control oscillator frequencies, and their use in narrow-band wave filters, e.g., to remove an r.f. carrier from the sidebands; these uses depend on the fact that a piezoelectric crystal has a natural frequency of resonance determined by its geometry, and that with electrodes it behaves electrically for nearby frequencies as an impedance often represented as a series LCR combination and parallel capacitance. The effective Q factor can be made very high by careful mounting, sometimes in a vacuum and the device is used as the heart of the filter.

We saw that ferroelectrics exhibit an effective piezoelectricity below T_0 due to the spontaneous polarisation P acting as a bias, so that they may be used in any of these piezoelectric devices. The ceramic forms must be poled to produce the P. The time and temperature instabilities of ferroelectrics mean that where high frequency-stability is sought, quartz is still used. But in many of the other devices, ferroelectrics have been used for many years, initially Rochelle salt, but increasingly barium titanate and its derivatives. This is so particularly in view of the versatility of the ceramic forms, which are made in blocks, discs, hollow cylinders, and many other shapes, and in sizes up to several inches; shapes can be arranged to focus radiated acoustic energy. Fig. 5 last month showed d values around 10^{-6} statcoul./dyne, 100 times larger than quartz values. (Divide by 30,000 for values in coulomb/newton.) In addition, the high ϵ values of ferroelectrics give the devices lower capacitive impedances than with traditional materials, so that the charge measurement at low frequencies is easier.

The cutting and plating of piezoelectric materials is a well-documented subject. The piezoelectric uses of ferroelectrics do not differ in principle, and this is not the place to repeat the details. We have already discussed the various piezoelectric coefficients. Briefly, when in use to produce mechanical stress or motion, the mechanical impedance of piezoelectrics is high enough to match well into liquids or solids. For use in air, the lower mechanical impedance and greater motion of a bimorph unit or "bender" is used (Fig. 11); the variations of response

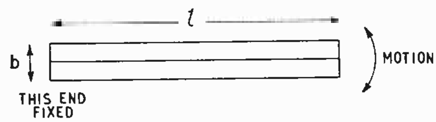


Fig. 11. Bender unit. The components are cut so as to vibrate longitudinally in opposite directions. They are cemented together and the motion shown is 3l/b times greater than the longitudinal motions.

with temperature are then less. Twister units are also used. The *natural* frequency of any piezoelectric device is altered by altering its dimensions; the natural frequency of a bender is relatively low, so that they are in use for audio-frequency devices. For ultrasonics (say 100 kc/s) a simple longitudinal vibrator may be used, and a more perfect single resonance is then generally obtainable. For work in the megacycle regions one may use the thickness vibrations of a suitably cut plate of the piezoelectric (transverse vibrations are also used). For this mode, the mean frequency used will correspond to a wave length $2b$ if b is the crystal thickness (e.g., b about 1/20 mm in X-cut quartz for fundamental 60 Mc/s). Here the requirement is usually that over the required frequency range as much of the electrical power as possible should be transferred. Suitable design may give 70% transfer over a frequency range of 10%. The input signal to a ferroelectric must remain small enough to avoid disturbing the spontaneous P so a high E_c is an advantage. 4% lead titanate in barium titanate ceramic has allowed transfer of 1 watt per sq. mm. For microphones, on the other hand, power is not so important as uniform response over a large frequency range. 5% barium zirconate (itself not a ferroelectric) in ceramic barium titanate is suitable for transducers, its natural frequency changing 4% over 50C°.

In pickups, a 30-mil 2-cm element will give signals of 1 volt. Ceramic barium titanate benders now replace Rochelle salt, which cannot survive high humidity. For pressure-sensitive microphones, double strip designs include cases in which the ferroelectric is the diaphragm disc, and others where a metal diaphragm actuates the free end of the strips. Vibrators and accelerometers may often be used in combination, to excite vibrations in engineering structures at selected frequencies and to detect the amplitude of the response; when the structure is part of a rotating machine, both devices must often be light; an $\frac{1}{8}$in × 10-mil barium titanate strip has

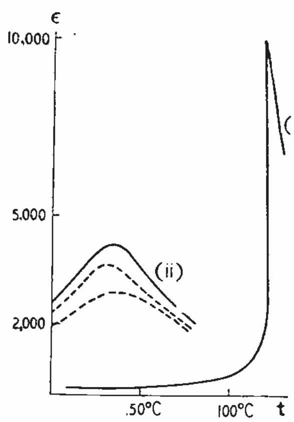


Fig. 12. Dielectric constants. (i) Barium titanate crystal, along ferroelectric axis; (ii) A typical ferroelectric ceramic. Dotted curves, effects of bias (10 and 14 Kv/cm).

produced 10 millivolts for movements of 1 part in a million of its size. This is an order more than resistance strain-gauges, and a vibration strain-gauge giving 100 mV for 1 in a million has been reported more recently.

Capacitors.—The high dielectric constant of ferroelectrics near T_0 leads to their use in capacitors wherever high value or small size is required and temperature stability is not too important. Fig. 12 shows the dielectric constant of barium titanate crystals and the results achieved in ceramics by additives such as strontium titanate or calcium titanate. In these the high ε range has been brought down to a convenient temperature, and flattened to improve temperature stability. The ε peak values indeed are lowered, but the value at operating temperatures is not. The high ε values allow capacitors to have smaller dimensions and they can be in any of the standard shapes. Pressing is used for the familiar disc-shape, and extrusion for capacitors of cylindrical shape. Power factors are usually about 0.01. For capacitors, of course, the non-linearity is a disadvantage, and results in the ε value increasing if measured with a larger a.c. voltage, and also altering if there is any bias across the capacitor. Fig. 12 shows the effect of bias. The non-linearity is less marked away from low frequencies and T_0. Mixtures of zirconates and niobates are also used, particularly when higher temperatures are encountered; T_0 is high for such materials as lead titanate, potassium and lithium niobate (see Table I), and some antiferroelectrics, but it is often falling resistivity of ceramics which limits their use at high temperature.

Very small components are made with ceramic films only a few mils thick. These have working voltages around 300 volts d.c. and breakdown at about 1 kV, for values up to 0.01 μF; higher values are made by packing several such films together, as in mica capacitors. The lead inductances can be kept low since the components are small. The leakage conductance varies strongly with temperature, but it has been kept up to 200 megohms well above 100°C for 0.1-μF film capacitors.

The ε and the power factor of ceramics "age" over several months, ε (and also *d*) decreasing 20%, while Q increases. For most purposes, the values are stable enough several weeks after manufacture, or appropriate heat treatments will remove the aging. We saw that ε is partly due to the domain walls moving when a field is applied. In a ceramic the walls are subject to more stringent interference by irregularities than in a crystal. We may expect it to be more difficult to escape from a temporary trap B to the "deepest" trap A, and this will take place only after some time. Once there, the motions are more restricted, so that ε is then smaller. The power factor, for frequencies below 10 Mc/s, also ages and has been ascribed to movement between traps.

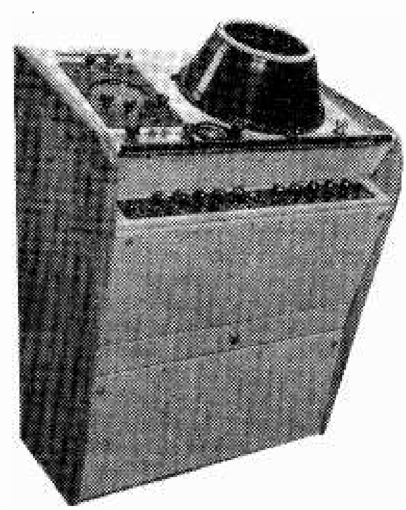
Poor electrical strength means that ferroelectrics are not very suitable for power capacitors. The instability with time and temperature results in their being used for by-pass and blocking capacitors, and also as smoothing capacitors at higher voltages, rather than in tuned circuits.

Acknowledgements

A section of the photograph Fig. 10 was used in a paper by the author in *Proc. Phys. Soc.*, 1st April, 1957. Fig. 12 (i) is taken from a paper by W. J. Merz in *Phys. Rev.*, **76**, 1221, 1949, and (ii) and the dotted curves from Fig. 7 of a paper by P. Popper in *Journ. Inst. Elec. Eng.*, 2, 450, 1956.

(*To be continued*)

RANGE OF MARINE RADARS



"Unit System" has been adopted by Kelvin-Hughes for their new range of marine radars. Standard scanner and transmitter receiver are combined with alternative displays, power supplies and motor-generators to form range of radars to suit most requirements. Photograph shows largest display unit (Type 14/16P) which uses 16-in c.r.t. and provides reflection-plotter and true-motion facilities.

PARIS AIR SHOW

NAVIGATIONAL AND COMMUNICATIONS EQUIPMENT AT THE 23rd SALON

A PREDOMINANT impression gained from a brief visit to this year's Salon International de l'Aeronautique at Le Bourget airport was the extensive use of transistors in all kinds of aircraft radio equipment. As an example the French firm C.S.F. showed a light, fixed-loop radio compass which weighed only 12 lb, compared with the 40 lb of previous models, and measured only 14.6cm × 16.5cm × 11.4cm. It has push-button selection of four pre-set frequencies and the directional accuracy is ±2°. Current consumption is less than 400mA. This firm also had an f.m. radio altimeter which was transistorized except for the transmitter oscillator. The weight was 20 lb. Accuracy of measurement was 10% above an altitude of 100 ft. On the Air-Equipement stand an automatic pilot equipment was noticed which used silicon transistors throughout, and this design has already been installed in a good many American military aircraft.

On the communications side an outstanding example of what can be done by transistorization was the neat Bendix RA-21A v.h.f. receiver. This provides for 560 channels at 50kc/s spacing in the range 108-136Mc/s. It is a triple superhet circuit, transistorized except for four valves in the front end, and uses printed wiring and inductors. There is an automatic tuning system utilizing rotary stepping solenoids, and the selected frequencies are displayed by a digital indicator. The receiver unit, including power supplies, weighs only 8 lb, and measures $7\frac{3}{4}$in × $2\frac{5}{8}$in (front panel) by $12\frac{1}{4}$in deep.

This receiver can be used for communications alone or as an input to a navigation unit, which is a fully transistorized equipment of corresponding size giving VOR (v.h.f. omni-directional radio range) and "localizer" information. The companion v.h.f. transmitter for these receiving equipments gives an r.f. power output of 25-30 watts. It is transistorized in the i.f. circuits and the switching relay circuits and weighs $14\frac{1}{2}$ lb including power supplies

It is well known, of course, that transistors are now being used in the electronic circuits of guided missiles, where their small size, reliability and low power consumption are particularly advantageous. As an example, G.E.C. were exhibiting a transistorized version of the guidance equipment for the Royal Navy's ship-to-air guided missile Seaslug. The equipment is made up of 40 units, each of which is readily replaceable. Printed circuits are used in these units and also in the "cable form" which consists of two double-sided printed boards extending along the whole length of the equipment. The system is said to be about half the weight and size of the equivalent valve equipment and to require only one third of the operating power.

A transistor pre-amplifier, designed as a replaceable plug-in unit, is used in a Murphy airborne tape reproducer which operates at $3\frac{3}{4}$in/sec and weighs 20 lb. This equipment has separate heads for the two tracks on the tape and when the tape is automatically reversed at the end of its travel (by a microswitch control system) the appropriate head is switched to the pre-amplifier. The reproducer is intended for use in conjunction with a passenger announcement equipment, and there is an automatic fade-up and fade-down system to avoid abrupt changes between the recorded programme and the announcements.

Incidentally, this firm also displayed their "leader cable" equipment which is used in the blind landing system recently developed by the Royal Aircraft Establishment. The principle of this azimuthal guidance system, based on the magnetic fields picked up from two cables laid either side of the runway, was described in our December, 1958, issue (p. 579). The a.c. signal frequencies in the two cables are 1,070c/s and 1,750c/s respectively. After separation by filters in the airborne receiver the two signals are applied to a cathode-follower comparator circuit. Any inequalities in amplitude, due to the aircraft being displaced from the runway centre line, cause the comparator to produce an unbalance voltage which is fed as a correcting signal to the aircraft's automatic pilot.

A good many radar equipments were on show, of course, some of them being associated with computer-controlled systems for automatic navigation and fire-control in fighter aircraft. Such a system was shown by the French firm S.I.N.T.R.A. for use with the famous fighter aircraft Mirage III. In the sphere of ground-based radar an interesting development of special value to traffic controllers was demonstrated by C.S.F. This was an image transformation equipment by which radar displays can be presented with enhanced brilliance on television screens. The heart of this equipment is a special storage tube, TMA 403, with a p.p.i. "writing" section at one end and a television-scan "reading" section at the other end. Storage time can be varied by an operator from a few seconds to several minutes.

The idea of the system is to avoid the need for viewing radar screens in a darkened room—often a source of difficulty in airports because the control tower staff cannot always leave their posts to look at the radar. Furthermore, because of the storage facility provided by the image transformer, it becomes possible to see the routes of aircraft by the tracks they leave on the screen.

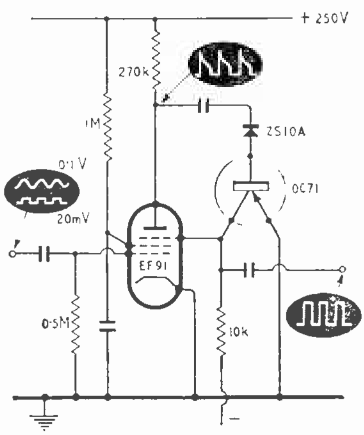
The demonstration by C.S.F. at Le Bourget was actually a television display of a p.p.i. radar picture generated at Orly airport (to the south of Paris)—showing that transmission or distribution of radar pictures over long distances is a practical proposition. The transformation was done at Orly and the 625-line television picture was transmitted northwards to Le Bourget by microwave links.

Apart from the advantages mentioned above, this system, which has already been installed in a good many American airports, offers the possibility of mixing other sources of display information with the radar picture. For example, distance marker rings or "electronic maps" can be superimposed on it.

Technical Notebook

High Efficiency Class-C Power Amplifiers are by no means new: indeed, there is a German patent of 1917 (by G.D.T.) which deals with the use of harmonic resonators in the anode-circuit of a class-C stage as a means of broadening and flattening the anode current pulse—and so improving efficiency. Although superficially similar, the arrangement described by V. J. Tyler in a recent *Marconi Review* (Vol. XXI, No. 130), differs in that the grid-drive to the amplifier does not contain the harmonics for which resonators are provided. In its simplest form Tyler's amplifier is driven by a square wave (containing only the odd harmonics) and has two "loss-free" parallel-tuned circuits, which resonate at the second and fourth harmonics of the signal frequency, in series with the tank: these resonators aid the anode-voltage waveform to take up a shape not unlike the output from a single-phase rectifier without reservoir capacitor. Two experimental amplifiers, one of high power rating, one of low, are quoted as giving anode efficiencies of 93.8% and 90.4%. Output powers as much as three times that given by a normal class-C stage are obtained with ordinary transmitting valves and a further example quotes KT45 valves (television line-output pentodes) as producing 200 watts of r.f.—an increase of power output of over 400% of the normal class-C output. Another favourable point is that mistuning of the anode circuits does not produce a sharp rise in anode dissipation, also the arrangement is capable of high linearity with anode modulation because the output voltage and supply voltage are rigidly inter-related.

Hybrid Monostable Circuit, using a valve and a transistor, has been designed by E. Patterson, of English Electric Aviation, to produce pulses for binary circuits from the small signals given by photocells in an optical shaft encoder. Since ten of these circuits were required for each encoder—one per channel—it was desirable to have a circuit containing the minimum number of components, with no transformers, and operating from existing power supplies. The output impedance of the photocell circuit was of the order of 0.5MΩ, requiring a high impedance input to the device. A regenerative hybrid circuit, in which a pentode suppressor grid was controlled by a transistor switch driven from the pentode anode via a diode, was found to give the required high gain and monostable switching characteristic. The circuit produced rectangular pulses on the suppressor greater than 10 volts from 0.1-V sine waves or 20mV pulses. Triggering



pulses could be obtained from the anode by suitable filtering. Pulse rise times of the order of 3μsec were obtained, and investigation has shown that faster rise times are possible. Since this circuit was developed, the designer has become aware of an article in *Electronics* for April, 1959, "Series Diode Increases Multivibrator Sensitivity," in which the author, M. M. Vojinovic, shows how the stability of the circuit is controlled by the diode in the feedback path. The high impedance offered by the diode before breakdown is sufficient to prevent the loop gain from exceeding the critical value. However, when the anode voltage is sufficiently high the diode breaks down and regenerative action commences. For the best performance of the circuit shown, component values must be chosen to suit the frequency and amplitude of the input signal in order to avoid frequency multiplying or dividing effects.

Parametric Limiters are discussed by A. E. Siegman in a letter to *Proc.I.R.E.* for March 1959. The signal to be limited is applied as the pump input signal to a parametric oscillator. For input pump powers below a certain level, no oscillations are produced and the pump output increases with the pump input. For input pump powers above this level, oscillations are produced and the pump output is limited at a fixed level. An advantage of this method of limiting is that it can theoretically be made phase distortionless.

Ophitron, from the Greek for a serpent, has been chosen by the G.E.C. as the name for a backward wave oscillator using a new type of electrostatic focusing in which the electrons travel in a wavy path. The electron path shape and electrode configuration are similar to those used for slalom focusing (see *Technical Notebook* for May 1958), the electrodes consisting of two charged flat plates one in front of and the other behind a ladder-like slow-wave structure. The relative potentials of the various electrodes in an Ophitron are, however, different from those used for slalom focusing; the two plates now being at unequal potentials with one much more positive than the other; although, as for slalom focusing, the ladder line is made more positive than either plate. With these changed potentials, the electrons in an Ophitron remain always on the same side of the ladder line so that the crests of the wavy electron path now lie between the ladder rungs rather than in front of or behind them as with slalom focusing. This results in better interaction between the electrons and slow-wave ladder line than with slalom focusing. The curves in the wave-like beam path result in focusing forces which counteract the space-charge repulsion. It is expected that because of the removal of ions to the focusing plates, the noise will be less than with magnetic focusing, the usual method of focusing used. Ophitrons should also be

less susceptible to stray magnetic fields than magnetically focused valves. The first Ophitron made by the G.E.C. is for the 10,000 Mc/s band and delivers a few tens of mW power over a 40% bandwidth. Its weight and dimensions are only 7oz and 6in by ¾in diameter respectively.

Scientific Uses of Television

ONE ASPECT OF THE BRIT.I.R.E. CONVENTION AT CAMBRIDGE

DOMESTIC television development, though not exactly at a standstill, certainly seems to be passing through a phase of marking time. At the present juncture nobody but an incurable optimist would think of running a technical conference on this subject alone. The Brit. I.R.E., though undoubtedly optimistic in outlook, was realistic enough to give its recent Convention, held at Cambridge University, the carefully worded title of "Television Engineering in Science, Industry and Broadcasting." The net was therefore cast wide and some interesting fish were caught, including a psychologist talking on subliminal perception, an American on space television, two Russian engineers on various aspects of Soviet television and the well-known television pioneer, Dr. V. K. Zworykin, who gave the Clerk Maxwell Memorial Lecture and surprised everyone by not talking about television at all.

As to the scientific applications of television, it was quite obvious that a great deal of specialized study has been devoted to what is generally known as "industrial television" or "closed-circuit television" equipment. A few years ago, when the potentialities of television as a "remote eye" for viewing in difficult positions were first realized, there was an enthusiastic rush to couple television cameras on to everything possible connected with visual inspection. This enthusiasm has now been tempered with the knowledge of what can happen to such equipment when it is subjected to heat, moisture, radioactivity and so on, and out of this experience new designs have evolved. The photoconductive pick-up tube owes its present high state of development largely to industrial television, and now the normal range of visual observation is being extended into the infra-red, the ultra-violet and to regions of extremely low light levels.

One example of observation at low levels of illumination occurs in astronomy, and here one is thinking in terms of individual light quanta rather than in the more familiar light units. The great problem is in examining celestial bodies through the semi-transparent layer of the earth's atmosphere. For a good many years photographic plates and photoelectric devices have been used for integrating the light from very weak sources, and more recently special electronic image converter tubes have been developed in which electron-sensitive photographic film is enclosed in the vacuum chamber. These methods, however, tend to be cumbersome and complicated in practice, and as a result television has been tried as a possible alternative. A paper by B. V. Somes-Charlton described what has been achieved since about 1951 when the author, in collaboration with P. B. Fellgett, first carried out tests with television cameras coupled to telescopes at the Cambridge Observatories.

The image orthicon pick-up tube was used because of its high sensitivity, and in 1956 some tests indicated that there was a gain in light sensitivity by a factor of 3 over the best photographic film available. This is not a great deal, and it is possible that film emulsions have caught up in the meantime, but the television technique still has the great advantage of electronically variable contrast, which is of tremendous value in clarifying the detail of images.

