Wireless World

JUNE 1954 VOL. 60 No. 6

New Licences

WE have long thought the broadcast sound and vision receiving licences issued by the Post Office to be queer documents. Nearly 10 years ago, we protested that some of the provisions of the sound licence were unduly restrictive. As a result a few changes were made, but fewer than we would have liked. There still remain clauses that must be a source of minor annoyance to the very few people who trouble to read the licences, and, at the same time, have a dislike of unwarranted bureaucratic "bossiness."

For example, on what grounds does the Postmaster-General forbid a direct connection between mains and aerial? A deplorable practice, admittedly, but surely a matter for the P.M.G.'s colleague the Minister of Health, who may have the expense of treating transgressors for shock under the National Health Service. Perhaps, however, this clause is intended rather as a recommendation than a veto; the warning that the licence does not confer authority to infringe copyright is rather more forthright but surely equally irrelevant. A gun licence does not warn the holder against using the weapon for, say, felonious wounding.

Several of the apparently irrelevant clauses of the broadcast licences are perpetuated in the large crop of new radio licences recently issued by the Postmaster-General which are summarized elsewhere in this issue. No doubt these relatively harmless things are done in drafting by over-cautious officials whose main object is to protect their department from possible litigation. There are also several apparent anomalies, particularly in the matter of charges, between one class of licence and another. Why, for instance, should a single ambulance vehicle, equipped with radio-telephony for expediting its journeys of mercy, pay £3 a year, while a whole police communication network, with an unlimited number of stations, pays only £2?

The charge for one new type of licence seems altogether excessive, and will, we hope, be revised. This is the Hotels licence, for which it is apparently proposed to charge, for sound broadcast reception, a fee of £1, plus £1 a year for each room installed. For television the fee is £3 plus £3. We should imagine that only the luxury hotel could afford to pay these charges.

Shared Television Masts

SO far as competitive television is concerned, there is only one point on which the political parties are agreed: this is that the aerials of the Independent Television Authority, if it comes into existence, should be carried on the masts of the B.B.C.'s present stations. What the B.B.C. itself thinks of this proposal, incidentally, is not stated.

At first sight the idea seems technically to have everything in its favour. The existing B.B.C. main stations were planned to give the most economical coverage of the densely populated areas, and it is doubtful if better sites could be chosen. For the viewer there is a distinct advantage in having both the B.B.C. and the I.T.A. transmissions radiated from the same point. This would allow combination receiving aerials to be used, pointed in the same direction. With separate transmitter sites, most viewers would have to erect more clumsy, unsightly and costly aerials. Where neighbours share a chimney stack, an impossible situation might arise.

All the B.B.C. "standard" stations have Band II slot aerials, for future use in sound broadcasting, occupying the top 100ft of the mast. It should be technically possible to interlace a high-gain Band III television aerial with the slot system, but, if this proved unexpectedly difficult, the portion of the mast immediately below the slotted section might be used without excessive loss of range.

On the masts of the five lower-power B.B.C. stations to be erected shortly provision has been made for Band III aerials, and there seems no *technical* reason why they should not be used by the I.T.A. If enough Band III channels could be freed for both B.B.C. and I.T.A. programmes, the two services could be "diplexed" to a common aerial.

Colour Television on 405 Lines

Demonstration of Compatible Systems for British Standards

WHEN the Television Advisory Committee issued their first report in 1953 they suggested that a compatible colour television system for Britain could be achieved by an adaptation of the American N.T.S.C. system,* with the colour signal transmitted outside the normal video band, either in an adjacent clear space or in part of any already-occupied adjacent channel. This method, of course, requires more bandwidth than the normal N.T.S.C. system, where the colour signal is transmitted within the same band as the monochrome signal. It has the great advantage, however, that the colour signal cannot interfere with the monochrome signal and produce a pattern of crawling white dots on the screens of black-and-white receivers. In this respect it is more compatible than the normal N.T.S.C. system—although the T.A.C.'s interpretation of compatibility suggests that the colour signal should be kept within the same band as the monochrome signal. The possible application of this "adjacent channel" system to British television has already been discussed in *Wireless World*.†

The idea has now been tried out on an experimental basis by Marconi's, and recently in London they gave a demonstration of it on a 405-line closed-circuit television system. At the same time a demonstration was given of a straightforward adaptation of the normal N.T.S.C. system to British standards, and it should be mentioned here that Marconi's were really presenting the two systems for comparison purposes: they were not advocating either one or the other. Comparisons could be made between the resultant pictures as they appeared on colour monitors and on ordinary black-and-white commercial receivers. It was also possible to see the effects of different bandwidths in the channels conveying the colour information. The subjects televised were live scenes, both indoor and outdoor, a colour film and some still colour transparencies. On the same evening as the demonstration, L. C. Jesty, of Marconi's, discussed some of the technical points in a lecture to the Institution of Electronics.