To give an idea of the performances of light detectors Mr. Somes-Charlton said that ideally each photon of the incident light should effect the reduction of one grain of silver halide in a photographic emulsion or liberate one electron from a photocathode. This would represent a "quantum efficiency" of 1. In fact the best approach to this was given by the photomultiplier tube, with an efficiency of 0.05-0.1 (the human eye having a maximum of 0.05), while the image orthicon tube gave a figure of 0.02-0.03 and photographic films 0.001-0.01 (with a reported recent improvement to as high as 0.1). However, some recent experiments had been conducted by R.C.A. in America on modified image orthicon pick-up tubes containing special image intensifiers using phosphor-photocathode stages and electron accelerating voltages. With these it was claimed that an image of 400 lines definition could be produced with a photocathode illumination of only 10^{-6} or 10^{-7} foot candles.

Incidentally, Mr. Somes-Charlton demonstrated a simple apparatus which he had used for testing the relative performances of pick-up tubes and photographic plates in sensitivity and resolution. It consisted of a metal plate perforated with holes of graded diameters having behind them grey filters of graded densities. The whole mask was illuminated from behind by a cold light source and viewed from the front by the television or photographic camera. The performance of the camera, television or photographic, could then be judged by which particular holes were just on the limits of visibility due to their reduced contrast (dense filters) and resolution (small diameters).

Space Television

Another method of mitigating the effects of the earth's atmosphere on astronomical observations was mentioned in a paper by B. I. Sardiko of the U.S.S.R. (read by B. A. Berlin). This was the use of stereoscopic television on telescopes spaced widely apart. But probably the most advanced idea of all is to get outside the earth's atmosphere altogether by means of space vehicles. One proposal has been for an astronomical telescope orbiting in space and fitted with a television scanning system controlled from a ground observatory. At the Convention A. J. Viterbi, who has been connected with recent satellite launchings in the U.S.A., discussed some of the important design criteria for such a television system, which, for close observation of some of the planets, would have to work over ranges of the order of 25 million miles.

Because of the low received signal power (estimated at 10^{-18} watt) and the high noise level, the channel bandwidth has to be severely restricted—in fact, to as narrow as 1c/s. Bandwidth compression to this extent is achieved by recording the video information on magnetic tape at normal speed then replaying and transmitting it over a long period of time (for example, one 200-line image would take about 1.85 hour to transmit). Another problem arises from the fact that the carrier frequency of the transmitter is varied by the Doppler effect as the vehicle travels rapidly through space. This means that simple frequency modulation cannot be used for overcoming the noise in the transmission channel. Instead the video information is used to frequency modulate a sub-carrier, and the sub-carrier modulates the phase of the carrier signal.

At the receiver the Doppler-shifted carrier is recovered from the noisy signal by a "coherent tracking filter." This is a form of servo-mechanism called a "phase-locked-loop" containing a variable-frequency oscillator which is kept locked in phase and frequency to the incoming signal by control from an error signal. The output from this oscillator is then mixed with the received signal to recover the original frequency-modulated signal, and this is passed to a discriminator to give the final video information. The discriminator has to deal with a very noisy signal and it again takes the form of a "phase-locked-loop" servo-mechanism. The local oscillator is controlled by an error voltage and it is this voltage which provides the video output signal.

Radiation Problems

Compared with space projects, nuclear energy has become almost a common-or-garden application for television techniques. Here the transmission problems may not be difficult but the environmental ones certainly are. For observation purposes in a nuclear reactor the television camera has to contend with heat and radioactivity. The heat problem can be tackled by gas cooling and, according to a paper by P. Barratt and I. M. Walters, nothing practicable can be done about radiation shielding. Lead shields for protection against gamma rays would be far too big and heavy, while neutron-absorbing materials would have undesirable effects on the operation of the reactor.

The paper includes an interesting table showing the effects of radiation on the electrical and other properties of electronic components. Resistors and capacitors are changed in value by only a few per cent (varying with the materials used in their construction), television pick-up tubes suffer a temporary increase in dark current and semiconductor devices show much higher leakage currents than normal. It emerges, however, that the most serious effect of all is not electrical but optical—the discoloration of the glass in the camera face-plate and lenses due to changes in its molecular structure. It is only necessary to replace the affected glassware and the camera is fit for use again.

Another paper, by E. C. Sykes, dealt with the use of television for microscopical examination of nuclear fuel samples which have been irradiated in a reactor. The camera is coupled to the microscope in such a way that the optical image is directly focused on to the sensitive area of the pick-up tube, so that no camera lenses are required. Apart from allowing safe observation of the specimens by several people simultaneously, the television system offers a useful facility for the accurate size measurement of details such as hardness indentations. Two electronic cursors, consisting of vertical and horizontal black lines, are generated on the picture by a system of black-out pulses and time delays. These can be moved across the picture by calibrated controls, and since the overall magnification of the microscope-television system is known it is possible to make accurate size measurements—actually to within $\pm\frac{1}{4}$ micron at an overall magnification of 3,000 times.

Incidentally, this paper discussed some interesting practical experience on the use of stereoscopic television for observation of manual operations carried out remotely by master-slave manipulators. It was found that stereo television was not so helpful to the operator in achieving speed and dexterity as single-channel television with strong oblique lighting from two directions which gave visual positioning information by means of the shadows.

Medical Observations

The development of medical colour television was reviewed in a paper by R. D. Ambrose and A. R. Stanley, who also discussed future possibilities in the particular field of endoscopy. The endoscope is an optical tube which permits observation of the interior of the body without recourse to surgery. Normally it is only possible for one person to make observations, unless photography is used, so the possibility of coupling a television camera to the external end of the endoscope tube offers some distinct advantages. The main problem is in getting enough illumination into the interior of the body, particularly for colour television. It is also desirable to have smaller and more manœuvrable cameras than are available at present, and there has been work on the development of miniature transistorized cameras for this purpose.

Another aspect of medical television mentioned in a paper by J. H. Taylor was the use of infra-red light, with a television equipment designed for this region, to examine the inside of the eye. The point here is that the eye pupil does not close in infra-red light. In other parts of the body it becomes possible to study details of the superficial venous system because the skin is transparent to infra-red radiation. Mr. Taylor described a high-grade television equipment using a special vidicon-type pick-up tube with a spectral response of 4,000 to 10,000 angstrom units (the visible region being 4,000 to 8,000). Another tube, for the ultra-violet region, has been developed with a response giving down as far as 2,350 angstrom units.

Television techniques are now being used for image amplification in X-ray fluoroscopy, and here one is dealing with very low light levels in the region of 10^{-4} to 10^{-1} foot-lambert. E. Garthwaite and D. G. Haley described a special image orthicon tube developed for this work.

Finally, if we have not made any mention of the papers on the domestic side of television it does not necessarily mean that we agree with a certain speaker at the Convention banquet who made fun of the Convention title "Television Engineering in Science, Industry and Broadcasting." He said it was problematical whether there was any science in Industry or even any industry in Science, but he was quite certain from personal experience that there was neither science nor industry in Broadcasting!

LETTERS TO THE EDITOR

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

Monophonic or Monodic?

"FREE GRID" makes a reasoned plea in your June issue for "monodic," but he has misled you by saying that monophonic reproduction means "one-sound reproduction." This is not at all the intention of those who, despite "Free Grid's" diverting contribution and your weighty editorial, are still in favour of "monophonic."

The primary meaning of φωνη is not "sound" but "voice"; an educated friend tells me that the original Homeric meaning was "voice" and that only much later did the word acquire the derived meaning of "sounds from inanimate objects." What could be more appropriate than "monophonic" to refer to the use of a single-channel reproducer, which, like you and "Free Grid," speaks with one voice?

Having established the semantic propriety of "monophonic," let us bear in mind its two great advantages:

(1) it is already well established, particularly in America, and

(2) it makes a convenient pair with stereophonic.

Incidentally, "Free Grid" cannot claim the paternity of "monodic"; it was suggested in my letter published in the January issue of *Electronic & Radio Engineer*, as an alternative to "monophonic."

London, N.2. E. L. E. PAWLEY

"Free Grid" Comments :

Even if Mr. Pawley's remarks about the Greek word φωνη were correct, I do not see how the case for the use of "monophonic" is thereby strengthened. As for his argument about this word being well established in the U.S.A., must we follow American usage in this matter as we have done in the terminology of household sanitation? But Mr. Pawley obviously bases his main argument on the original meaning of the word φωνη, and so I had better confine myself to that.

Going right back to the obsolete verb phao (φαω), meaning, *inter alia*, to speak, we find several words associated with it, but the only two which concern us here are φονη and φωνη, both of which are transliterated into our alphabet as "phone." The first of these words started life meaning "mouth," and was used figuratively in such expressions as "to put to the mouth (or edge) of the sword." A handy example is to be found in Exodus, XVII, 13, where, in the Septuagint, occur the words εν φονη μαχαιρας to describe the rough house which Joshua gave the Amalekites.

Φονη eventually came to mean the effect of putting to the sword, namely, slaughter. While φονη originally meant the *mouth* of the sword, its stable mate φωνη meant the *voice* of the sword (poetical fellows these Greeks), which was a picturesque way of saying the *sound* of slaughter, and in particular the noise of battle.

Now the noise of battle is a confused jumble of sound, and in those days the first thing that would be heard would be the clash of arms, a very inanimate sound. Thus the primary meaning of φωνη was obviously an inanimate sound, but I will, of course, admit that it would soon be followed by the thoroughly animate sound of the cries of wounded horses and men; but the inanimate meaning of φωνη beat the animate one, even if only by a short head!

London, S.E.1. "FREE GRID"

IF "monophonic" is to be excluded because it does not ". . . . call to mind . . . . the rich polyphonic sounds of music and well modulated voices . . . .", then can we permit the transmission of monodic works through a stereophonic system?

Furthermore, if it seems incongruous to transmit polyphony over a "monophonic" system, would it not be even more so to employ a "monodic" system, since the term "monody" means "a song for one person." It is derived from the Greek word for an ode sung by a single actor in the ancient Greek tragedy, and is also used in connection with early opera in distinction from polyphonic style.

Whilst paying due homage to the erudition of your cognoscenti, may I suggest that the term monodic be left alone since it already has a perfectly sound connotation. Keeping the prefix "mono," and I am sure that "mono" and "stereo," once accepted, will always be recognized terms, may I suggest that one might do worse than take from biology the term monophyllous (single-leafed), and change it to monophyllic. In spite of its "ph" and "ll" the word is easy to say and there is less likely to be confusion with a term borrowed from a more remote science or art. Monothetic is another fairly neutral alternative. "Monophonic" is still the best sounding term, however irregular the derivation.

Eccles, Lancs. Wm. THURLOW SMITH,
"Eroica" Sound Recording Services.

I THINK the B.B.C. have found a very pleasant sounding word in "monophonic," and whatever its origins and whatever it means we will enjoy using it. Your "monodic" sounds like a cold in the head.

Lausanne, Switzerland. R. H. WILLIAMS.

Mavars

I HAVE just read the excellent and entertaining article on MAVARS by "Cathode Ray" in the May issue of *Wireless World*.

In the discussion of names for the parametric device, reference to my article in the September 26, 1958, issue of *Electronics* gives the erroneous impression that I am the originator of the term MAVAR. Although I wish I could claim credit for this, such is not the case. Unfortunately, a search of my notes fails to disclose who was the first to use this term, so I cannot set the record completely straight.

Another name which has been proposed and which has some merit is the REACTATRON (*Proc. I.R.E.*, January 1959, p. 42). This term is intended to describe specifically the diode parametric amplifier, although I see no reason why it cannot be extended to other forms. It avoids the use of the term "mixer" which "Cathode Ray" feels so strongly about.

New York. SAMUEL WEBER,
Associate Editor, *Electronics*.

Facsimile Television

IN connection with the recent experiments in transatlantic television *via* the cable*, it is interesting to recall some very early history. I understand that the present technique is to transmit the successive frames of a film at slow speed by means of a special telecine machine and record them on the other side of the Atlantic. The film is then televised in the normal way after processing.

In 1934, on the occasion of the London to Melbourne Air Race, the G.B. Newsreel Company used the normal Radio Facsimile Service to transmit from Australia the separate frames of a cinematograph film of the winners arriving in Melbourne. The received pictures were rephotographed on to cine film in London. I believe it took about 20 hours facsimile transmission for a few seconds of film projection, but the attraction of seeing the film in the cinemas the day after the event more than justified the means. As in the present case some "compression" of the signal was achieved by omitting alter-

* See pp. 314 and 362 of this issue.—Ed.

nate frames of the film at the transmitting end and replacing them by repeats of the previous frame in the final printing process.

Mr. Castleton Knight, who pioneered this experiment, expressed surprise to me some time ago that "Wireless Pictures" as he called them, had not become a daily occurrence. His record has remained unchallenged for 25 years and it would be a pleasant gesture if the results of his efforts were taken from the vault where they now rest and televised for our enjoyment along with those of the present experiment.

Enfield, Middlesex. L. C. JESTY,
Sylvania-Thorn Colour Television
Laboratories, Ltd.

Wide-Band Aerials

I HAVE read with interest the two articles by Mr. F. R. W. Strafford in the April and May issues entitled "A Second Band III Programme?—The Aerial Problem."

I think it should be pointed out to your readers that a very satisfactory solution to this wide-band aerial problem exists. The type of aerial to which I make reference is known commercially as the Labgear "Spacematch," which became available on the market in August 1958.

The "Spacematch" aerial, at Band III frequencies, is essentially a form of long wire array having "V" configuration. The length-to-diameter ratio has been made quite low by adoption of the skeleton cone principle. By a proper choice of element diameter and included angles the impedance at the extremities of the aerial may be made to approximate the characteristic impedance of free space. Under ideal conditions, using this technique, the gain normally associated with a "V" beam type of aerial may be further enhanced to the extent of 3 dB. I agree with Mr. Strafford that a wide-band aerial providing a gain of about 9 dB would be extremely valuable and, indeed, it would suit most applications in-between circumstances permitting the use of simple inside aerials and those requiring extremely elaborate high-gain fringe arrays. Naturally television broadcasting stations have been so situated as to minimize the number of fringe arrays required.

In practice, individual elements of the "Spacematch" aerial have been made approximately $1\frac{1}{4}$ wavelengths long on Band III, which brings the unit into $\frac{1}{2}$-wave resonance just outside the low frequency end of Band I. However, because of its fan-like construction, it exhibits the broad width associated with this type of aerial and provides remarkably uniform response not only over Band III but also over the whole of Band I. Naturally, the excellent gain yielded on Band III (8 or 9 dB) cannot be maintained on Band I and its performance is similar to that of a simple dipole. Models are available, however, which incorporate the addition of a channelized Band I reflector where reception conditions make this necessary.

Cambridge. S. R. KHARBANDA,
Labgear Limited.

Displaying Valve Characteristics

I WAS most interested to read of Mr. R. G. Christian's method of displaying valve characteristics and their axes in the June issue.

The author appears to be satisfied with presenting what are, in effect, dynamic characteristics, and a change in anode load therefore affects these characteristics. From the students' point of view this is undesirable, and it is much better to use the actual anode voltage to give the X deflection, rather than the supply voltage, since the static characteristics would then be given as shown by the accompanying Fig. 1.

If a step voltage waveform is applied to the grid, the valve load line can be displayed as a shortening of the high-voltage ends of the traces. (Fig. 2). This property extends the usefulness of the demonstration because discussion can be made of the choice of a suitable anode load. The effect of negative feedback on the characteristics can be shown by the use of feedback circuits in common use. In particular, the effect of current negative feedback on output impedance can be demonstrated if a series resistance is used in the cathode lead. (Fig. 3).

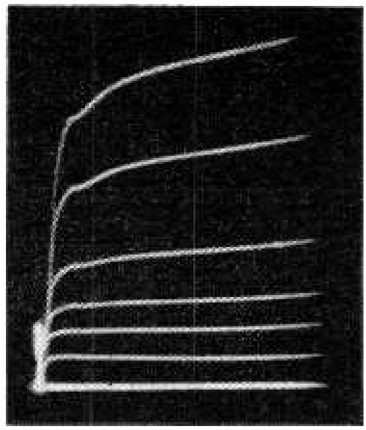


Fig. 1. Beam tetrode characteristics.

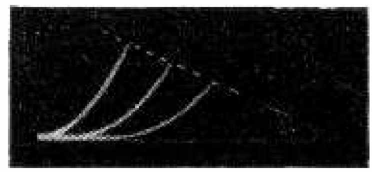


Fig. 2. Triode anode characteristics, showing load line.

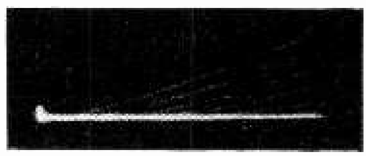


Fig. 3. Triode anode characteristics with current negative feedback.

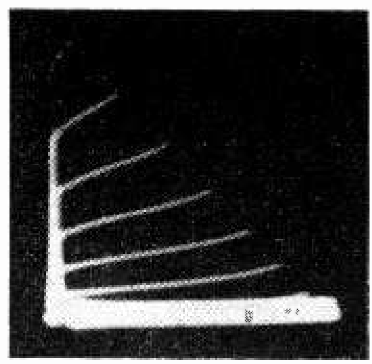


Fig. 4. Low-power transistor emitter characteristics.

In addition, if the step voltage is applied through a high resistance, a step current waveform can be obtained, which may be used to show the emitter input characteristics of transistors (Fig. 4). A high resistance should be put in series with the collector supply to ensure that the thermal runaway point is not exceeded.

The problem of the return trace, as mentioned by Mr. Christian, may be overcome by flyback blanking.

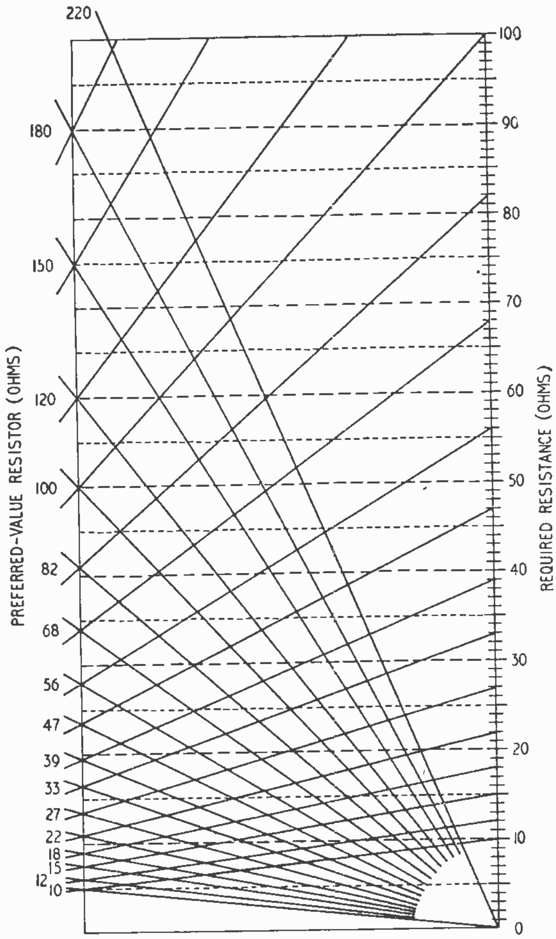
The accompanying photographs were obtained from a device showing several anode characteristics simultaneously, which has proved most useful in the work of the B.B.C. Engineering Training Department and it is described in the *Bulletin of Electrical Engineering Education*, Vol. 20, June 1958 (published at the College of Science and Technology, Manchester).

Wood Norton, Worcs. D. J. HENMAN,
B.B.C. Engineering Training Dept.

Resistors in Parallel

CHART FOR USE WITH PREFERRED-VALUE RESISTORS

By M. A. HAMMOND



THE accompanying chart provides a quick reference to the preferred-value resistors which, when connected in parallel, give a required non-preferred value of resistance.

Example: A resistance of 30Ω is required. At the 30-Ω point of the right-hand scale move horizontally to the left until a point of intersection of two diagonal lines is encountered. By following each of these diagonals from the intersection to the left-hand scale, it will be seen that 47Ω and 82Ω are the required preferred values to be paralleled for a resultant 30Ω.

Alternative points of intersection can be found very close to the 30-Ω line formed by intersections of the 39-Ω and 120-Ω lines and of the 56-Ω and 68-Ω lines respectively (left-hand scale).

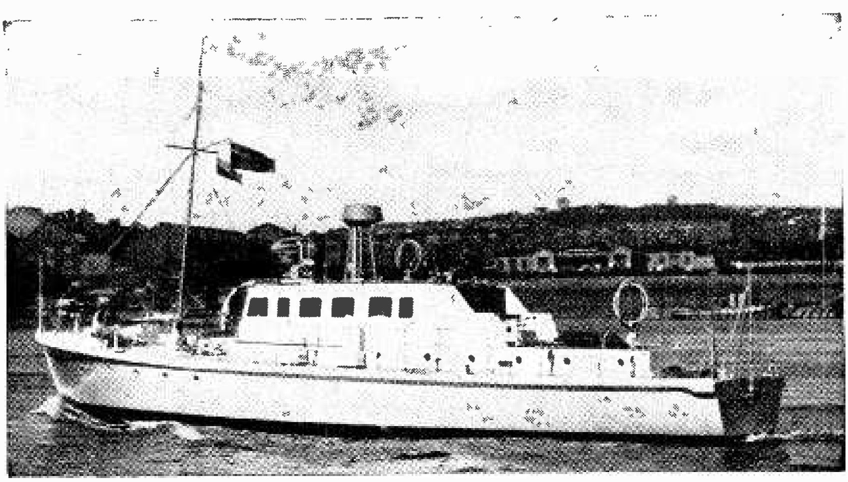
It is obvious that this will apply to the higher decades also if the necessary "noughts" are added to the significant figures and providing both resistors to be paralleled are in the same decade. For example, the resistance resulting from paralleling 18kΩ and 180Ω cannot be extracted from the chart.

Acknowledgement is made to J. W. D. Cunningham and L. F. Poole, for observations made while compiling the chart.

Small Radar for Small Ships

AS the "mains supply" most usually available on a small vessel is a nominal 24-V d.c. derived from accumulators, power consumption must be kept to a minimum and the radar must work from an input which may vary between 20V and 32V. The voltage-variation problem is overcome in the new Marconi Marine "Consort" by the use of a transistor regulator which reduces the input to a constant 19-V d.c., and e.h.t., h.t., negative bias and special supplies (such as the c.r.t. heater power) are derived from this 19-V d.c. by a transistor oscillator.

To reduce the power demand the equipment is normally kept in the "stand-by" condition in which the valve heaters only are energized and the current consumption then is 4A. A "press-to-view" button, mounted on the display unit, switches on the remaining supplies and the scanner motor, when the current consumption rises to about 10A. After roughly two minutes (governed by the heating and cooling of a bi-metal strip)



Radome-protected scanner on its tripod base installed on Marconi-Marine's demonstration yacht, Elettra II.

the radar reverts automatically to the stand-by state.

Voltage regulator, power supplies, transmitter and receiver are all contained in one case and printed wiring is used as far as is possible for its advantages of low cost and exact correspondence between boards.

The scanner employs a 3-ft-long slotted-waveguide array driven by a 1/24-horse-power motor. The use of this small drive power is made possible by enclosing the array in a fibre-glass radome which also prevents the ingress of sea spray. Fibre-glass is used, too, as the support for a "lens" formed from thin close-spaced vertical wires. This is mounted at the mouth of a short horn section extending from the waveguide aerial and it is used to reduce the amplitude of residual side-lobes.

Scanner-mount height limits the maximum range realisable to about 14 miles: other scales are 8, 4, 1.5 and 0.6 miles. Only a relatively small transmitter power is required to give effective cover to 14 miles so the peak-power output (p.w. 0.15μsec, p.r.f. 2,000/sec) of about 2.5kW is sufficient. Because the magnetron does not heat up appreciably at this low rating, its frequency does not drift seriously. This initial stability, together with a greatly-improved version of the 723AB local-oscillator klystron (English Electric) and a little "spare" bandwidth in the receiver, enables the complications of a.f.c. to be dispensed with. In fact, the fine-tuning control is preset, mounted on the display-unit rear panel.

The display unit, which is designed for mounting on the deckhead, bulkhead or table, uses a 5in-diameter c.r.t. This is fitted with a magnifying lens to increase the effective diameter to about 8in. Rotating-coil scanning is used for which the drive is obtained by a direct mechanical link (Bowden cable) to the scanner and the only "user control" fitted on the display unit is the press-to-view switch.

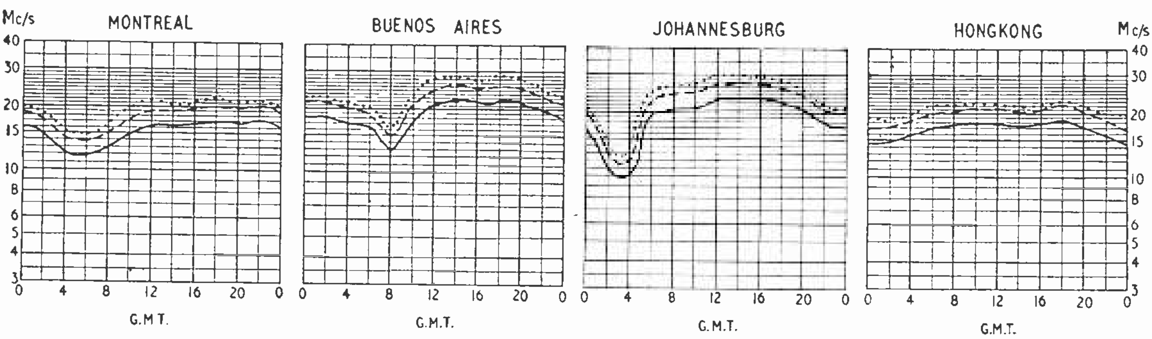
A complete installation weighs just over one hundredweight and costs about £800.

Sound Equipment at Stratford-on-Avon

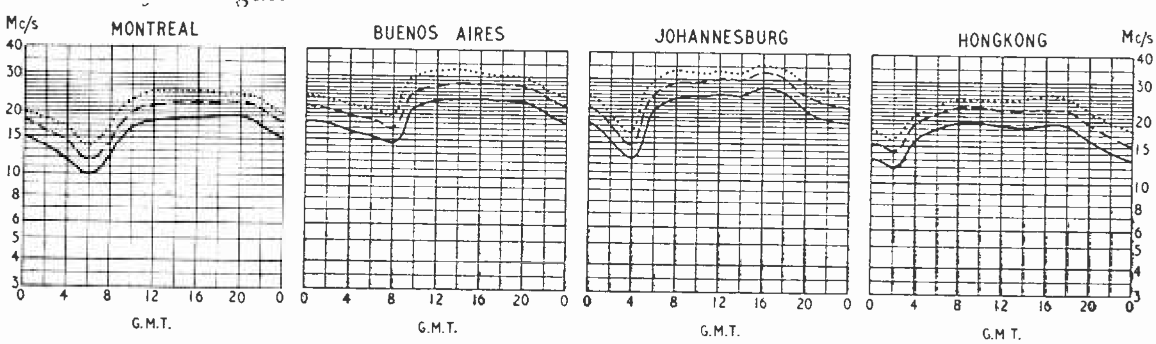
NEW sound-amplifying equipment has been fitted at the Shakespeare Memorial Theatre, Stratford-on-Avon. Designed and installed by R.C.A. (Great Britain), Ltd., the equipment provides single-channel speech reinforcement from three microphones on the stage and a 40-W amplifier feeding four line-source column loudspeakers placed in the auditorium, a two-channel sound-effects system (fed from two tape decks) with two amplifiers and five loudspeakers which may be placed anywhere on the stage, another single "effects" channel feeding a loudspeaker mounted over the stage, and a stage/orchestra liaison system through which the orchestra can follow the action although they are unable to see the stage. The signal to each of the five loudspeakers can be raised and lowered in turn, so that an impression of movement may be created. All four amplifiers are identical and they can be inter-switched so that a failure in one is not obvious to the audience.

SHORT-WAVE CONDITIONS

Prediction for July



Prediction for August



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

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

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

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

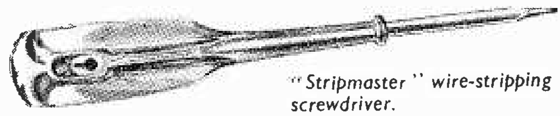
——— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Wire-stripping Screwdriver

THE "Stripmaster" is a screwdriver which carries in its shatterproof moulded-plastics handle a metal cutter with a keyhole-shaped aperture. The cutter forms a quick and effective wire stripper: in use the wire is passed through the large end of the "keyhole", forced down the slot and then pulled out, so stripping cleanly the insulation without "nicking" the wire. The overall length of the screwdriver is 6in and the screwdriver



"Stripmaster" wire-stripping screwdriver.

blade-width is $\frac{1}{8}$in. Retailing at 3s 6d, the "Stripmaster" is distributed by L. J. Hydleman and Co., Ltd., Grove Park, London, S.E.5.

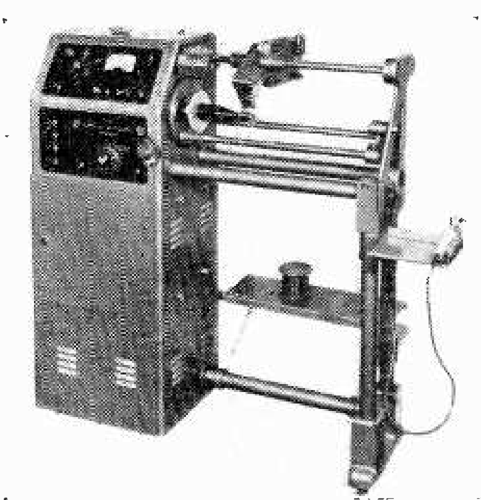
Sub-miniature Wire-wound Resistors

THE Alma Components Type RM2 precision sub-miniature wire-wound resistor is rated at $\frac{1}{10}$W and is designed to fit into both the 0.1-in and 0.15in printed circuit grids. Only 0.25-in in diameter and slightly over 0.3-in long, this resistor is available in values from 100Ω to 200kΩ, and with two standard tolerances (±1% and ±0.1%) at 20°C. The temperature coefficient is less than ±0.002% per °C and a stability of 0.05% over 1,000 hours running time is achieved. Manufacturers: Alma Components Ltd., 551, Holloway Road, London, N.19.

Electronic Coil Winder

PRECISION winding of multi-layer coils without paper interleave and with wires down to 0.002in in diameter (No. 47 s.w.g.) is one of the features of the new Douglas electronic coil winder described as the "Supermatic Layer Winding Machine."

Separate electrical drives are used for the headstock



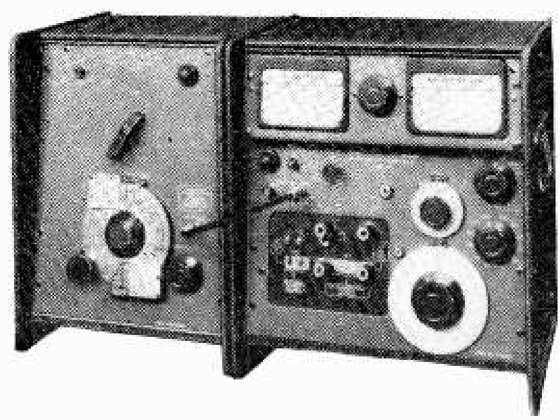
Douglas (Avo) electronic-controlled coil winder.

and for the wire traversing mechanism and any deviation from exact layer winding with adjacent turns touching is immediately corrected by means of a "sensing" head on the traversing carriage and associated electronic apparatus. Another feature of the new coil winder is that it can be set up to wind single-layer coils with precise spacing of the turns, the spacing being maintained as predetermined by the electronic equipment.

The makers are Avo Ltd., Avocet House, 92-96, Vauxhall Bridge Road, London, S.W.1.

Q-meter

THE new Marconi Type TF1245 Q-meter incorporates separate low and high frequency circuits to enable Q values from 5 to 1,000 to be measured at frequencies between 1kc/s and 300Mc/s with an accuracy which decreases with increasing frequency from ±5% at 100Mc/s to ±20% at 300Mc/s. Both the l.f. and h.f. measurement circuits are of the usual series-resonant type in which the Q is obtained from a measurement of the voltage across the tuned circuit capacity. The signal voltage is injected across a 0.02Ω resistor in the l.f. circuit and a 0.1mμH inductor in the h.f. AδQ range of ±25 is also provided. An external oscillator is necessary to make measurements, and two specially designed units are available, the TF1246 covering 40kc/s to 50Mc/s and the TF1247 covering 20Mc/s to 300 Mc/s. Matching transformers may be obtained to allow these oscillators to be used also as general-purpose signal generators.

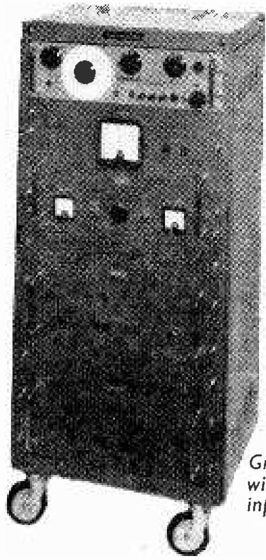


Marconi Q-Meter Type TF1245 (right) with external oscillator Type TF1247 (left).

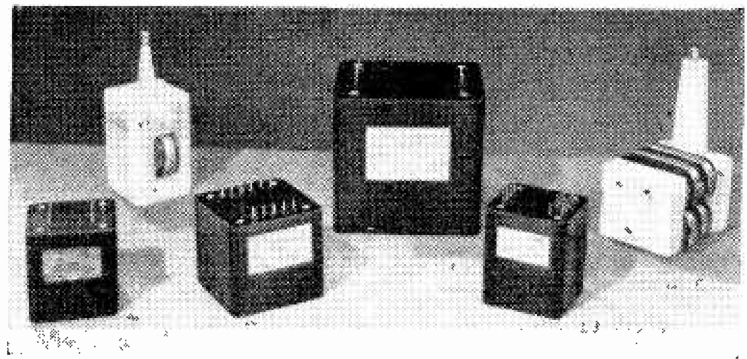
The TF1245 Q-meter costs £176 and the address of its manufacturer is Marconi Instruments Ltd., St. Albans, Herts.

Low-frequency Power Amplifier

A SINE-WAVE output power of 100 watts (r.m.s.) with a distortion less than 2% may be obtained at any frequency from 10c/s to 5kc/s from the Grampian v.l.f. amplifier. The input inpedance is 10kΩ and 3V is required for full output. Output impedances between 10Ω and 100Ω are available according to requirements, and the frequency response is flat within ±$\frac{1}{2}$dB. This amplifier costs £360 or more according to the number of



Grampian v.l.f. amplifier with Ediswan Type R666 input oscillator.

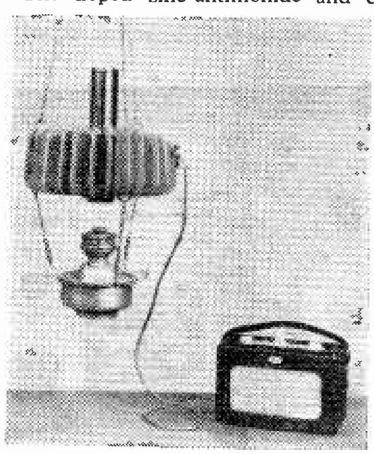


Examples from Wayne-Kerr's new range of resin-cast transformers.

output tappings or other special modifications required. The address of its manufacturer is Grampian Reproducers Ltd., Hanworth Trading Estate, Feltham, Middlesex.

Paraffin Power for Portables

A NEW version of the thermo-electric, receiver power supply (Type T.E.G.1) previously illustrated on p. 227 of our May, 1956, issue is now available in this country. The doped zinc-antimonide and constantan



Thermo-electric generator supplying power to an "all-dry" portable receiver.

couples normally give outputs of 80 to 90V at 10 to 11mA, 1.0 to 1.2V at 0.21 to 0.52A and 8 to 10-V grid-bias: it is thus suitable for many "all-dry" receivers. The T.E.G.1 is imported from the U.S.S.R. by International Technical Developments, Ltd., of Willow Road, Poyle Estate, Colnbrook, Buckinghamshire, and it costs £16, or £20 with lamp.

Resin-cast Transformers

WAYNE-KERR LABORATORIES have introduced a range of resin-cast transformers in ratings between 5 and 350W. Designed to replace oil-filled units where the possibility of oil leakage cannot be tolerated, the transformers use C-core construction and comply with the requirements of R.C.S.214. Vacuum impregnation with a polyester resin enables insulation resistances of better than 100MΩ at 130°C to be achieved and the black epoxy-resin encapsulation material does not support combustion. Also a range of pulse transformers developing between 7kV and 50kV at up to 60MW peak power is available. The manufacturers are Wayne-Kerr Laboratories of Roebuck Road, Chessington, Surrey.

Fixed Capacitors

A RANGE of isolation and suppression capacitors covering values between 470pF and 10,000pF is announced by T.C.C. The dielectric is high-permittivity ceramic and a non-cracking heat-resistant protective coating prevents the ingress of moisture and provides insulation sufficient for the capacitor to be mounted in contact with other components or the chassis, whilst still complying with the requirements of B.S.415—1957. The maximum rating is 500 d.v. (300 r.m.s. a.v.), capacity tolerance is -20 $+80\%$ and the capacitors also comply with B.S.2818—1957 (for fluorescent-lighting interference suppression).

A new T.C.C. range of low-working-voltage paper-dielectric capacitors has each foil electrode wound with two thicknesses of paper; but with improved machinery and new materials the physical size is comparable with that of the metallized-paper type. With a maximum d.v. rating of 150, the Type 143 is made in capacities from $0.02\mu F$ to $0.5\mu F$, the sizes ranging between $\frac{5}{8}$-in long by $\frac{1}{4}$-in diameter and $1\frac{1}{8}$-in long by $\frac{9}{16}$-in diameter respectively. The capacity tolerance is $\pm 20\%$ and the temperature range is -30 to $+60°C$. Manufacturers: The Telegraph Condenser Co., Ltd., London, W.3.

Two X-band Isolators

ONE of the new Sanders (Electronics) ferrite isolators is a small-size unit for use in commercial systems. It has an isolation of better than 35dB over a $\pm 500Mc/s$ bandwidth around any required frequency between 8.2 and 12.4kMc/s. Its insertion loss is 0.7dB, and its input voltage standing wave ratio better than 0.9 to 1. Up to 150W mean power can be handled by this unit, and it costs £35. The other isolator is for laboratory use over the broad frequency band from 8.2 to 12.4kMc/s. Its isolation is at least 30dB, its insertion loss less than 1dB and its input v.s.w.r. better than 0.87 to 1. Up to 15W can be handled by this unit and it costs £85. Both these isolators are manufactured by W. H. Sanders (Electronics), Ltd., of Gunnels Wood Road, Stevenage, Herts.

Sanders broad-band microwave isolator.

Equatorial Sunset Effect

Observations Over a Whole Sunspot Cycle Point to an Unexplained Propagation Anomaly

By A. M. HUMBY,* M.I.E.E.

IN August, 1947, a year of high solar activity (Fig. 1), the writer observed at Singapore that teleprinter operation of the Admiralty circuit to London became extremely difficult, if not impossible, from about 1900 to 2100 local time Singapore, i.e., 1200 to 1400 G.M.T., a condition which the operating personnel (often only too ready to blame the man at the *other* end) referred to, in those days, as the "Whitehall Lunch-time Effect"!

The circuit had been equipped with suitably directive aerials at each terminal for operation on a number of frequencies between 4Mc/s and 22Mc/s, according to the time of day, season and epoch of the 11-year solar cycle.

For distances exceeding 4,000km propagation takes place by a number of complex modes, and it has been found empirically that, for a given frequency, propagation via the F_2-layer is usually practicable so long as the ionosphere at "control points," distant 2,000km from each terminal (Fig. 2), supports transmission at that frequency irrespective of the condition of the ionosphere elsewhere along the great-circle path. If this condition is not satisfied at each "control point" a change to a lower frequency is usually necessary.

*Royal Naval Scientific Service.

In certain cases E-layer propagation may be possible, the investigation of which involves two additional "control points" distant 1,000km from each terminal.

The extent to which the frequency may be lowered depends upon such factors as the effective radiated power of the transmitter, absorption of signal, and the level of atmospherics and the type of aerial at the receiving terminal. The condition of the ionosphere at any given location is assessed from regular ionosphere soundings carried out at a large number of measuring stations throughout the world, and from this data groups of charts are prepared on a month-to-month basis representing world-wide variations of ionization with the time of day, season and solar activity.

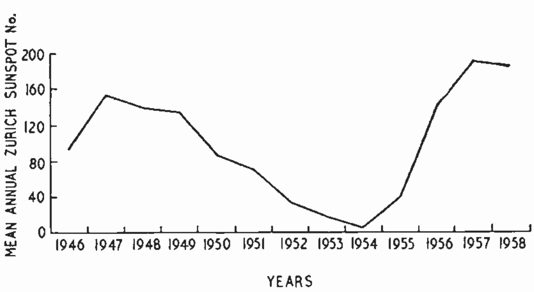


Fig. 1. Mean Zurich sunspot numbers for the years 1946 to 1958 inclusive.

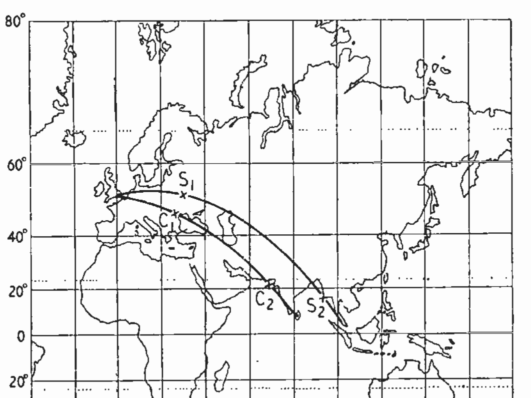


Fig. 2. The "control points" mentioned in the text; S_1 S_2 on Singapore/London and C_1 C_2 on Colombo/London great-circle paths respectively.

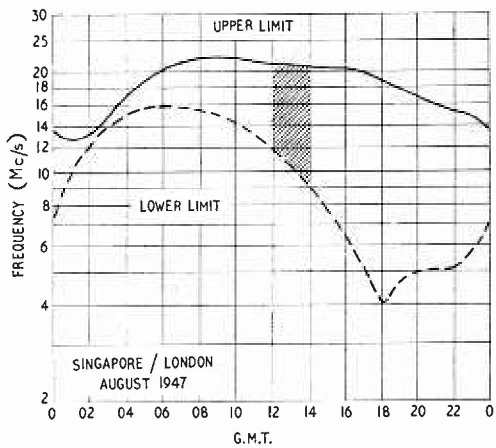


Fig. 3. Upper and lower predicted frequency limits for radio-teleprinter operation between Singapore and London, August 1947.