The frequency characteristic of the "adjacent channel" type of colour transmission is shown in Fig. 1(b) alongside that of N.T.S.C.-type signal at (a). In both cases the brightness information is transmitted in the full 3-Mc/s bandwidth and provides the ordinary black-and-white picture for existing receivers. The remaining information, hue and saturation, appears at the transmitting end in the form of two colour-difference signals, which are modulated on to two components of a carrier frequency displaced 90 deg in phase. In the wide-band system (b) this carrier is transmitted outside of the monochrome signal, whereas in the N.T.S.C.-type system (a) it takes the form of a sub-carrier (actually 2.6578125 Mc/s) on the main signal, so that the colour information is transmitted within the monochrome 3-Mc/s band. Fig. 2 shows how the standard 405-line waveform is adapted to the N.T.S.C. type of signal. It will be noted that the peak-white/sync-pulse ratio has been reduced from 70/30 to 60/30 to accommodate (partially) the positive excursions of the colour sub-carrier. In addition, the back porch of the sync pulse carries a short burst of sub-carrier frequency which is used for synchronizing the homodyne colour-signal detectors in the receiver.

It was clear from the demonstration that the adjacent-channel system (b) gave better colour pictures than the N.T.S.C. type of system, and on the screens of the ordinary black-and-white receivers there was no sign of an interference pattern. Another point in its favour, mentioned by Mr. Jesty in his lecture, was that it would make for simpler and less expensive receivers than those required for the N.T.S.C. system. For possible colour transmissions in Bands IV and V the extra bandwidth required would not present any difficulties (the T.A.C. having already proposed that channel widths of 7.5 Mc/s should be made available to stations). On Bands I and III, however, it would be necessary, as Mr. Jesty pointed out, to make the colour signal of one station overlap the monochrome signal of the station in the

* *Wireless World*, Nov. 1953, p. 524
† *Wireless World*, Dec. 1953, p. 599

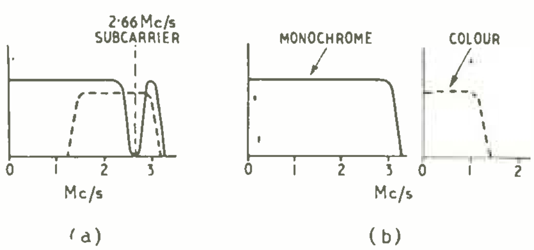


Fig. 1. Frequency characteristics of (a) N.T.S.C.-type signal adapted to British standards and (b) "adjacent channel" signal. The dip in the monochrome characteristic at (a) represents filtering to remove colour-signal interference.

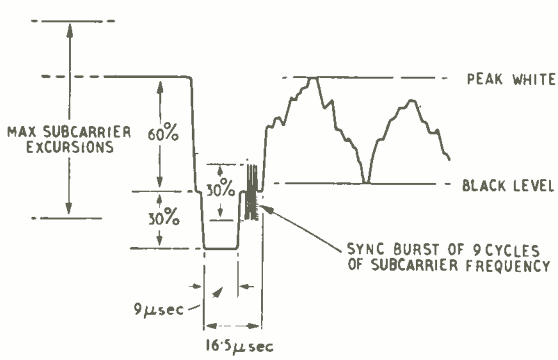


Fig. 2. Showing how the standard 405-line waveform is modified to carry the extra colour information in the N.T.S.C.-type system using a sub-carrier.

adjacent channel.** The cross-talk between them would probably be troublesome in fringe areas, but it could possibly be overcome by the use of directional aerials.

At the demonstration comparisons could also be made between two possible methods of presenting the colour pictures, namely the R.C.A. tri-colour cathode-ray tube†† and a triple-tube projection system using optical combination of primary-colour images. Most observers agreed that the tri-colour tube gave the better pictures, both in colour rendering and definition. This was in spite of the fact (mentioned by Mr. Jesty) that in the R.C.A. tube the pattern of mask-holes and dots is liable to cause an interference pattern when interacting with our 405 scanning lines. Moreover, it seems that R.C.A., in order to avoid this beat effect with their 525-line structure, have made the pattern of holes and dots a good deal coarser than would otherwise be desirable, and as a result the definition of the tube is limited to about 250 lines.