Considerable success is now being achieved by ionospheric forecasters in determining the most probable upper- and lower-frequency limits in any given case, and fortunately for the radio engineer discrepancies between prediction and practice are gradually being eliminated.

Predictions of the type referred to above for the case of the Singapore/London circuit for August 1947 are shown in Fig. 3, from which it would appear that a wide band of frequencies should have been suitable for teleprinter operation between 1200 and 1400 G.M.T.; in point of fact although communication on several frequencies within the predicted limits was attempted, this period, as stated

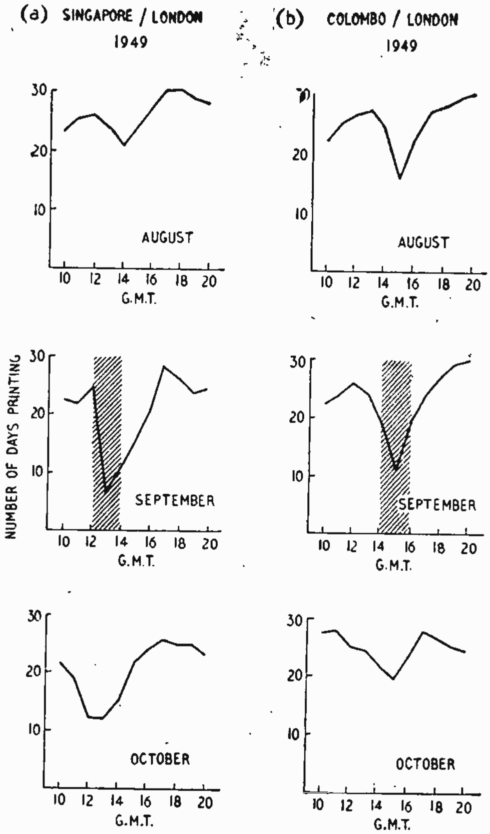


Fig. 4. Communication conditions on Singapore/London and Colombo/London radio circuits near local sunset (equatorial region) for equinox months of 1949.

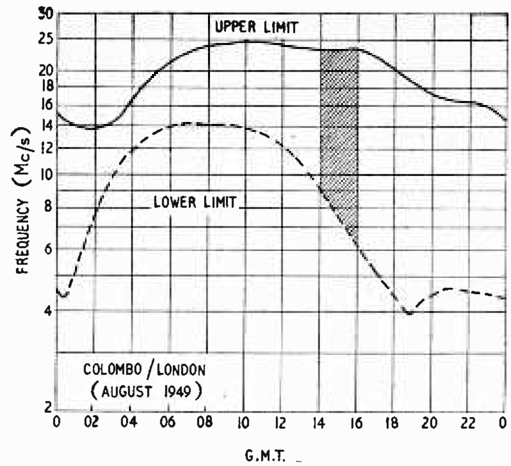


Fig. 5. Upper and lower predicted frequency limits for radio teleprinter operation between Colombo and London during August 1949.

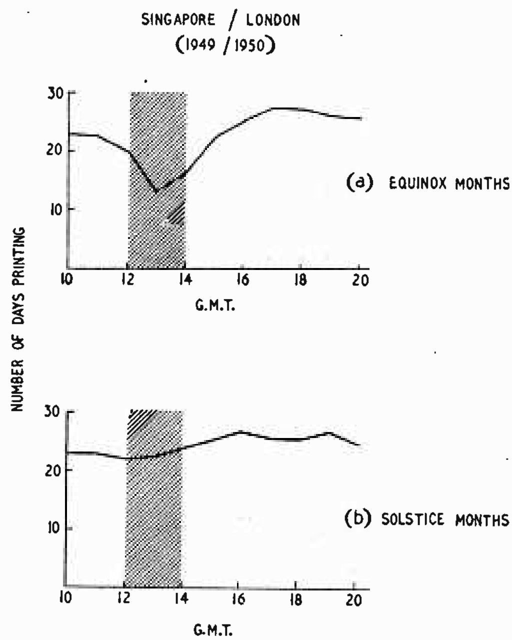


Fig. 6. Number of teleprinter operating days on Singapore/London radio circuit for equinox and solstice months of 1949/1950.

earlier, was one which proved in practice to be one of extreme difficulty.

The period 1900 to 2100 local time Singapore, i.e., shortly after sunset, was characterized by:—

(*a*) A reduction of signal intensity in each direction of the Singapore/London circuit.

(*b*) Excessive multipath distortion arising from the reception of a number of echo signals arriving over different radio paths with sufficiently large time delays to prohibit operation of the circuit at normal teleprinter speed (50 bauds).

However, on many days the signal-to-noise ratio was adequate to permit Morse operation at slow speeds (e.g., 15 to 20 bauds), where, on account of the much longer time intervals between transmitted signal elements, multipath effects were less troublesome. Reception in these cases was carried out either by ear, or by undulator recorder, methods which in themselves are less sensitive than the teleprinter one to multipath distortion.

(*c*) Direction of arrival of incoming signals being diffused, or "flat," suggesting considerable azimuthal scattering of the received energy.

With the introduction in the autumn of 1949 of hourly circuit-merit figures indicative of the diurnal performance of all Admiralty radio-teleprinter circuits, it became apparent that a similar, though somewhat less pronounced, difficult period was also being experienced daily on the Colombo/London circuit from about 1900 to 2100 local time Colombo, i.e., 1400 to 1600 G.M.T.

Figs. 4(a) and 4(b) show the deterioration in performance of these two circuits near local sunset at Singapore and Colombo respectively for the months of August, September and October, 1949.

As in the case of the Singapore/London circuit, frequency predictions for the Colombo/London circuit based on the "two control-point" method (C_1 and C_2 of Fig. 2) indicated that a reliable teleprinter circuit should have been practicable during the above period of the day (Fig. 5).

Further investigation disclosed that the above difficulty on each circuit was essentially a condition peculiar to the equinox as distinct from the solstice. Let us compare, for example, the performance of the Singapore/London circuit for the six equinox months [Fig. 6(a)], with that for the six solstice months [Fig. 6(b)], of the twelve-month period August, 1949, to July, 1950, inclusive.

The continuation of such records throughout the period 1949 to 1958 inclusive has provided confirmation that the effect under discussion was substantially non-existent in solstice months.

The performance of the Singapore/London and Colombo/London circuits for equinox months are compared in Fig. 7 for each year commencing 1949 and ending 1958, and it will be seen, by reference to the annual solar indices shown in Fig. 1, that the equatorial-sunset effect under discussion was associated with years of high solar activity.

To summarize.—The effects described above relate to difficulties of communication with terminals situated in equatorial areas, the salient feature being a considerable azimuthal scattering of signals for about two hours near local sunset at the equatorial terminal, notably during the equinox months of years of high solar activity.

Directly related to this phenomenon would appear to be that reported by Osborne[1], as part of the work of the Radio Research Board. He has drawn

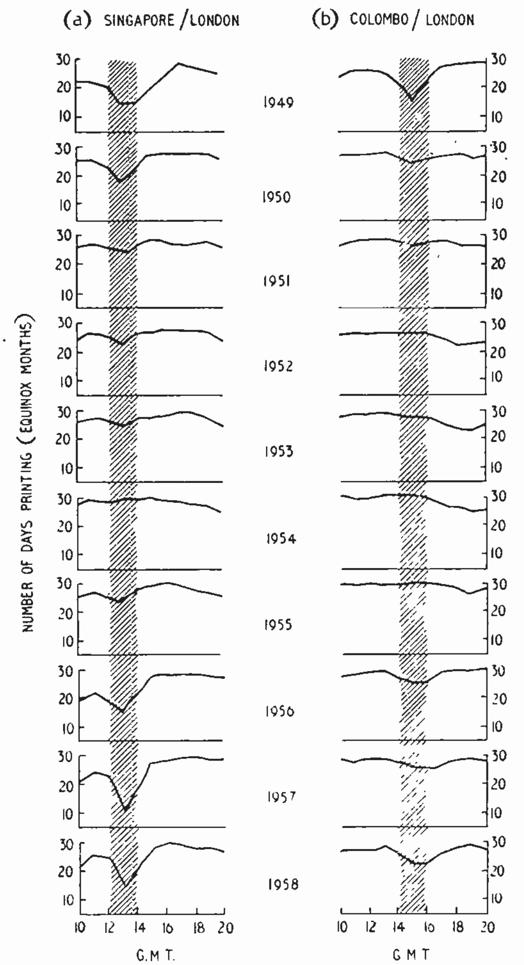


Fig. 7. Number of teleprinter working days on Singapore/London and Colombo/London circuits during equinox months from 1949 to 1958 inclusive.

attention to the disintegration of the F_2 layer at Singapore near the time of local sunset during equinox months; and has referred to the possibility of the frequency of occurrence of this equatorial scatter being greatest at the maximum of the 11-year solar cycle. The effect in practice, he states, is that reflected signals from the F_2 region are not always intelligible, even though the signal strength may be high, whereas at the solstices propagation conditions are better at these hours, when the layer often remains intact throughout the evening.

Some light on the extent to which circuits to other equatorial points are affected in this way has been thrown by Hitchcock[2] who has drawn attention to the fact that during the autumn of 1956 many radio circuits operating in low latitudes suffered severe propagational difficulties shortly after local sunset. This took the form of severe fading, or weakening, of signals sufficiently serious to degrade, or interrupt, the services. In all cases, he states, the normal operating frequency, and the alternative frequencies used in an attempt to maintain communication, were well clear of the predicted upper and lower limits. And he adds, moreover, that the effect was not generally noticeable on circuits during sunspot minimum years.

In view of the apparent correlation between the circuit data from various sources and the results of ionospheric soundings, it is possible that there is a fundamental obstacle to the sky-wave operation of tropical, or partly tropical, circuits under the conditions which have been referred to.

Since the last war the number of high-frequency circuits has considerably increased, and the period 1947 (high solar activity) through 1954 (low solar activity) to 1958 (exceptionally high solar activity) has thus afforded an excellent opportunity of studying many of the effects of the solar cycle on communication by ionospherically reflected rays.

In this connection it is perhaps not without interest to recall the following statement made by Appleton in 1947[3] "Sir Edward Appleton (in reply): I strongly support Dr. Smith-Rose's plea for continued, and indeed extended, post mortem examination of operational results. Only in this way is it possible to check the accuracy of our ionospheric predictions. Moreover, nature has many surprises for us in work of this kind, and, with a laboratory as large as the earth itself, it is only with the co-operation of an army of radio operators that we can ensure that many interesting abnormalities do not escape attention."

Acknowledgments.—The author wishes to thank Miss S. S. Aucken and B. W. Smith, of the Royal Naval Scientific Service, for their assistance in the presentation of the data in this article, which is published by permission of the Admiralty.

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[1] Osborne, B. W. "A Note on Ionospheric Conditions Which May Affect Tropical Broadcasting Services After Sunset." *Journal of the Brit.I.R.E.*, Vol. 12, No. 2, February 1952.

[2] Hitchcock, R. J. "Propagational Difficulties on Radio Routes Operating Near the Magnetic Equator." (Private communication, 30th January, 1957.)

[3] Discussion on "The Investigation and Forecasting of Ionospheric Conditions," by Sir Edward Appleton; *Journal I.E.E.*, 1947, Vol. 94, Part IIIA, p. 878.

Elements of Electronic Circuits

4.—USE OF SHORT TIME CONSTANT CIRCUITS WITH DIODES AND TRIODES

By J. M. PETERS, *B.Sc. (Eng.), A.M.I.E.E., A.M. Brit. I.R.E.*

WE have seen in Part 1 (April issue) that the application of a square waveform to a CR circuit of very short time constant compared with the recurrence period results in a distorted waveform across the resistor. In the extreme case, when the time constant is very much less than the period, the output becomes a spike and approximates to the mathematical differential coefficient of the input wave. In other words, the shape of the output wave corresponds to the rate of change, with respect to time, of the input voltage wave; hence the term "differentiation."

Now let us examine what happens when a diode is connected in parallel with such a CR circuit (Fig. 1). The recurrence period of the square wave

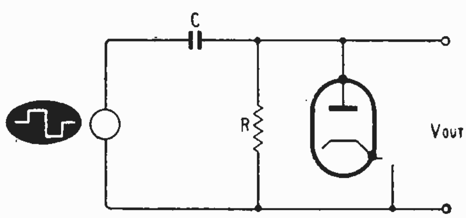


Fig. 1.

input is assumed to be 1 millisecond whilst the time constant is 1 microsecond.

Immediately the diode anode is driven positive by the square wave the diode conducts. As the rise time of the applied wave is finite, i.e., cannot occur instantaneously, the spike X shown dotted in Fig. 2

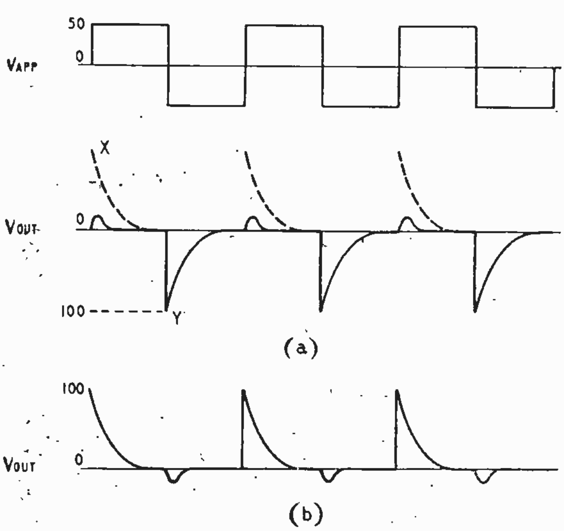


Fig. 2.

does not appear in practice and a small positive "blip" results. In effect, the diode clamps the positive excursion of the input wave to zero (Fig. 2 (a)). The negative excursion of the differentiated wave remains; the portion YZ is the result of C discharging through R. If the diode connections are reversed the spike appears all positive, as shown in Fig. 2 (b).

By means of this simple device it is therefore possible to derive waveforms consisting of very sharp positive- or negative-going spikes of the repetition frequency of the applied square wave.

If the same short time constant CR circuit is connected in the grid circuit of a triode (Fig. 3)

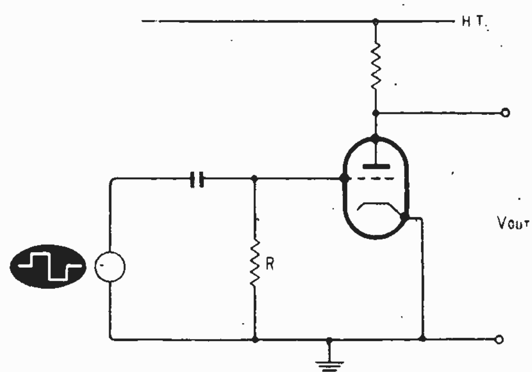


Fig. 3.

and a square waveform applied as before the result is as shown in Fig. 4. The triode's grid and cathode take the place of the diode's anode and cathode respectively and the spiked waveform now appears at the grid. As the negative excursions of the spike

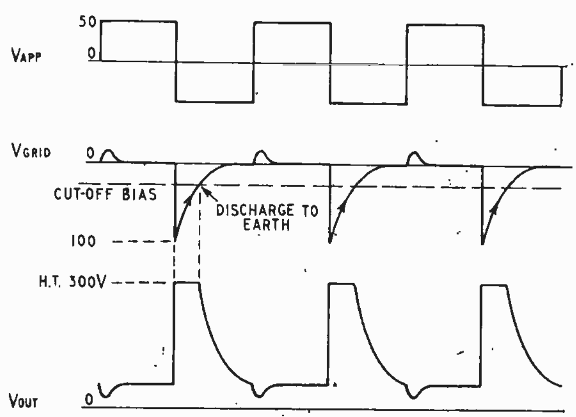


Fig. 4.

drive the triode beyond cut-off the resultant waveform at the anode appears as short positive-going square-topped pulses. The valve therefore performs a "squaring" function.

If instead of coupling the grid leak to earth it is taken to h.t. (Fig. 5), then an even narrower

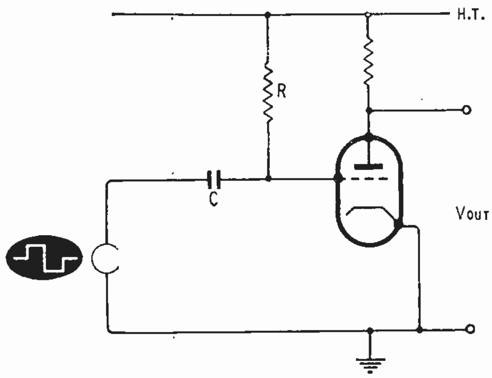


Fig. 5.

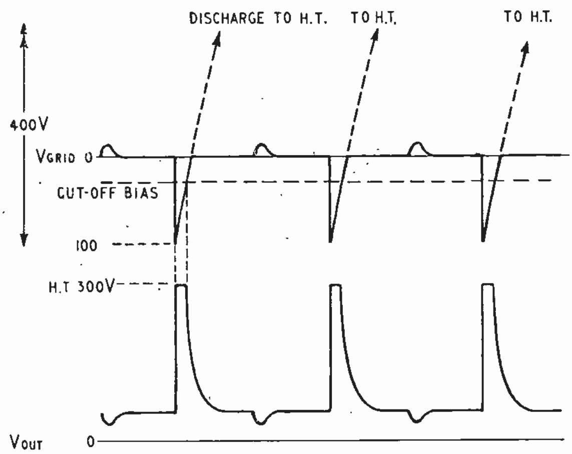


Fig. 6.

square-topped anode voltage pulse can be obtained (Fig. 6). In this arrangement C discharges exponentially towards the h.t. voltage. The voltage/time gradient is steeper than when R is connected to earth and the anode voltage pulse is consequently narrower.

In the examples shown the maximum excursion of the square pulse is ±50 volts, C is instantaneously charged to 100 volts, while the h.t. voltage is assumed to be 300 volts. It will be seen that the effective voltage in Fig. 6 is therefore 400 volts, compared with only 100 volts in Fig. 4.

Short Pulses from a Sine Wave.—It is possible for a distorting amplifier followed by a stage of bias differentiation (Fig. 7) to convert a sine wave into a narrow square-topped trigger or sync pulse. This is illustrated in Fig. 8.

Grid limiting by the distorting amplifier V1 produces an approximately square waveform at the anode of V1. Differentiation by the short time constant CR circuit and squaring of the spike by V2 results in the V2 anode voltage waveform shown.

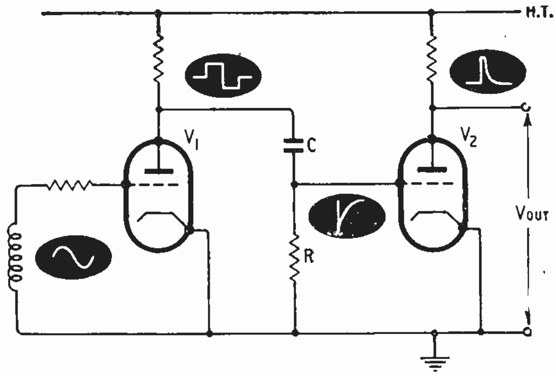


Fig. 7.

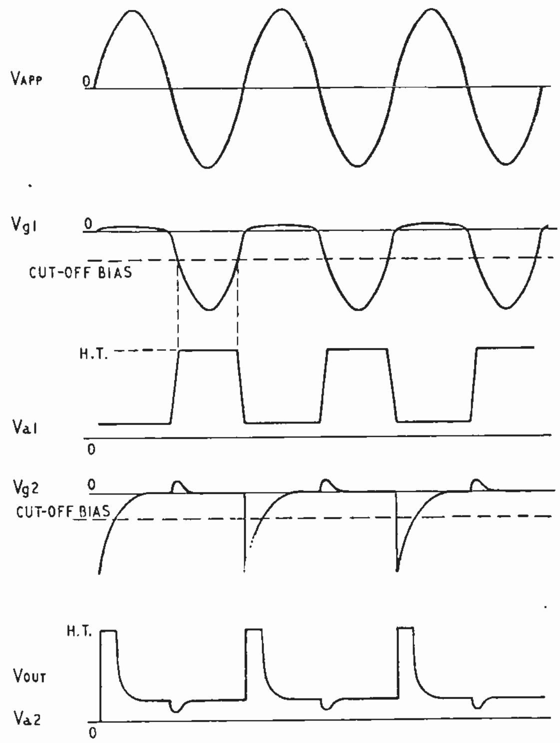


Fig. 8.

The repetition frequency of this pulse, which can be used for triggering or synchronizing purposes, is that of the applied sine wave.

The usefulness of a pulse of this kind will be appreciated later when its application as a trigger pulse for circuits such as the multivibrator will be described. As already described, a narrower pulse can be obtained by connecting R to h.t. instead of to earth.

Technical Digests are again to be issued monthly by the D.S.I.R. Each month's digest will consist of fifteen summaries of ideas and techniques recently published in this country's 300 or so technical periodicals. Each summary will be presented on a separate sheet. A year's subscription costs three guineas and particulars are obtainable from the D.S.I.R. Charles House, 5-11, Regent Street, London, S.W.1.

International Transistor Convention

1.—NEW SEMICONDUCTOR TECHNIQUES AND APPLICATIONS DESCRIBED

ALTHOUGH the seats in the Earls Court lecture halls gave more the sensation of a surface barrier than a comfortable diffused junction as one would have wished, it is a tribute to the quality of the papers presented at the I.E.E.'s Transistor Convention that all sessions throughout the six-day event had large and attentive audiences. There were about 2,000 delegates altogether, of whom 400 were from 26 overseas countries. Particularly crowded was the opening session, which had the special attraction of introductory lectures by the joint inventors of the transistor, Professor Bardeen, Dr. Brattain and Dr. Shockley—a triumvirate which the Supporting Chairman, G. Millington, mysteriously linked with Faith, Hope and Charity.

While Professor Bardeen and Dr. Brattain outlined the history and recent development of the transistor, Dr. Shockley seized the occasion to talk about the principal product of his company, the four layer p-n-p-n junction diode, or "transistor diode" as he called it. This device, with its negative resistance characteristic (see October 1957 issue, p. 502), is becoming an important competitor to the conventional transistor in switching circuits because of its much greater power handling capacity. Dr. Shockley predicted that in two or three years transistor diodes will attain power levels 10 to 100 times higher than equivalent transistors with comparable frequencies and efficiencies. One recent experimental device was capable of switching on 1kW in 20 millimicroseconds (or nanoseconds, as Continental speakers preferred it).

The great problem in this high power work, Dr. Shockley explained, was to produce a uniform avalanche current multiplying effect over large-area junctions, and he mentioned two new operating principles, called impulsive charging and majority carrier extraction, by which this effect could be achieved.

Many organizations are developing the basic p-n-p-n structure and in some cases a third connection is made, analogous to the grid of a thyratron valve, to give a controlling or gating action. One example is the controlled silicon rectifier, of which some applications in industrial power control were described by H. S. Lowry. As distinct from the thyratron, the silicon controlled rectifier (as it is called) needs current pulses of about 1A for triggering purposes, and circuits were described using Unijunction transistors (January 1957 issue, p. 40) to provide them. One method of manufacturing p-n-p-n devices was presented in a paper by R. Freestone. This consisted of forming an n-p-n structure by the "melt-back" system, in which impurities are segregated by controlled cooling in a furnace, and then adding the extra p-type layer by alloying a pellet of indium on one end.

While some delegates were probably surprised to hear talk about switching hundreds of amperes by semiconductor devices, others must have been equally astonished at the discussions on transistors working at hundreds of megacycles (one was described for 3,000 Mc/s). This very high frequency operation is made possible largely by diffusion manufacturing techniques, in which extremely thin base layers are produced by diffusing impurities into the surface of the semiconductor. The supreme example of this at the moment is the "mesa" transistor (see p. 350). Diffusion technique also makes possible the grading of impurities to give accelerating electric fields in the base layers of drift and alloy-diffused transistors. Unfortunately the high concentration of impurity on the emitter side leads to low emitter-base breakdown voltages, which can be a problem for circuit designers. One paper, by W. Fulop, suggested how this could be overcome by inserting an extra layer of high resistivity material between the emitter and the graded base. Analysis showed that the breakdown voltage would be improved without unduly affecting the frequency response.

Diffusion techniques are also important for another reason. They are very convenient for manufacturing "solid circuits," in which integrated circuit assemblies of transistor, diode, resistance, capacitance and conducting elements are produced electro-chemically on extremely small wafers of semiconductor material. A paper by T. M. Liimatainen described the use of photo-lithographic and photo-engraving methods for etching away selected areas of a semiconductor wafer into which a base layer had been previously diffused. When metal contacts and electrodes have been deposited and alloyed with the semiconductor the result is a "printed transistor". It can take the form of an individual package or be part of an integrated circuit assembly. Multiple units can be produced on a single semiconductor wafer. Typical examples have common-emitter current gains of 15 and alpha cut-off frequencies of 48Mc/s.

Dielectric Devices

An entirely new class of semiconductor devices, known as dielectric diodes and triodes, is likely to arise out of recent research by various workers on space-charge-limited currents through insulating crystals (see p. 350). These currents are analogous to those flowing through the insulating vacuum of the thermionic valve. A paper by G. T. Winch described experiments on crystals of cadmium sulphide, through which steady current densities of several amperes per square centimetre had been obtained with only a few volts applied.

The idea of space charge also came into a group of papers on the theory and measurement of transistor parameters. Ever since transistors began to be used extensively for switching and pulse work it was realized that the established small-signal a.c. theory, based on such things as alpha cut-off fre-

and Exhibition

AT THE CONVENTION

quency, effective base resistance and collector capacitance, was not very helpful for non-linear operating conditions. In 1957, Beaufoy and Sparkes, who presented papers at the Convention, introduced a new approach to transistor operation based on the concept of charge control. The central idea of this was that a number of current carriers (say holes in a p-n-p transistor) was necessary between emitter and collector to sustain the current, and this number represented a stored "charge" which varied with the working point.

The so-called charge-control parameters worked out on this basis proved a very convenient way of dealing with large-signal transients in switching circuit design, and at the Convention several speakers paid tribute to its usefulness. J. J. Sparkes presented a paper on the measurement of these parameters (e.g. collector time constant is defined as Q_B/I_C, base charge over collector current), while R. Beaufoy showed how they are used in switching circuit design. Another paper, by A. Kruithof, demonstrated that the charge-control concept lends itself very well to a graphical representation of transient response.

Charge-Control Theory

Taking the idea even further, R. D. Middlebrook expounded a whole new theory which integrated the valve and the transistor on the basis that both are fundamentally charge-controlled devices, not voltage-controlled and current-controlled, respectively, as we are accustomed to regard them at present. One example of the approach is that in a charge-controlled device the transit time of charge carriers across the active region is inversely proportional to the nth power of the total charge in transit; n being 0 when the current is diffusion limited in semiconductors, $\frac{1}{2}$ when it is space-charge limited in vacuo and 1 when it is space-charge limited in semiconductors.

Professor Middlebrook also conducted an experiment in subliminal perception by presenting about a dozen lantern slides loaded with mathematics in quick succession, but in spite of this his interesting paper was very favourably received. It should be well worth studying in more detail when the Proceedings are published by the I.E.E. Particular praise came from speakers who were concerned with the present unsatisfactory state of technical education in semiconductor, as compared with valve, theory and practice.

On the manufacturing side, one or two papers discussed the relative advantages of the three basic junction-forming techniques—alloying, growing and diffusion—in such factors as cost, complexity and reproducibility. It emerged that the diffused base transistor was likely to be the great thing of the future. There was no doubt that this device had a wider field of application than the others. It was more complex and costly to produce at the moment, but the possibility of processing the junctions in large batches, combined with the wide market, would undoubtedly bring down the price in the future. The alloy junction transistor was notable for its design flexibility but showed potential disadvantages in cost and was poor in reproducibility. By contrast the grown-junction transistor had cost advantages due to reduced complexity and better reproducibility, but was lacking in design flexibility.

Reliability of transistors also came in for some discussion, and certain speakers were obviously worried by conflicting evidence in the papers concerned with it. For example, R. Brewer and W. W. D. Wyatt, in a reliability appraisal based on life tests, stated that there was no evidence of any major changes taking place which would constitute a "wearing-out" process in semiconductor devices. On the other hand, F. F. Roberts, J. C. Henderson and R. A. Hastie, describing an accelerated ageing experiment on germanium alloy transistors, mentioned that a rapid increase of collector-base leakage current (and noise) had occurred in some units at little more than 2,000 hours. This had been almost the sole cause of failure; current gains had shown deterioration only after the onset of the excessive leakage.

Two other deleterious effects, with the sinister names of "creep" and "wiggle," were mentioned. The first is a variation of reverse current produced when a sustained reverse bias is applied to a p-n junction. The second is a variation of transistor input capacitance (and conductance) with frequency, probably due to electron storage in the emitter—the "wiggle" being the distorting effect on pulse and switching waveforms.

Incidentally, one speaker made a strong plea to manufacturers to give more comprehensive technical data on semiconductor devices, particularly on their performance at different temperatures. He remarked that the tabular data usually presented was quite inadequate for design purposes. (Loud applause from the audience.)

On the applications side, there were very few papers concerned with domestic radio, television and audio circuits, and none on hearing aids, but d.c. amplifiers received some attention. A large number of contributors, however, dealt with the applications of transistors in line communications and data processing. In both of these fields, where amplifying or switching devices are needed in large quantities, the small size and low power consumption of the transistor make it an ideal component. The communications papers covered digital speech transmission systems as well as straightforward amplification in carrier telephony, while the data processing papers covered telephone switching as well as digital computing.

In the field of computing, circuits are now being developed to operate at pulse rates of 50Mc/s and above, with pulse rise times of only 1 or 2 millimicroseconds. As examples, G. B. B. Chaplin described a 50-Mc/s binary scaler using micro-alloy diffused transistors and showed a transistor-generated pulse of a few millimicroseconds on a 30-mμsec transistor-generated c.r.o. timebase.

At these frequencies transistors have the advantage over valves, not only because of their lower impedances but because they can be packed very much closer together to minimize transmission time delays of pulses. There is, in fact, a limit on the dimensions of a computer for such work since the transmission time delays of the wiring become significant and the required timing arrangements and speed of operation could be adversely affected. Mr. Chaplin demonstrated this fact most effectively by causing his millimicroseconds pulse to travel down a line a few feet long and be reflected from a short circuit to appear on the 30mμsec timebase at some distance from the generated pulse.

Many different types of switching and computing circuits were described in other papers. The discussion on them was wound up by a general plea from one speaker that there should be some kind of agreed standardization and simplification in such circuit techniques. This would enable manufacturers to concentrate on producing first-class transistors with the best possible characteristics for switching work.

2.—INTERESTING THINGS SEEN AT THE EXHIBITION

Dielectric Valves being investigated by the Electrical Engineering Department of Birmingham University are similar to ordinary valves except that the electrons flow through a dielectric rather than a vacuum insulator. Normally currents cannot be made to flow through a dielectric insulator as through a vacuum for two reasons: potential barriers are set up at any external contacts, and in addition, imperfections in the dielectric crystal lattice structure trap any electrons which may flow initially so that an electric field is produced which inhibits any further flow. However, these two difficulties have now been overcome. Thin plate crystals of cadmium sulphide have been grown with a sufficiently perfect lattice structure to pass currents of tens of amperes per square centimetre at a few volts, and in addition, external contact potential barriers have been avoided by diffusing indium contacts into the surface of such crystals. Dielectric valves offer a number of general advantages over ordinary valves or transistors. They should be much easier to construct than either transistors or ordinary valves, although, for a given high frequency response, the dielectric valve, like the transistor, will have to be much smaller than the corresponding ordinary valve. Also, the current/voltage characteristics of dielectric valves can be modified by altering the characteristics and number of the remaining imperfections in the crystal. No heater is needed in a dielectric valve since the free electrons in the metal contacts flow directly into the dielectric.

Alcatrons shown by the French C.S.F. are experimental field-effect majority-carrier devices similar to the Tecnetron in consisting of a piece of n-type semiconductor material with a very narrow (about 10 microns wide) constriction in it. The supply voltage is applied between two terminals referred to as the source and drain on opposite sides of the constriction. Along the constriction is formed a p-n junction called the gate across which the input signal is applied. This signal modulates the current between the source and drain so as to produce an output in the external circuit connecting them. In the Alcatron there is, however, an additional much longer p-n junction from the gate to the drain parallel to the gate junction but on the opposite side of the constriction. This extra junction acts rather like the screen grid of an ordinary valve and also reduces the effects of surface variations at the gate. The geometrical arrangement of the electrodes in the Alcatron is also different from that in the Tecnetron. The Tecnetron consists of a long cylinder with the source and drain at its ends and the gate in the middle. The Alcatron resembles a Tecnetron rotated about its drain, and consists of a flat disc with the drain at the centre, source at the circumference and ring-shaped gate between. Since the volume at the constriction for a given narrow width is thus much greater in the Alcatron than the Tecnetron, the Alcatron offers a higher allowable power dissipation and transconductance than the Tecnetron in its original form.

Mesa Transistor base layers thin enough (a few microns) to give a short transit time between the emitter and collector, and thus a high cut-off frequency, are made by gas diffusion of the appropriate base impurity into the surface of the collector. Such diffusion also produces a gradual change of the resistivity through the base from the pure base-type semiconductor to the collector type, from n-type to p-type material or *vice versa* as the case may be. This gradual change results in an electrostatic "drift" field in the base region which still further reduces the transit time between emitter and collector, and increases the cut-off frequency by a factor of five or more over that of a transistor with a similar base thickness but in which the base material is uniform. In the mesa transistor the emitter and base connections are applied to the base surface close together so as to minimize the resistance between them, but edge on to each other to keep the capacity between them low. Finally the material outside the emitter and base connection area is etched away around the base to reduce the collector capacity, the material near the collector being left unchanged so as not to reduce the allowable collector dissipation. The name mesa is derived from the characteristic shape of a flat base plateau on a larger collector produced by this process. The highest quoted α-cut-off frequency for a mesa was 600Mc/s for the Texas Instruments 2N1142; prototype and experimental mesa transistors were shown by Sylvania-Thorn and the French C.S.F. respectively.

Power Transistors.—Fairly high powers at a fairly high frequency—a few tens of watts at a few Mc/s—are offered for example by the Texas Instruments 2S012 or 2S013 and experimental silicon transistors shown by the French C.S.F. and Ferranti.

The highest power audio transistors seen were the Westinghouse silicon TS10 to TS26 series in which the allowable collector dissipation falls to zero at 150°C and in which the derating factor or thermal resistance is quoted as 0.7°C/watt. The extent to which the current gain decreases at high-current levels depends on the emitter injection efficiency and hence the impurity level in the emitter region. By adding to the normal indium emitter material some substance such as aluminium which is more soluble in germanium than indium this injection efficiency can be improved. This process is used in the Mullard OC28 and OC29 for example.

(*Continued on p.* 351)

Tetrode Transistor giving a power gain of 20dB at 70Mc/s was shown by Texas Instruments (3S004). In this transistor the thin base is sandwiched between the relatively much thicker collector and emitter. The extra bias electrode is placed on the edge of the thin base opposite the base connection. The bias current which thus flows through the base at right angles to its narrow dimension reduces its effective area. Although this reduces the current gain it has two overriding advantages. It reduces the base resistance and thus decreases the necessity for neutralization at high frequencies and, in addition, it increases the cut-off frequency by a factor of about five. A convenient method of varying the current gain available in such tetrodes is to vary the bias current.

Switching Devices.—A number of manufacturers were showing p-n-p-n multilayer sandwich constructions. If a sufficiently high potential (about 100V) is applied across such a device the normally reverse-biased central junction breaks down and switches the total forward resistance from a high to a low value. The width of the central p and n regions determines the voltage required for switching, a higher voltage being required for a wider region. The Westinghouse Dynistor has similar characteristics to such devices except that its reverse resistance is low.

A recent development of these p-n-p-n devices shown by Westinghouse (as the Trinistor) and also by the B.T.-H. Research Laboratories and International Rectifier is the addition of a third control electrode at one of the central regions, generally the p-region. This electrode can be used to switch the device independently of the external circuit and at a lower switching power level, a control signal of a few tens of milliamperes at a few volts switching currents of up to a few tens of amperes Such devices thus have properties similar to those of thyratrons or grid-controlled rectifiers, but in addition have a number of advantages. These advantages include the absence of a heater and its attendant warm-up time and standby power requirements, a much lower voltage drop (about 1V) in the conducting state leading to a higher efficiency, and a faster triggering time (about 1μsec). Like thyratrons these devices can only be switched off by reducing the operating current below a certain value.

In the R.C.A. Thyristor currents of a few tens of milliamperes can be switched off as well as on from the control electrode with a control signal of a few milliamperes at a few tenths of a volt, and a triggering time of about 0.1 μsec. The Thyristor is a modification of a mesa transistor with the base used as the control electrode. Its action depends on the fact that the collector can become an electron injector at high current levels.

Diodes for Special Purposes.—Zener diodes shown by International Rectifier included a 5-W range for use up to 160V and a very stable 8.4V, 10mA unit in which the voltage changes by only 0.001% per °C. A very wide operating temperature range of from −65°C to +325°C is possible in an 800mW gallium arsenide regulator introduced by Texas Instruments. Forthcoming additions to the range of Lucas semiconductor diodes recently made generally available will include both Zener and clipper diodes—the latter are Zener diodes with equal sudden current overload characteristics at a certain voltage for both forward and backward voltages.

Small photodiodes with diameters of less than 0.1in were shown by Sylvania-Thorn and Texas Instruments. A photocell shown by the German Te-Ka-De consisted of two n-type germanium regions separated by a very narrow p-type dislocation, so that a movement of the illuminated region of only 10^{-1}cm across the dislocation reverses the direction of current flow. This device is grown from two n-type crystals butted together at a small angle. This method of producing an impurity layer offers possibilities of avoiding temperature variation effects.

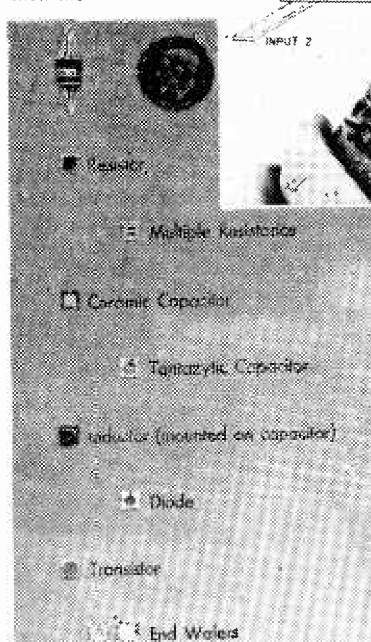
A variable-capacity diode usable for a.f.c. up to 250Mc/s was shown by Siemens Ediswan (Y100).

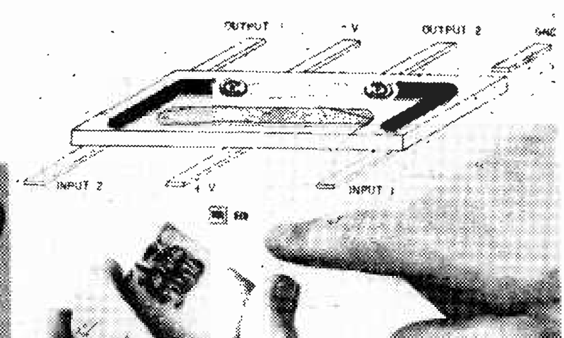
Silicon Carbide for making semiconductor devices which can operate up to 600°C is being investigated by Raytheon. Although it is difficult to make crystals larger than about 0.01in across, diodes have already been constructed.

Hall Effect Devices for multiplication, modulation and magnetic field measurement were shown by the German Siemens and Halske. These included a unit with an effective air gap of 5.5×10^{-4}in for reading magnetic tape. With this method of reading, the output is, of course, proportional to the flux rather than the rate of change of flux, and is thus independent of the tape speed.

Miniaturization Techniques were shown by the R.C.A and Texas Instruments. Texas have succeeded in forming together in a single piece of semiconductor all the components of a circuit, including transistors, diodes, resistors and capacitors. Component densities of about 20,000 per

R.C.A. separate Micromodule components with complete stacked circuit at the top near a penny to show the size.





Texas instruments miniaturized multivibrator. This incorporates two transistors, two capacitors and eight resistors made in a single piece of silicon less than ¼in by ⅛in by 1/32 in. The finger points to two such units, the one on the right being hermetically sealed They can be compared in size with a conventional transistorized printed circuit multivibrator held in the other hand. A greatly enlarged drawing of the Texas unit is shown above.

cu in can be obtained by this method as compared with, for example, 30/cu in using sub-miniature printed circuit techniques. R.C.A. form their components separately in the shape of thin wafers 0.3in square which are then stacked on top of each other to give the required circuit. Component densities of about 300/cu in can be obtained by this method.

Small transistors of about 0.10in diameter by 0.15in long for use in hearing aids were shown by Raytheon and Brush.

Transistor Test Set shown by Siemens Ediswan (Type R2285) uses variable feedback from the collector to the base of the transistor to be tested to produce oscillations which are made audible by a loudspeaker. When the oscillations just cease the overall gain round the feedback loop is unity so that the transistor gain can be determined from the setting of the variable feedback control. Collector leakage currents can also be measured.

As many as seven dynamic and five static n-p-n and p-n-p transistor parameters can be measured at any collector potential up to 30V and any emitter current up to 5mA by means of the compact ($8\frac{1}{2}$in by $6\frac{1}{2}$in by $4\frac{1}{2}$in) Telefunken Teletrans 1. The seven dynamic parameters are measured at 1kc/s and are the standard "h" and "y" parameters. These include the current gain, inverse voltage transfer ratio, two transconductances and three resistances. The five static parameters include four cut-off currents and the base voltage. A bridge measurement circuit eliminates any effects due to mains voltage variations, and the measurement accuracy is $\pm 5\%$.