The live scenes in the demonstration were televised by a new type of camera which uses only two pick-up tubes as compared with the three tubes in the R.C.A. colour camera. This represents an important step towards the ultimate aim of a single-tube camera. The principle of operation takes advantage of the fact that the eye is not able to see colour in fine detail, and in this way the camera is well adapted to the transmission systems (Fig. 1), which both make use of the same peculiarity. One pick-up tube produces a normal-definition monochrome picture of 3-Mc/s bandwidth while the other is arranged to give two low-definition colour signals, actually the red and blue primary-colour components. These are obtained by means of a filter consisting of alternate red and blue stripes arranged at right angles to the scanning lines. The green component is not required because it is not transmitted separately in the Fig. 1 systems but derived at the receiving end by subtracting the red and blue signals from the monochrome signal (which, of course, contains all three colour components).

This arrangement is obviously more economical than the three-tube type of camera, which produces red, green and blue colour-component signals of normal definition and combines them to form the monochrome signal, using only the red and blue outputs to provide the information for the transmitted colour signal (which does not need the full definition in any case). It also has advantages over the single-tube type of camera, which uses a very fine-pitch colour grid on the pick-up tube with red, green and blue stripes at right angles to the scanning lines. With this the pitch of the colour grid has to be about three times the definition of the equivalent monochrome picture, so that red, green and blue colour-component signals can be obtained for each individual picture element. By contrast, the two-colour grid in the Marconi camera is much coarser and gives exactly half the definition of the equivalent monochrome picture (1.5 Mc/s) since this is all that is required for colour information in the transmission system. Another advantage of the two-tube arrangement is that because the two-colour image is of low definition it does not have to be so accurately registered with the green image (contained in the monochrome picture) as in the three-tube camera, where all three images are of normal definition.

** *Wireless World*, Nov. 1953, p. 509.

†† *Wireless World*, May 1954, p. 242.

Monochrome Television Camera

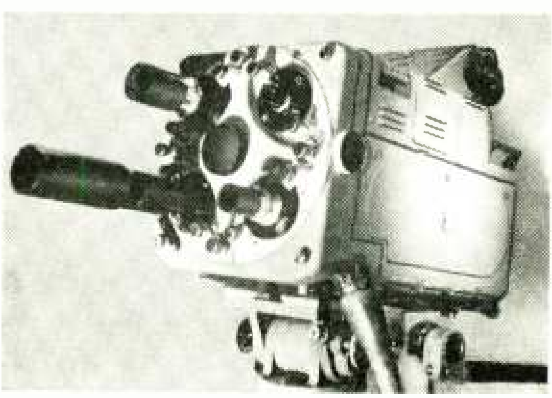
AT another recent demonstration by Marconi's a new camera for monochrome television, the Marconi Mark III, was shown in operation on a closed circuit. It can be used with either the 3-in or the new 4½-in English Electric image orthicon,* and in the demonstration the latter was employed.

As shown in the photograph, the camera has a four-lens turret, the lens in the lower left corner being the operative one. A control of light intensity is provided by means of discs in the turret, one of which carries a number of fixed filters and the other of which provides a continuous control of light transmission. Partly because of the placing of the tube and its coils to one side of the apparatus, and partly because of the use of electronic temperature control of certain windings, it has been possible to dispense with a blower for cooling.

The viewfinder is of the electronic type and is in a separate unit pivoted to the top of the camera. It is possible, therefore, to tilt the camera to any angle and yet keep the viewfinder in a position convenient to the operator.

The camera is designed for the 405, 525 and 625-line systems and with the 4½-in tube is claimed to give an output signal/noise ratio of better than 40 db. The sensitivity is such that for the best picture an incidental illumination of 10—20 ft candles is needed with an *f*/5.6 aperture. The power consumption is 1.5 kVA and the camera weighs 140 lb and measures only 17¼ in. high by 15¾ in. wide by 26½ in. deep.

A new flying-spot film scanner was also demonstrated and is suitable for 50- or 60-c/s frame frequencies. Scanning is effected with the film stationary and the film is pulled down during the frame flyback period of some 1 msec. It is the ingenious mechanical arrangement which permits this extremely rapid pull down that constitutes the main new feature of the scanner. The present model is for 16-mm film and for standard 2-in. by 2-in. miniature slides.