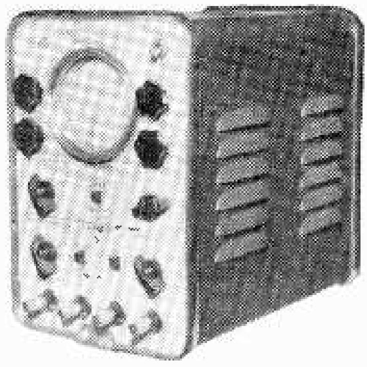
A series of adaptors is now available from Wayne-Kerr for enabling various transistor admittances to be measured from 100c/s to 5Mc/s to within $\pm 3\%$ using their TA100 and B601 transformer ratio-arm bridges. These adaptors automatically set up the appropriate transistor and power supply configurations while avoiding stray capacitances and couplings and unwanted loading due to the supplies. The three-terminal facility of transformer ratio-arm bridges by which the impedance between two points can be measured independently of the impedances between these two points and a third is particularly useful for transistor measurements.

In an automatic tester shown by S.T.C. the various parameters are measured in turn by integration for two successive five-second periods. Integration simplifies the measurement of small currents and reduces the effects of switching from one parameter to the next, while short-term drifts are detected by comparing the two successive five-second integrals.

Semiconductor Measurements shown by Siemens Ediswan included that of the three hybrid-π transistor equivalent circuit parameters using the equivalent circuit and transistor in two arms of a bridge. If a broad frequency band input signal such as a square wave is used, the balance point will determine three parameters rather than the usual two.

Current gain measurement using a transformer ratio-arm bridge was illustrated by the B.B.C. A variable fraction of the collector current is fed to one ratio arm, and the emitter current with a variable phase shift is fed to another ratio arm. The outputs from the two ratio arms are arranged to act in opposition in the secondary detector winding. The settings of the variable phase and amplitude controls for no secondary detector output then determine the phase and amplitude of the current gain.

G.E.C., Newmarket and Texas Instruments used the variation with temperature of certain semiconductor parameters such as reverse leakage currents to give, after calibration in an oven, a measure of junction temperature in the measurement of permissible ratings for a given temperature. The semiconductor device was continually switched between the temperature measurement and permissible rating test conditions.

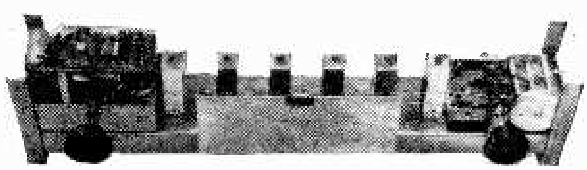


Dawe prototype transistor oscilloscope Type 720 using only eight transistors.

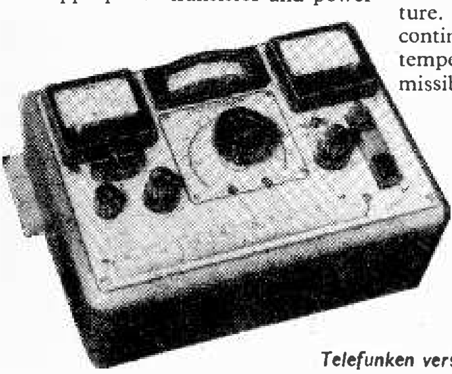
When a diode is switched from the forward to the backward direction a reverse current flows temporarily until the remaining current carriers are removed from the material—a phenomena known as hole storage. The decay time constant of the reverse current pulse varies considerably with the particular operating conditions so that it is more useful to specify the total charge in the pulse. As shown by the G.E.C. this charge can be measured by charging up a condenser from a repetitive pulse and measuring the mean current produced, since this current is equal to the repetition frequency multiplied by the required charge.

Analogue Circuits for investigating system performance data which are too difficult to calculate are, of course, a very old idea, but two of the circuits shown had unusual general features. Mullard showed a large-signal analogue of a high-frequency transistor which used transistors to provide some of the non-linear capacities required. S.T.C showed an analogue circuit of an alloy-junction transistor which was made three dimensional to take account of the fact that the minority carrier flow between emitter and collector is not exactly in parallel lines across the base but spreads out somewhat from the emitter.

Oscilloscopes using transistors were shown in experimental form by



B.B.C. experimental v.h.f./f.m. receiver incorporating balanced crystal mixer.



Telefunken versatile compact transistor test set "Teletrans I".

Cossor (on the Livingstone Laboratories stand) and B.T.-H, and in prototype form by Dawe. The Dawe Type 720 uses only 8 transistors. Its Y-amplifier has a maximum sensitivity of 30mV/cm falling by 3dB at 5c/s and 50kc/s, and a high (for transistors) input impedance of 1MΩ. Although the response in the two experimental models extended to at least 500kc/s, they each used about 20 or more transistors.

Receivers for the v.h.f./f.m. band were shown in experimental form by the B.B.C. and Texas Instruments. The transistor cut-off frequency must be higher for r.f. amplification than for oscillation so that because of the difficulty of obtaining sufficiently high frequency transistors only the Texas receiver incorporated an r.f. stage. This used a 2N1142 transistor, and a 2N623 is used in the combined mixer-oscillator stage. The B.B.C.' receiver used a 2N247 as an oscillator feeding two GEX66 diodes forming a balanced mixer to reduce local oscillator radiation.

Miniature a.m. receivers which included short-wave bands extending up to 12Mc/s were shown by the two Japanese exhibitors Sanyo and Tokyo Shibaura. Thermistors for stabilizing the push-pull output stage against temperature variations are incorporated in the Sanyo receivers.

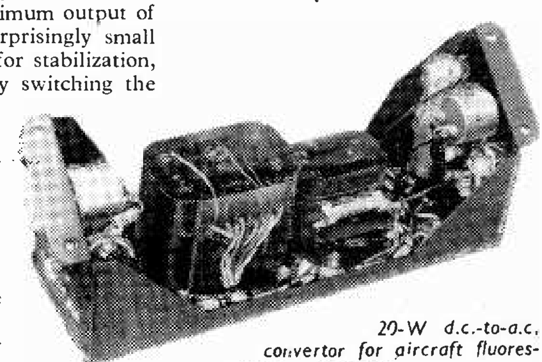
Stabilized Power Supplies.—In this field it would seem that the transistor has created a direct demand for itself. For experimental work with transistors a stable supply variable between about 1 and 30V at a current of the order of 1A is often necessary, and it is to the stabilization of such supplies that the small power transistor is peculiarly suited. Many manufacturers were showing mains-derived power supply units of this nature which were broadly similar: most used a form of emitter-follower circuit with the reference potential derived either from gas-filled stabilizer valves or Zener diodes. Output impedances of the order 0.05Ω are generally achieved.

When delivering a current near the maximum rating at a low voltage the major part of the supply's power is dissipated in the output transistors. To enable the use of an economically-sized output stage most of the power units were fitted with a coarse voltage switch selecting two or three taps on the mains transformer, but G.E.C. were showing a unit capable of continuous variation between 6 and 20V at 10A. Two firms (Elliott and Hatfield) had adopted special means of utilizing a smaller output stage than was usual. The Hatfield L.E.400 is rated at 30V 1A but the single output-voltage control varies not only the proportion of the reference voltage used (this time derived from Zener diodes) but also the input voltage by means of a continuously - variable transformer. Elliott use a rather different approach in their Type B.673 supply. This has a maximum output of 50V at 1.5A and surprisingly small transistors are used for stabilization, which is achieved by switching the supply into large-value electrolytic capacitors. A drop in voltage below a preset limit switches the supply on, and a rise switches it off: this is achieved by a bistable circuit whose reference voltage is derived from Zener diodes and the switching rate varies between about 3c/s and 300c/s for the minimum and full load conditions.

Mobile Power Supplies.—The difficulties of obtaining high, direct or alternating voltage from the low-voltage d.c. supplies available in cars or aeroplanes are only too well known. The transistor, however, can be used as a repetitive switch which has very good performance compared with mechanical interruptors and, in such a mode, it dissipates but little power within itself. Most convertors follow the same general outline—oscillating transistors feed "chopped" d.c. into a transformer where it is stepped up to the required potential and, then, for a d.c. output, rectified and smoothed.

An example of one typical approach was the Ultra UA1701 convertor which is designed as a direct replacement for a rotary machine in some of this company's airborne equipment. Four transistors in a bridge oscillator circuit interrupt the 28-V d.c. supply, feeding it to a square-(hysteresis)-loop transformer, whose output is rectified by junction devices to provide 250V at 250mA d.c. Efficiencies, on the whole, are good: for a d.c. output the use of a square-loop transformer helps considerably as this enables the transistors to be operated with the minimum of internal power loss. However, for an a.c. output the preferred practice seems to be to use either a separate sine-wave oscillator driving a fairly-efficient output stage, or to use the power transistors as sine-wave oscillators, so avoiding the use of filters.

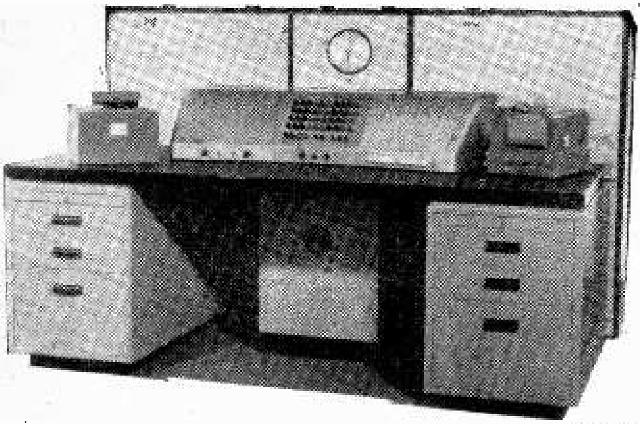
D.C.-to-a.c. convertors have been made in sizes handling hundreds of watts, but one which caught our eye was on the Elliott stand. This was rated at 20W (Type B.725) and gives a 400c/s output which was displayed together with 400c/s from an a.f generator on a double-beam oscilloscope. There was a barely discernable difference between the waveforms. The use of these convertors seems worthwhile even for purposes such as fluorescent lighting in aircraft, cars and railway carriages. Many oscillators designed expressly for this purpose were shown in a variety of sizes from 6 up to about 150W. A side issue of this is that G.E.C. have been able to reduce appreciably the magneto-strictive noise from the transformers by coating them with a ¼-in-layer of solid polyurethane.



20-W d.c.-to-a.c. convertor for aircraft fluorescent lighting (G.E.C.).

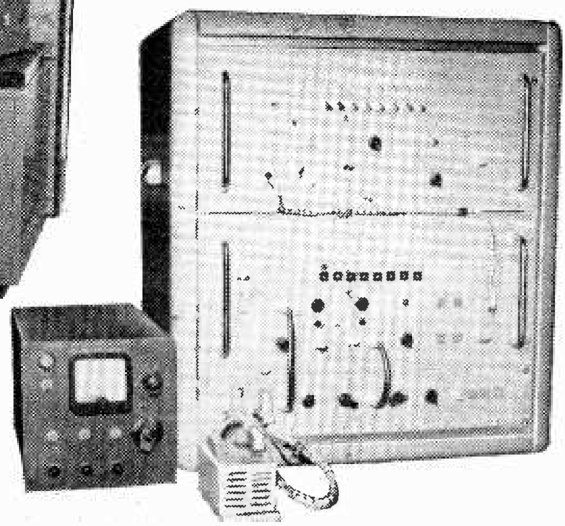
Transistor H.T. Smoothing.—Where there are severe limitations on space or weight a transistor may be used in place of the normal L-C h.t.-smoothing arrangement. This was illustrated by a unit from the "Sea Slug" guided missile in which a small power transistor is used to smooth an h.t. supply. Again the circuit used is an emitter follower, the base being connected to a supply smoothed by a simple, small R-C filter.

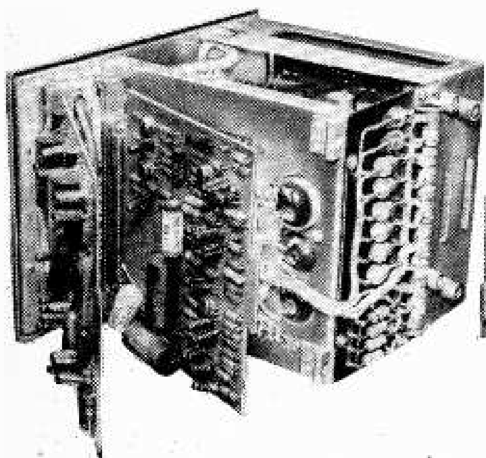
Data Processing.—The Ferranti "Sirius" is a new, general-purpose digital computer designed mainly for the user who needs a computer but who does not have sufficient work to keep a large machine economically occupied. The computing elements are transistor-transformer units employing "ballot-box logic" and the 1,000-word store



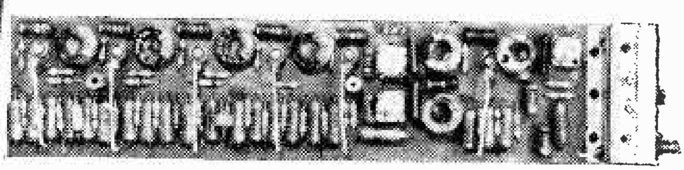
Ferranti "Sirius" general-purpose digital computer.

Armstrong-Whitworth analogue-to-digital and digital-to-analogue convertors (upper and middle decks of large cabinet) wired together for demonstration.





Rear view of Ferguson "Digitizer" 5-bit analogue-to-digital convertor using "book-leaf" construction.



6.6Mc/s i.f. strip (using toroidal coils) from S.T.C. i.l.s. receiver.

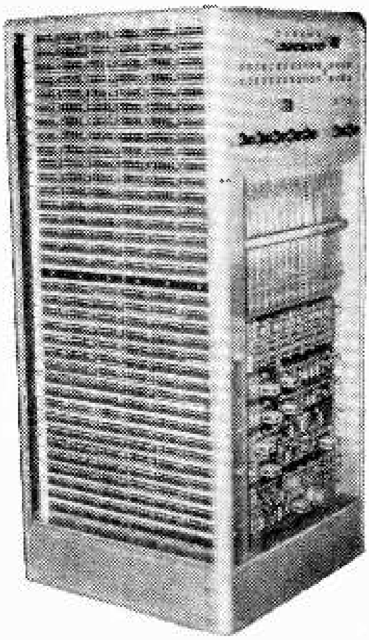
is made up from 20 torsional nickel-wire delay lines using magnetostrictive input and output. The logic circuits are made up on colour-coded plug-in boards. No cooling system is necessary. Notable features of this computer are its small size, 7ft × 3ft 6in × 4ft; low weight, 5 cwt; power consumption, 600W; and price, £15,000 complete with input and output apparatus (5-hole paper-tape equipment).

The Ferguson "digitizer" is a comparatively simple medium-speed analogue-to-binary code convertor giving a straight 5-bit output. Housed in a cubic box of side 6-in, it is mains powered and is built on the book-leaf pattern. The Armstrong-Whitworth analogue-to-digital convertor is rather more sophisticated—this gives an 8-bit output in both serial and parallel form and a 500-kc/s digit-pulse rate is achieved by the use of surface-barrier transistors. It has a companion digital-to-analogue convertor which accepts an 8-bit number, stores it and then uses it to control transistor switches feeding a resistor network, from which the output voltage is produced.

Experimental use of the automatic letter-sorting machine has shown the G.P.O. that a serious barrier to the extension of its use is the difficulty of teaching quickly the special code fed in by the operator. To overcome this difficulty a translator has been developed at the Post Office Research Station which feeds to the sorting machine the required two-letter code. This code is derived from the three initial and two final letters of the name of the "post town" (this large number is necessary to avoid ambiguities) which are fed in by the operator from an ordinary typewriter keyboard. The translator unit uses a 5 × 26 matrix of square-loop cores, whose output is amplified by transistors and used to strike cold-cathode tubes feeding the sorter.

A device which could replace square-loop cores in computing applications is the p-n-p-n junction. On the stand of the A.E.I. Research Laboratories these devices, which exhibit similar characteristics to those of a gas-discharge tube, were shown operating in a 5 × 5 matrix, a saw-tooth generator, a bi-stable circuit and two forms of ring-counter (see circuit diagram). Their chief advantage in a matrix is that they are individually replaceable, whereas in a core matrix a failure of one core usually means that the whole matrix has to be replaced.

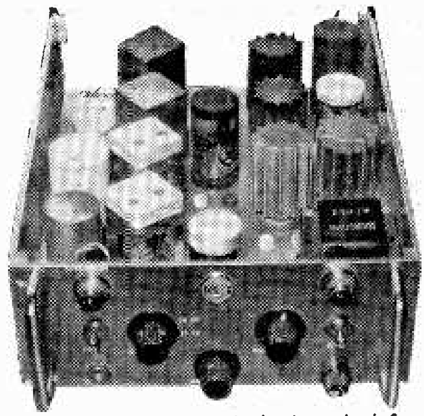
Communications: — R.C.A. were showing a single-channel transistor v.h.f. receiver (the AR108) for the 108- to 156-Mc/s band with a performance of a surprisingly high order—50mW output is obtained for a 2-μV input, with a signal/noise ratio of 10dB at 30% modulation. The large amount of power wasted in valve receivers is brought home with a vengeance by the power consumption of this set —8 to 10W maximum at 12Vd.c. for a 2-W a.f. output. The underside of the chassis of the AR108 is a little disappointing—all that can be seen is wiring between octal valve sockets! Into these sockets plug resin-encapsulated units each con-



Code translator for G.P.O. letter-sorting machine.

taining all the components for a particular stage. The units are coded by colour and shape and the overall size of the receiver is such that two can be mounted side-by-side in a 19-in rack (height 3in). It is also available in a 117/234-V, 50 to 60c/s version.

Another striking example of miniaturization by the use of transistors was shown on the Ministry of Supply stand. This was a "Forward-area Time-division Multiplex Equipment" which is contained in one box, weighs only 30lb. and consumes 5W of power at 12Vd.c. This provides four, good two-way telephone channels over a radio link or land line of very poor quality. Contrasted with its 8-year-old "valved" equivalent which consisted of sixteen



R.C.A.'s all-transistor single-channel v.h.f. receiver using potted plug-in component assemblies and (below) potted plug-in unit from R.C.A. AR108 receiver.

boxes each weighing 50 to 80 lb. and consuming 1.5kW the new equipment can be considered truly portable and suitable for "forward-area" use.

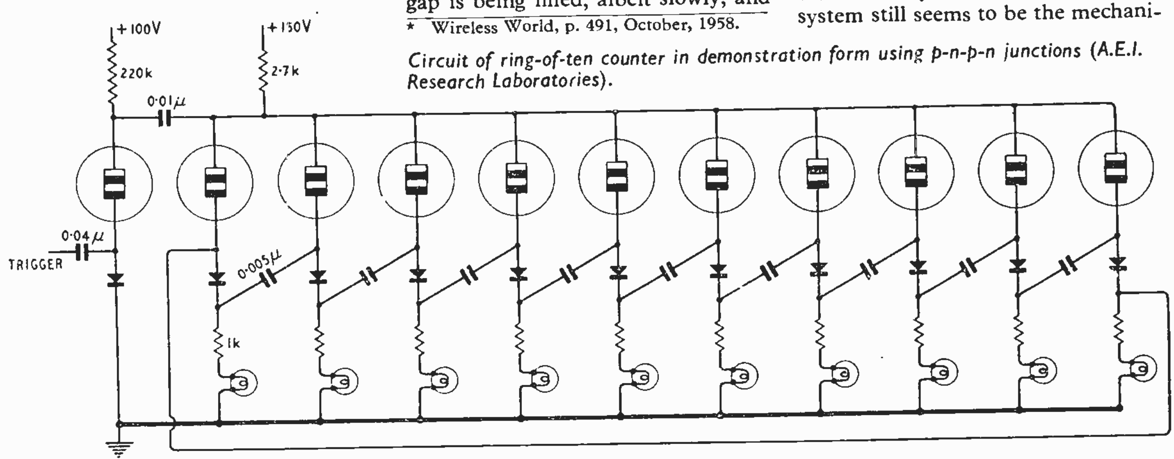
The growing use of transistors in airborne equipment was noted at last year's S.B.A.C. show*. The general trend seems to be to allow a reasonable amount of "spare" space in the layout so that servicing is rather easier than with valved equipment. One example of this was an i.f. strip from the S.T.C. i.l.s. glide-slope receiver. Operating at 6.6Mc/s this uses six stages of grounded-emitter amplification to provide 100dB ± 6dB gain over a bandwidth of 200kc/s. Transmitters are at present limited by the lack of suitable transistors: however this gap is being filled, albeit slowly, and

* Wireless World, p. 491, October, 1958.

Mullard were showing an "S.O.S." transmitter with a 4-W output at 500kc/s. This used a pair of OC24s in Class-B push-pull, driven from a crystal oscillator using an OC45. The efficiency realised was about 50%.

Circuitry.—D.C. amplifier design, is at the best of times, a difficult business and it is not eased by the additional drifts present in transistors, but these disadvantages are being overcome. One item on the Mullard stand featured a display of 8 types of d.c. amplifiers, together with some performance data. The first type was a direct-coupled amplifier having a current gain of 500 and which used germanium devices. The drift exhibited by this was about 5μA/°C, referred to the 2-mA input. The use of silicon transistors and base stabilization by Zener diodes in the second example raised the input impedance from about 100Ω to 300kΩ and cut the drift to 0.1μA/°C referred to the input. The third example was a set of germanium long-tailed pairs with a drift of 1.5mV, relative to the maximum input of 10mV, from 20 to 35°C. and again replacing the germanium devices by silicon reduces drift and increases input impedance. No. 5 illustrated the use of temperature stabilization of the input stage by means of a subsidiary amplifier controlling a small heating coil round the transistor. This reduced drift by a factor of 20 and temperature was sensed by a second transistor inside the coil. The sixth example used chopper techniques and the chopping was done by a silicon-diode bridge —a drift of about 2.5mμA/°C was achieved relative to 1-μA input, with a gain of 1000. Another chopped design used a transistor as a parallel switch across the input. This had a drift of only 0.5mμA but the best system still seems to be the mechani-

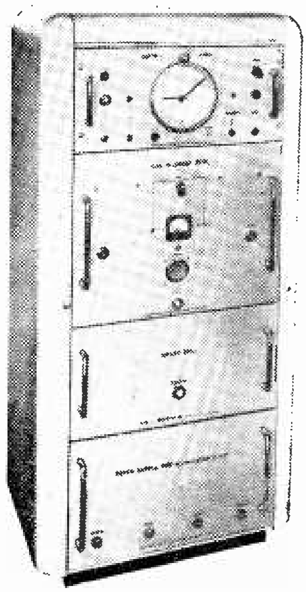
Circuit of ring-of-ten counter in demonstration form using p-n-p-n junctions (A.E.I. Research Laboratories).



cally-chopped amplifier. The last example, using a Carpenter relay, exhibited a gain of 50,000 with a very small drift, which is time-dependant. The temperature control method mentioned above was used in an amplifier panel offered by the G.E.C. as a basic "brick" for instrumentation purposes. This amplifier has a guaranteed minimum gain of 200,000, a drift of $\pm$ 2.5μV and a noise level of 5μV peak to peak referred to the input. The output is $\pm$ 10V and synchronous-chopper techniques are also used. All the transistors are germanium types arranged in feedback pairs and the low-noise GET106 is used for the first stage.

Work at the Royal Radar Establishment on the use of transistors in radar has resulted in the development of a very-linear timebase for a magnetically-deflected c.r.t. This uses an r.f. transistor as a switch (not specifically for its high cut-off frequency; but for its low leakage current) across the scan-determining capacitor, one plate of which is connected the input of an amplifier whose output is developed across a low value resistor in the emitter circuit. The output voltage is fed back to the other plate of the capacitor. Thus something very similar to the single-pentode Miller circuit is achieved. To neutralize the leakage current of the switching transistor a similar transistor is connected, in the reverse sense, to the capacitor. The Miller voltage waveform developed across the emitter resistor in the output stage causes a linear current sawtooth to flow through the deflector coils, which are placed in the collector circuit. The waveform has a peak current of 1A, is 120-μsec long, its linearity is better 1% and the leakage-current compensating circuit ensures that the velocity changes by less than 1% for a change in temperature from 15°C to 50°C.

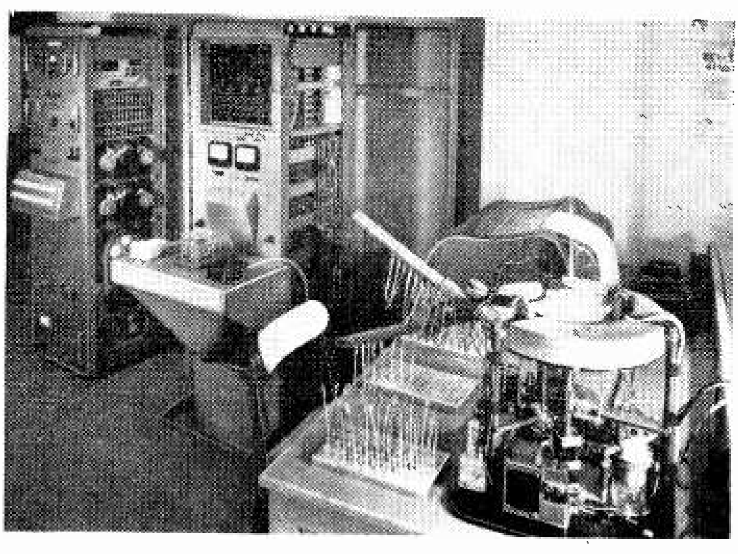
Medical Electronics:—A miniature, transistor heartbeat detector developed at R.A.E. Farnborough for use in physiological tests was shown on the Ministry of Supply stand. Skin potentials are developed which depend on heartbeat action; but normally, in an active subject, these are masked by the noise made by the working of the muscles. To overcome this, skin potentials are monitored at two places approximately equidistant from the heart, preferably on antagonistic groups of muscles so that the noise of one muscle contracting does not coincide with that of the other, which is then relaxing. A common electrode is placed near the heart and the two pick-up voltages, after amplification, are applied to a coincidence detector, which produces a 2-V pulse at each heartbeat only.



FORTY-NINE POLE TIME SWITCH

AS MANY as forty-nine processes can be switched on over a total period of up to 2½ hours by the Venner programme record/playback console Type TSA 50 shown in the photograph. The command pulses are stored on standard magnetic recording tape. This instrument is made by Venner Electronics Ltd., Kingston By-Pass, New Malden, Surrey.

Automatic Component Testing



Automatic: est machine and equipment in a laboratory at Sylvania-Thorn.

AN AUTOMATIC machine for the testing of components and the individual recording of their characteristics has been developed by Sylvania-Thorn Colour-Television Laboratories, Ltd. The machine applies up to 10 tests sequentially at the rate of 10,000 per hour, recording the results simultaneously on punched paper tape and on a paper roll, printing out through a teleprinter receiver.

If a component fails one test, other tests can be inhibited and another valuable feature of the machine is that it can retest components after an environmental stress has been applied, giving a read-out interlaced with the original figures on the teleprinter. This second readout appears only when a change has occurred during the stress period. Test results, in the form of analogues, are converted by a transistor digitizer to a 5-bit code, which is then converted to telegraph code to operate the teleprinter. The machine can also test other components such as transistors.

PARAMAGNETISM

By "CATHODE RAY"

An Apparently Insignificant Phenomenon Comes to Life

TWO months ago I objected to the term "parametric amplifier" because (among other reasons) some but not all of such amplifiers make use of paramagnetic materials, and the two words occurring in the same context are bound to be confused. To make matters worse, some but not all "masers" are paramagnetic, though they are not parametric in the currently accepted sense.

We are likely to hear more about paramagnetic materials and paramagnetism. Most of us know something about magnetism, which we usually associate with permanent magnets and with currents flowing through coils. These are considered officially under the respective headings *ferromagnetism* and *electromagnetism*. We may even remember vaguely that there were two other things, called *diamagnetism* and *paramagnetism*, but it was difficult to remember which was which, and anyway they seemed insignificant. Now that paramagnetism is in the news perhaps we have been hastily looking it up in our textbooks, and (unless you were luckier than I was) finding it highly confusing.

Early Theories

About 130 years ago the great electrical pioneer Ampère, meditating on the discovery that a current flowing round a coil makes it a magnet, surmized that magnetism in iron, etc., was caused by small circulating currents in each atom. The idea was expressed more definitely by Weber, not so very long after. This, remember, was when very little was known about atoms, and, of course, nothing at all about electrons. Modern science, though it has upset so many old ideas, has confirmed this one, which was a remarkable flash of prophetic genius.

We now know that atoms are constructed largely of electrically charged particles – protons and electrons – which revolve in orbits and also spin on their own axes. Both these movements are essentially tiny electric currents flowing round tiny one-turn coils, and have the same result as we find on a vastly larger scale in magnet coils.

The fact that with very few exceptions materials as a whole are not magnets can easily be explained on the very natural assumption that the magnetic fields of the individual atoms cancel one another out by their random arrangement. The problem then is to explain the exceptions.

These exceptions, notably iron and its alloys, have an enormous multiplying effect (called permeability) on any magnetic field in which they are placed; and some of their magnetism remains after the field is switched off. Such effects, called ferromagnetism, were plausibly explained by Ewing as being due to the atomic (or rather molecular) magnets being forced gradually into alignment until forced back by a field in the opposite direction. This was the theory I was brought up on (in an establishment presided over by the said Ewing), and when later it was thrown out in favour of what was called the domain theory, it seemed to me that this new theory was essentially the same as the old, except for the name and the larger size of the elementary magnets. However, when one goes into the thing in detail the differences are considerable, and if you want to know more about them you had better refer again to the series by Dr. D. H. Martin in the January to April issues of last year. Since our present subject is paramagnetism I will just mention in passing that ferromagnetic materials are those in which large groups ("domains") of atoms all face the same way magnetically, held so by internal forces many thousands or even millions of times stronger than magnetic fields sufficient to saturate iron. The reason why so few materials are ferromagnetic is that the particular atomic structure needed for it is quite exceptional.

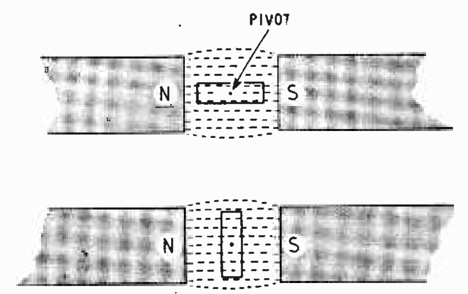


Fig. 1. All substances, suspended between the poles of a magnet, tend to take up one of these positions. Ferromagnetic and paramagnetic adopt position (a); diamagnetic, (b)

It's easy enough, of course, to tell which materials are ferromagnetic, by seeing if they are attracted by a permanent magnet. If we made the test more scientifically we would suspend a short rod of the stuff between the poles of a magnet, as in Fig. 1, so that it is free to turn round but not move in any other way. We all know that a piece of iron takes up the position shown at (a) with considerable alacrity, rather than lying across the field as at (b). Why?

We might say that the magnet attracts the piece of iron, and position (a) is the one that brings it nearest. To be more specific; iron being what it is, the field magnetizes it, making the end nearest N an opposite pole (S), and the same in reverse at the other end. Unlike poles attract, so energy would have to be supplied from outside to turn the iron from position (a) to (b). It is a general rule that the energy of a system tends to change from available to unavailable forms (heat), as when a metal object in water sinks. So the iron tends to move from position (b) to (a).

If we tried the same experiment with a bar of aluminium or frozen oxygen we would probably fail, unless we were as careful experimenters as Faraday. He found that some "non-magnetic" substances tended to take up position (a), though with considerably less alacrity than iron (of the order of a hundred million times less) while others such as copper and

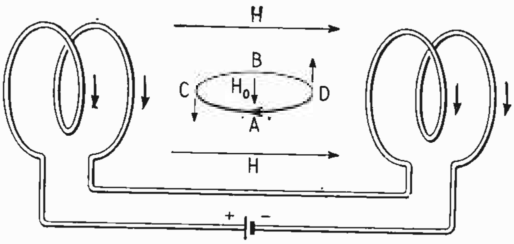


Fig. 2. The effect of a magnetic field (H) on a revolving electron (or proton) is to make its orbit slowly rotate around an axis parallel to H.

bismuth preferred position (b), though with possibly even less enthusiasm. If the former were like heavier-than-water bodies sinking, these could be likened to lighter-than-water bodies floating. He came to the conclusion that all substances other than the few ferromagnetic kinds fell into one or other class. Those that follow the example of iron, but so very much more feebly, are called paramagnetic, and the opposite kind are diamagnetic.

This exceedingly lukewarm reaction either for or against a magnetic field suggests no very obvious use. Certainly the materials wouldn't justify even a moderate cost as magnetic cores, or even anti-magnetic ones! The whole thing seems to have only academic interest. Hence, no doubt, our haste to forget all we ever learnt about it. The reason for a recent change in attitude is that paramagnetic effects involve energy changes in atoms, and these (in accordance with the quantum principle) are directly related to frequency.

Magnetics in Molecules

But before tackling paramagnetism we must know that basically everything is diamagnetic, and that the paramagnetic substances (and, of course, still more the ferromagnetic) are those in which the diamagnetism is more than cancelled out by the opposite effect.

The first thing to get hold of is that nearly all molecules are constructed in such a way that the magnetic effects of their individual electrons exactly cancel out. So the molecules are not permanent magnets. Still less can any objects made of the molecules be permanent magnets. It would be possible and, in fact, natural for the molecules, even if they were magnetic, to be so jumbled up that their magnetic effects would cancel out in any piece of material. But that is not to say that the molecules (and material made of them) cannot be magnetized, by putting them in a magnetic field.

This is one of the places where the books became hard to follow. They plunge into a highly mathematical treatment of such matters as Larmor precession and Coriolis forces, finally emerging with the conclusion that when the magnetic field is applied the response is in the contrary direction; in other words, the permeability of the material is (very) slightly less than 1. This is rather surprising to simple minds, because if, say, the single electron in a hydrogen atom was flying round an orbit which caused it to generate a tiny magnetic field, one would expect that putting it in a magnetic field would make it turn, like a compass needle, into such a position that its own field would add its modest quota to the whole. And that molecules, in which there are usually equal numbers of electrons with opposite rotation, would experience equal and opposite forces, so as wholes would be unaffected. But that is too simple to be true.

Fig. 2 shows a pair of coils with current flowing through them, and as the direction of current viewed from the left-hand end is clockwise, by the cork-screw rule the magnetic field must be in the direction marked H. In this horizontal field an electron is spinning around in a horizontal circle, clockwise when viewed from below, so the current is clockwise viewed from above, and its own magnetic field (H_0) is downward. When the electron is at positions A and B it (and the current) is moving parallel to the main field H, so is not affected thereby. But in positions C and D it is moving across the field, and the left-hand rule tells us that it is forced in the directions of the arrows.

This still looks as if it would tilt the whole orbit so that its field would come into line with the main field, just as our simple minds predicted. But we have forgotten that an electron has mass as well as electric charge.

Fig. 3 shows a top spinning at an angle to the vertical, so that gravity acting on its mass creates a downward force through its centre of gravity C, and of course the table on which it is spinning exerts an equal upward force at the point. This pair of forces might be expected to make the top fall over towards the right, and if it were not spinning it would certainly do so. But the spin momentum of the top carries it around, and the combination of this with the force of gravity makes the leaning angle move comparatively slowly round in the direction of spin. The faster the top is spinning and the less it leans, the slower this motion, which is called *precession*. If the top could lean over horizontally, still spinning on its point, the top as a whole would rotate in a horizontal plane about its point.

If you have ever handled a gyroscope, you will know the rather uncanny feeling of trying to tilt it as in Fig. 2 and finding that the result is to make its plane of rotation turn over in an unexpected manner. Suppose the electron is at C. Then its orbital motion would be bringing it round to the front (opposite to the direction of the arrow, which refers to the conventional positive current); but the addition of the downward force actually brings it rather lower than A. In other words, the orbit as a whole begins to rotate around the lines of force H in a clockwise direction viewed from the left. This means a clockwise movement of the electron, or anti-clockwise movement of the current, which causes a component of magnetic field opposing H. The total field is slightly reduced.

Now suppose that the same molecule has another electron rotating in the opposite direction. If you work it out you will find that it too reduces the total

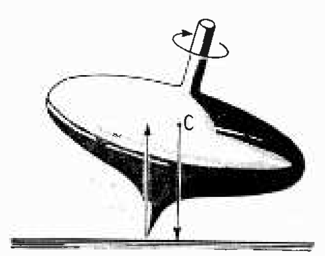


Fig. 3. The effect shown in Fig. 2 is something like the familiar slow motion of a spinning top.

field. So the permeability of material made of the molecules is less than 1. In other words, the stuff is diamagnetic, whether magnetically its electrons are all oppositely balanced or not.

Those that aren't exhibit paramagnetism as well, and if (as is normally so) the paramagnetism is greater than the diamagnetism, they will as a whole be paramagnetic. Since the molecules are not magnetically balanced, each one is a tiny magnet. Nevertheless the material as a whole is not a magnet, because heat energy is pushing all the molecules around in a completely random fashion; and with the stupendous number of molecules in even a small piece, the chances of there being any appreciable excess pointing in any one direction for an appreciable length of time is negligible.

But it is different when an external magnetic field is applied. If one could switch off all fields, including the earth's, a collection of thousands of vigorously shaken compass needles would point in random directions. Restoring the earth's field would swing them all round in one direction, making a sizeable magnet. Similarly with the paramagnetic material. The total magnetic flux is increased, so the permeability is greater than 1.

Actually the response at any temperature much above the absolute zero is very small indeed, for practical magnetic fields can do very little to counteract the disordering influence of heat. It is as if the compass needles were situated in a beehive, with the insects pushing them about in all directions so that only a slight trend towards magnetic north could be discerned. Obviously, then, paramagnetism (unlike diamagnetism) depends largely on temperature, being considerable near absolute zero and falling off as the temperature rises.

But there is more to paramagnetism than this. Very much more! After having struggled with a number of books on the subject I have arrived at the considered opinion that this must be an exception to the rule that there is nothing that can't be explained simply and concisely. It involves all the atomic matters we have discussed during the past year or two, in far greater detail and with very much added. And since the task of creating Honours Physicists in One Short Easy Lesson is not one that I propose to attempt, we shall have to make do with something less. To real physicists it will appear hopelessly over-simplified.

Energy Content

When an atomic magnet formed as just described, is placed in a magnetic field, it is thereby given an amount of energy which depends on the angle between its own magnetic axis and the field. If the two already coincide, like a compass needle that was already pointing north before it was put in the earth's field, it won't feel any inclination to move. But one lying across the field has potential energy, which is lost when it swings into alignment. One would expect the amount of energy to vary smoothly between one position and the other.

But you may remember* that one of the elementary facts about electron orbits around atomic nuclei is that the energy of an electron cannot change gradually by gradually enlarging or closing up its orbit; it can change only in certain fixed jumps, according to quantum rules. The same applies to magnetic energy levels.

Obviously, too, the energy varies in proportion to the strength of applied field. And so we get the kind of energy diagram we saw two months ago—Fig. 4. The direct proportion between energy jump and frequency ($E=hf$) holds, of course; so if a paramagnetic material is stimulated by power at a frequency corresponding to one of the energy gaps, atoms (or rather molecules) tend to be lifted up or "excited" across that gap. We saw how this was applied in paramagnetic masers, which can be made to amplify or oscillate. For electron-orbit magnets, the frequencies are usually in the microwave region. A useful feature, not possessed by the much larger energy gaps between orbits, is that the frequencies can be varied by controlling the applied field strength.

Another thing that happens in paramagnetic substances, as in diamagnetic, is precession. Now there is a difference in the energy of the spinning electron (or whatever particle it is that is precessing) depending on whether its magnetic axis is with or opposing that of the applied field. It is as if a top could spin either right way up or upside down; the latter having the greater energy, so that some outside boost is needed to effect the change-over.

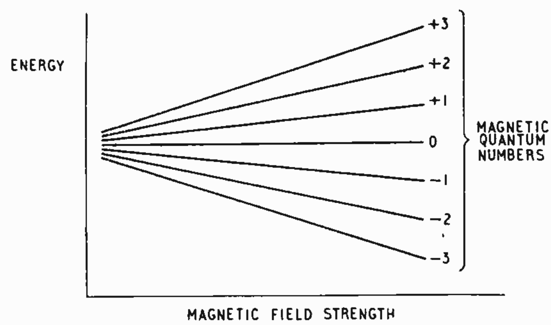


Fig. 4. The energy levels of a paramagnetic molecule vary in proportion to an applied magnetic field, but at any one field strength they occur at fixed intervals.

One way of imparting such a boost is to apply a magnetic field at right angles to the first applied field, rotating at the precession frequency. Suppose the top in Fig. 3 is the electron, precessing under the influence of a steady vertical field (represented by gravity). If now one were to move the table with a horizontal circular motion, so as to give the top a rotating sideways pull in time with the rate of precession, it would tend to turn upside down.

The required frequency for upsetting spinning electrons is of the order of 10,000 Mc/s. A rotating magnetic field exists in a waveguide or cavity into which power at the appropriate frequency is fed. The only thing is to make sure that the paramagnetic sample is placed in the right position, and that the steady field is applied at right angles to the plane of rotation. When the frequency of the microwave power comes into tune with the frequency of the spin energy difference (or when the latter is brought into tune with the former by varying the steady field) the accepting of energy from the microwave power can be detected as a sudden increase in loss of the system. It is just as if a loosely coupled circuit had been brought into resonance.

The protons in the nucleus of an atom also spin,

* E.g., March, 1958 issue, p. 115

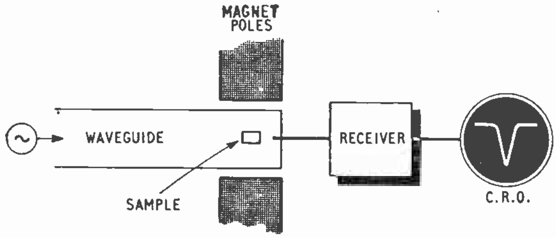


Fig. 5. Outline of apparatus for detecting atomic resonances and measuring their frequency and hence the energy jumps represented.

and if they are unpaired they cause paramagnetism; but because protons are so much heavier for the same charge as an electron they spin much more slowly and the energy differences are small, corresponding to frequencies of only a few Mc/s.

All these effects are very much influenced by interactions between all the particles concerned. In solids these interactions are greater than in liquids and have the effect of broadening the resonance peaks.

Fig. 5 is a diagram of the sort of set-up used for tracing the resonance patterns of paramagnetic materials. By such means a vast amount of information has been accumulated on the complicated goings-on inside atoms. It is a research tool of first-rate importance.

Another application of paramagnetism we did just touch on in the July 1957 issue, is superconductivity. Has it ever puzzled you how things can be cooled down to within a small fraction of one degree of absolute zero (0.000015°K was claimed some time ago)? One can get down to somewhere around 1°K by successive use of liquid gases, finishing up with helium. Then a paramagnetic material, such as iron ammonium alum, which is inside the apparatus and has been reduced to this low temperature, is magnetized by a strong externally-applied magnetic field. The effect is to cause the material to give out heat, which is carried away by the helium. Switching off the field has the reverse effect—heat has to be taken in by the material, and if it is thermally insulated the only way it can do so is to reduce its own temperature, like a starved man living on his own fat.

You might think that at those low temperatures the tendency for heat to leak in from the surroundings would make such a drop in temperature a very temporary—almost momentary—affair. So it is a convenient as well as astonishing fact that 1 cubic centimetre of the paramagnetic alum mentioned has, at 0.05°K, a thermal capacity equal to that of 16 tons of lead at the same temperature!

One way and another then, paramagnetism is acquiring practical as well as theoretical interest. And if some of the applications still seem a little highbrow to us radio engineers, perhaps at one time so did the physical researches that have now brought transistors on to the market in their millions.

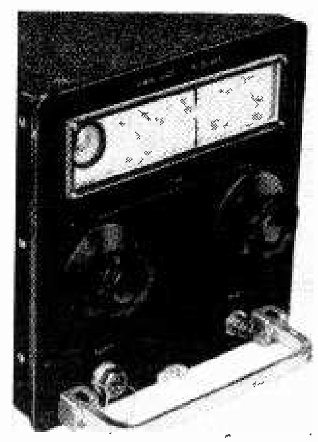
Addendum—"Hall and Holes"

ON p. 605 of the December 1958 issue I complained that nobody, repeat nobody, known to me had explained clearly how the Hall effect managed to distinguish between electron and hole currents seeing that both were in fact movments of electrons, and I appealed to any authors unknown to lodge claims. It has been necessary to go as far as Australia for one. Dr. J. L. Salpeter has called attention to his 16-page paper, "The Concept of the Hole in Semiconductors", in *Proc.I.R.E.Aus.* for December 1955, which I have found extremely interesting. One has to travel rather a long way with Dr. Salpeter to get to the point in question, but at least one would realize by then that the hole is not *quite* so simple as it is sometimes made out to be.

In a letter, Dr. Salpeter points out that my Fig. 6, showing two atoms before and after an electron movement has brought about a shift of positive charge, leads to difficulty if one considers what is happening *during* the movement. There certainly seems to be, as he claims, no escape from going into the wave mechanics of electrons in a crystal lattice if one is to understand holes correctly. Some writers use the concept of negative mass, but I felt some reluctance about putting that forward!

Low-noise U.H.F. Receiver

THIS receiver, primarily designed for ground-station missile-telemetry applications, features continuous tuning over the 420 to 500Mc/s band. Two tuning controls are provided, one for the r.f. circuits and one for the local oscillator; this, and the use of a low-noise grounded-grid r.f. stage (A2421), enables an overall noise factor of better than 10dB to be realized. The grounded-grid mixer (CV408) feeds a cascode first, i.f. stage (E88CC), which is followed by three high-gain pentodes (E180Fs). The i.f. is 45Mc/s and the overall bandwidth of the standard receivers is ±2.25Mc/s for a response at −3dB (compared with the central frequency): this bandwidth is achieved by stagger tuning the i.f. stages and the manufacturers state that it can be increased to ±3Mc/s without extra cost. Amplified a.g.c. is provided for the first i.f. stage and for operating the "magic-eye" tuning indicator; this bias is produced by a rectifier fed from an additional i.f. amplifier (E180F). The signal detector (semiconductor diode) feeds a cathode follower to provide a low-impedance output. The local oscillator (CV408) is run in the "oscillator high" condition and drift is given as 0.2Mc/s after 12 hours continuous operation (provisional figure only). The aerial input (unbalanced) impedance is 70Ω at 450Mc/s.



Armstrong-Whitworth low-noise u.h.f. receiver, "boxed" version.

The receiver is available in two forms: one for 19-in rack mounting, the other as a 8in×8in×15½in boxed unit to fit aircraft racking. The 19-in type (weight 42lb) includes a 200-250V 50c/s power supply; but the airborne version (weight 12 lb) requires an external supply of 190V at 110mA d.c. (stabilized) and 6.3V at 3.5A for the valve heaters. Manufacturers: Sir W. G. Armstrong Whitworth Aircraft, Ltd., Baginton, Coventry.

CONFERENCES AND EXHIBITIONS

Latest information on events from September to next March both in the U.K. and abroad is given below. Further details are obtainable from the addresses in parenthesis.

UNITED KINGDOM

National Radio and Television Show, Earls Court, London, S.W.5 .... Aug. 26-Sept. 5
(British Radio Exhibitions Ltd., 49 Russell Square, London, W.C.1.)

British Association Annual Meeting, York .... Sept. 2-9
(British Association for the Advancement of Science, 18 Adam Street, London, W.C.2.)

Scottish Industries Exhibition, Kelvin Hall, Glasgow .... Sept. 3-19
(Matthew H. Donaldson, 2 Woodside Terrace, Glasgow, C.3.)

Farnborough Air Show .... Sept. 8-14
(Society of British Aircraft Constructors, 29 King Street, London, S.W.1.)

Dielectric Devices (Conference), University of Birmingham .... Sept. 14-17
(Electrical Engineering Department, The University, Birmingham, 15.)

Modern Network Theory (Conference), University of Birmingham, Sept. 21-24
(Electrical Engineering Department, The University, Birmingham, 15.)

Some Aspects of Magnetism (Conference), Sheffield University .. Sept. 22-24
(Institute of Physics, 47 Belgrave Square, London, S.W.1.)

Cabinet Styling Exhibition, Victoria Halls, Bloomsbury Square, London, W.C.1. .... Oct. 6-8
(B.R.E.M.A., 49 Russell Square, London, W.C.1.)

Scientific Instrument Manufacturers' Association Convention, Hotel Metropole, Brighton .... Oct. 22-24
(S.I.M.A., 20 Queen Anne Street, London, W.1.)

Radio Hobbies Exhibition, Royal Horticultural Hall, London, S.W.1..Nov. 25-28
(P. A. Thorogood, 35 Gibbs Green, Edgware, Middx.)

Physical Society's Exhibition, Royal Horticultural Halls, London, S.W.1 .... Jan. 18-22
(Physical Society, 1 Lowther Gardens, London, S.W.7.)

Engineering Materials and Design Exhibition, Earls Court, London, S.W.5 .... Feb. 22-26
(Industrial and Trade Fairs Ltd., Drury House, Russell Street, London, W.C.2.)

OVERSEAS

Acoustics Congress, Stuttgart .... Sept. 1-8
(Dr. Ing. E. Zwicker, Breitscheidstr. 3, Stuttgart.)

Firato 1959; International Electronics Exhibition, Amsterdam .... Sept. 1-8
(Firato Secretariat, Emmalaan 20, Amsterdam, Z.)

International Trade Fair, Salonika .... Sept. 6-27
(Fair Committee Office, Salonika, Greece.)

French National Radio & Television Show, Paris .... Sept. 10-21
(Fédération Nationale des Industries Electroniques, 23 rue de Lubeck, Paris.)

Salon Belge de l'Electronique, Brussels .... Sept. 19-24
(Comité des Expositions de la Radio-Electricité, de la Télévision et des Industries Connexes, 7 rue de Florence, Brussels, Belgium.)

Telemetring Symposium, San Francisco .... Sept. 28-30
(Robert A. Grimm, Dymec Inc., 395 Page Mill Road, Palo Alto, Calif., U.S.A.)

Irish Radio and Television Show, Mansion House, Dublin .... Sept. 28-Oct. 3
(Castle Publications, 38 Merrion Square, Dublin, Eire.)

Communications Symposium, Utica .... Oct. 5-7
(E. William Morris, 224 Fairway Drive, New Hartford, N.Y., U.S.A.)

High Fidelity Music Show, New York .... Oct. 5-10
(Institute of High Fidelity Manufacturers Inc., 125 East 23rd Street, New York 10, U.S.A.)

Radio-Interference Reduction, Chicago .... Oct. 6-8
(H. M. Sachs, Armour Research Foundation of Illinois Institute of Technology, Chicago.)

I.R.E. Canadian Convention, Toronto .... Oct. 7-9
(Convention Office, 1819 Yonge Street, Toronto, 7.)

National Electronics Conference, Chicago .... Oct. 12-14
(N.E.C., 228 N. La Salle Street, Chicago, Ill., U.S.A.)

Electrical Techniques in Medicine and Biology, Philadelphia .... Nov. 10-12
(Dr. L. E. Flory, RCA Laboratories, Princeton, N.J., U.S.A.)

Magnetism and Magnetic Materials, Detroit .... Nov. 16-19
(D. M. Grimes, University of Michigan, U.S.A.)

Computer Conference, Boston .... Dec. 1-3
(J. H. Felker, Bell Telephone Laboratories, Murray Hill, N.J., U.S.A.)

Reliability and Quality Control Symposium, Washington ...... Jan. 11-13
(R. Brewer, G.E.C. Research Laboratories, Wembley, Middx.)

Solid-State Circuits Conference, Philadelphia .... Feb. 10-12
(Tudor R. Finch, Bell Telephone Laboratories, Murray Hill, N.J., U.S.A.)

I.R.E. National Convention, New York .... Mar. 21-24
(E. K. Gannett, I.R.E., 1 East 79 Street, N.Y. 21.)

RANDOM RADIATIONS

By "DIALLIST"

America via the Moon

AT the moment of writing no fewer than four different attacks are being made on the problems which beset long-distance wireless communications conducted on the direct transmitting - aerial - to - receiving - aerial systems in use today. The plain, blunt fact is that they're not sufficiently reliable: you can't guarantee a twenty-four-hours-a-day service on three hundred and sixty-five days a year. Amongst the chief snags are blackouts, fading and interference—and these are not the only ones. Many readers will remember the demonstration given by Professor A. C. B. Lovell in the B.B.C. Reith lectures last year of the fact that it had proved possible in experimental transmissions to use the moon as a reflector of wireless waves. Recently a joint effort by him and the Pye people succeeded in establishing a link for both morse and the spoken word between Jodrell Bank and the U.S. Air Force centre in Massachusetts. The power used was 1kW at 201 Mc/s, but the e.r.p. with 40dB of aerial gain would be 10,000kW. The large Jodrell Bank radio telescope, 250-ft in diameter and costing a vast sum of money, is hardly a practical proposition as a transmitting aerial. But Pye Telecommunications are getting down to the job of developing a 25-ft radio telescope, fed with radio waves of much higher frequency and with far greater power behind them. They will undoubtedly succeed before very long and it is likely that a very important advance in long-distance wireless communication will result.

Other Approaches, Too

But that's by no means the only way in which the problem is being tackled. The use of artificial satellites as relays was proposed many years ago, and the Press Secretary of the White House said recently that he confidently expects global television to come into being in this way before the end of next year. The most surprising idea of the lot is the child of Westinghouse, of Pittsburgh. They are already producing various types of balloon aerials, some made of fabric incorporating large numbers of fine metallic threads. These aerials are light and easily transportable. One suggestion is that they should be carried aloft in a deflated condition either by aircraft or by rockets and then be filled with suitable gas and launched.

Films Across the Pond

IN the system which it has developed for transmitting news films across the Atlantic, by telephone cable, the B.B.C. seem to have accomplished something akin to pouring a quart into a pint pot. In other words, they've evolved a method of squashing the normal 3Mc/s TV bandwidth down to well within 6.4 kc/s which was the channel width allocated for this purpose on the transatlantic cable. It has been done ingeniously by restricting the horizontal definition so that it corresponds to a 1.75Mc/s bandwidth in a 405-line system, by reducing the number of lines to 200 with sequential scanning and by transmitting only alternate film frames; at the receiving end each frame is recorded simultaneously on two adjacent frames. The effective repetition frequency is thus 12½ frames a second. But that's not the whole answer, for if nothing more were done the bandwidth would still be 450 kc/s and therefore unusable over the cable. It had to be reduced to one hundredth of this figure and that was done by increasing the scanning time. This means that a one-minute news film takes 100 minutes to transmit and record. Slow though the process may seem, it enables news films to be received on either side of the Atlantic a great deal earlier than if they were flown by fast 'plane. The 16-mm film (almost universally used for TV news purposes) is scanned at the transmitting end by a slow-speed flying-spot scanner, the slow-speed video signal being used to modulate a 5 kc/s carrier. At the receiving end the demodulated signal is fed to a flying-spot telerecorder with twin optical systems. For scenes involving rapid movements every frame can be scanned instead of every other one. This means that the transmitting time is doubled, but even so this system is much quicker than any other method of getting pictures across the Herring Pond.

New Giant Labs

WHAT a vast concern the research and development organization of the Bell Telephone System already is! It now employs nearly 11,000 people at 18 stations and soon it will be still bigger, for $20,000,000 is to be spent on the erection of new laboratories at the Holmdel site, famous for the work done there by Jansky on aerials and Southworth on waveguides. Jansky was responsible for the invention of the rhombic aerial and, later, for Musa (multiple unit

...ly steer- ...ials, which ...ord in short- ...usa principle ...last war into ...erable multi-rod ...el, too, the need ...shorter wavelengths ...nmense amount of ...rk by Southworth and ...ers on waveguides and ...elopment of components ...alized valves which are now essent... parts of microwave technique. A great deal of priceless work was done in the investigation of the background (sometimes foreground!) noise which can be such a nuisance in short-wave wireless. Jansky was specially interested in the continuous hissing heard when his rotatable aerial was directed towards a particular part of the heavens. He concluded that its origin was an area in the ga...xy some 27,000 light-years away. Thus he laid the foundations of radio astronomy, though it was Lovell who gave it practical form after the end of the war. The tropospheric forward-scatter systems had their origin at Holmdel and the work done on waveguides may point the way to a system in which something like 200,000 telephone circuits may eventually be carried by a circular waveguide.

steerable aerial), an electr... able array of the... was just a...

A Worth-while Guarantee

IT'S good to learn that several manufacturers have extended the guarantee period from six months to twelve months on all new cathode-ray tubes. Mazda state that since purchase tax on replacement tubes was knocked off in the Budget there has been a five-fold increase in the demand. Their expectation is that the doubling of the guarantee period will lead to a still greater increase in the sales of new tubes, since people will prefer them to those which have been rebuilt or repaired. They may be right in this, though my own feeling is that so long as there is a biggish difference between the cost of buying a new c.r.t. and a rebuilt one, those firms which have a reputation for doing reliable rebuilding work *and* are prepared to give as long a guarantee period (as C.R.T. Ltd. have announced) won't find themselves idle. The c.r. tube guarantee now lines up with the setmakers' overall guarantee, but there is still a mingy three-months' on valves. And as TV set owners and servicemen know, valve replacements are amongst the most frequently needed repairs.

UNBIASED

By FREE GRID

Caveat Amator

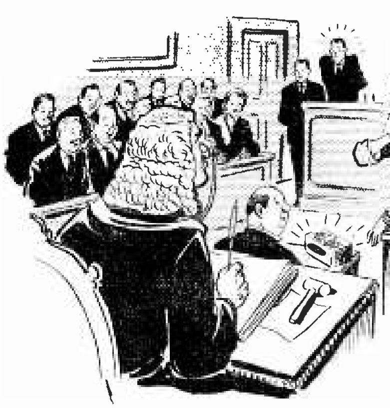
I HAVE previously discussed the question of the growing menace of the tape recorder which seems more and more to threaten the sanctity of our private conversations. To my mind the most irritating thing about it is that from a scientific and commonsense point of view, there is some justification for such recording.

But I cannot see any justification at all for a new use of it which, I read, is coming into fashion among modern girls. We all know that in Queen Victoria's time, girls used to tie up their love letters with pink tape and pack them away with lavender-filled sachets. Modern girls have them microfilmed and filed.

Unfortunately certain girls are equipping themselves with portable tape recorders so that they can have a permanent record of any proposals they receive. With some, the idea is undoubtedly to confront their husbands in later days with what they said long years previously. But I expect that with many of them the idea is to collect a round dozen or so of proposals and then to play them back and pick the man who makes the best oratorical effort.

This will improve the standard of eloquence in proposals as men will naturally buy one of these machines to practise on. Thus instead of the few faltering words which most men manage to stammer out, girls of the future may hear something worthy of Shakespeare.

If I had my time over again, I would make the perfect tape recording and then post it to the girl I wished to marry. I doubt if my blonde of long ago could have resisted me if I had used the magic words with which Cupid wooed Psyche, especially if I had finished off by bursting into the famous song "Lovely Art thou" from the opera "Xerxes." This song is, of course, usually known to the vulgar more by its tune—Handel's Largo—than by its passionate words.



A permanent record of a proposal

However, there is a real and serious danger that tape recordings may one day be accepted as evidence in a breach-of-promise action, and it would not be impossible for an unscrupulous blonde to forge a proposal. She could first obtain several tape recordings of her intended victim's voice in a perfectly normal manner. She could subsequently play these back, and feed the sequels into a sound-on-film recorder so that she could make a *visual* study of the idiosyncracies of the victim's voice.

Then, following the techniques of Rudolf Pfenniger, she could paint on a strip of virgin film totally fictitious utterances in her victim's voice. These could be played back, and fed to a tape recorder and this recording would then be taken to court, and played over to a sympathetic jury. Believe me, it is a very real danger, and no laughing matter.

[Popping the question on tape is not uncommon. The June issue of the *Grundig Gazette*, which circulates among dealers, records that Arthur Rowe, of Coventry, "wooed and won his bride-to-be in the U.S.A. with nothing more romantic than a mailspool."—ED.]

Audio and Photo

THE Photo Fair at Olympia in May had a lot in common with the Audio Fair held elsewhere a month earlier. Both exhibitions were intended to appeal to the same two classes of people, namely those whose chief interest lies in the design of the high-class instruments available at each show, and those who delight chiefly in the end-product, namely a work of art, visual in one case and aural in the other. In both shows were to be found many visitors who were interested in the means as well as the end, and not instead of it.

The Photo Fair was the bigger as it filled the National Hall at Olympia but I could not help thinking what a splendid opportunity there would be of lessening expenses and increasing interest if the Audio and Photo Fairs combined. Together they could easily fill the main hall at Olympia while the smaller National Hall could be fitted with a large number of sound-proof demonstration theatrettes such as are needed by both shows, the photographic people, of course, needing them for amateur talkie demonstrations.

In both the Audio and the Photo Fairs this year stereo was a leading feature, and here the Photo Fa. copy has a . behind it and . childhood days. . it was only too . that stereophony is sti. cutting stage of infancy, a. you who are fathers will kn. a howling hullaballoo that can .

Si-Fi

I OFTEN think that a small but somewhat important point of receiver design which manufacturers neglect is the provision of properly connected sockets for an external loudspeaker. Usually these are just inserted in parallel with the internal loudspeaker.

What's wrong with that, you may ask. Nothing at all if you are just going to use an extension loudspeaker a few feet away. Of course, if the set is of the "Hi-Fi" type even this will upset things a bit from the point of view of a musical purist. But I am not discussing things from the point of view of the long-haired fraternity, but from that of ordinary people like you and me who are addicted to the sugary sort of music usually known as "Si-Fi" because of the sighs it produces from its sentimental audience.

Now I may be a bit of an extremist, but I have an extension loudspeaker in every room. They used all to be of the conventional 3-ohm or less type, but I soon had to alter that. When you have only 3 ohms or less to play with, the resistance of long extension leads becomes a serious matter. Also, of course, the use of several 3-ohm loudspeakers in parallel means that the output valve is virtually working into a short circuit. If you want to know what that sounds like, try connecting a couple of 6-volt 36-watt car bulbs $(=\frac{1}{2}\text{ohm})$† in parallel with your loudspeaker.

Now I don't expect all manufacturers to provide me with a separate output valve for each of my extension loudspeakers but they could, I think, provide me with at least one extra secondary winding on the output transformer, such winding being of 15 ohms or so rather than 3 ohms. Naturally my extension loudspeakers would have to be of higher resistance too. If manufacturers can provide me with the extra 15-ohm secondary, I can easily rewind my speech coils. After all, 30 years ago all readers of *Wireless World* wound their own speech coils. If you don't believe me turn up your issues of 1927 and see for yourselves by reading the words of F. H. Haynes who designed and fathered the *Wireless World* moving-coil loudspeaker. It is now, I believe, in the Science Museum; if not, it certainly ought to be, side by side with the "Everyman Four" receiver which certainly is there.

† [Or less if they are not dissipating 72 watts.—ED.]