* *Wireless World*, May 1954, p. 225

WORLD OF WIRELESS

European Television Exchange • Earl's Court Plans • Increased Radio Exports • Cable & Wireless Jubilee

International Television

A FURTHER STAGE in the organization of the series of eighteen relays of television programmes between eight European countries for June and July was reached in Brussels early in May.

At the invitation of the European Broadcasting Union, which is co-ordinating the relays, the engineers and programme officials of the various broadcasting authorities met the technicians of the telecommunications administrations who will be responsible for the provision of cable links. The temporary radio links and the standards conversion centres will be the responsibility of the broadcasting authorities.

The telecommunications administrations have to provide a complicated network of international telephone circuits for: (1) programme sounds and commentaries in different languages; (2) operational instructions between administrations; and (3) connecting the national control points with the international co-ordination centre being set up at Lille.

Show News

THE DEMAND for space at the National Radio Show to be held at Earl's Court, London, from August 25th to September 4th, has been greater than at any time since the war, with the result that it may be necessary to reduce the amount of space devoted to combined electronic demonstration stands. All three Services will be participating this year and the scope of the Technical Training Display—introduced two years ago—will be enlarged. Incidentally, the Radio Industry Council has issued a booklet on careers in radio and electronics which is available on request.

With seven different sources of television programmes available for piping to the stands, receivers will be able to be demonstrated outside the normal B.B.C. transmitting hours. In addition a signal will also be available for demonstrating Band-III receivers and convertors.

Increased Exports

RADIO EXPORTS set up a new record in March with a total value of just over £2,800,000. Direct exports of communications equipment, broadcast transmitters, radar and other navigational aids and electronic equipment for industry accounted for £1.3M. This figure does not include equipment installed in exported ships and aircraft.

The March figure brought the total for the first quarter of the year to £6.9M.

C. & W. Jubilee

"THE cable engineers and the wireless engineers of the past have been replaced by a new generation of telecommunication engineers, conversant with the strong points of each method," writes Maj. Gen. L. B. Nicholls, chairman of Cable & Wireless, Ltd., in a booklet entitled "World-Wide Communication" issued to mark the company's silver jubilee. Brief explanations are given in the 40-page booklet of the methods employed to send messages and illustrations over the company's 114 W/T circuits, 85 R/T circuits, 18 radio phototelegraphy circuits and 150,000 miles of submarine cable.

In the section dealing with development and production work carried on at Radio House, reference is made to the development of the double current cable code (DCCC). This system enables two separate channels of communication to be sent over a single radio path. The signals of the two tape transmitters are fed alternately into a common sending unit and converted to DCCC. It can also be used as an automatic repetition system in bad operating conditions.

Patent Office Library

AN EXTENSION to the Patent Office Library in Chancery Lane, London, W.C.2, recently opened to the public, provides immediate access to over 3,500 scientific and technical periodicals published since 1920. Hitherto, much of this material has been available only on request. Another important addition to the library is the provision of a section for bibliographies and extracts.

The library remains open to the public until 9 p.m. on Mondays to Fridays and until 5 p.m. on Saturdays.

OPERATIONAL TRAINING. To provide radar training for Merchant Navy navigation officers under operational conditions the Sir John Cass College, London, has put into commission this 112-ft. motor yacht. It has classroom accommodation for 20 students and is equipped with Marconi and Decca radar, Decca navigators, Kelvin-Hughes echo-sounders and Marconi d.f. and radio-telephone gear. The radar observer courses in "Sir John Cass" last a fortnight.

Radio Expedites Goods Collection

AN interesting experiment is being conducted in Leicester by British Road Services with the object of improving the collection of goods from traders' premises. Three parcels vans are equipped with v.h.f. radio telephones and messages and instructions reaching the depot from traders requiring urgent collection can be passed on to the radio-equipped van nearest the premises concerned. This obviates the delay in waiting for a van to become available or of sending one specially from the depot.

Vans are equipped with 3-watt Pye sets and the traffic control station, which is located on a tall building and remotely controlled, has a 15-watt set. Amplitude modulation is used.

PERSONALITIES

The new post of chief engineer of the Communications Division of Marconi's W.T. Co., has been accepted by **C. Gillam,** who has been with the company since 1930. In 1942, he took over responsibility for aerial designs and became chief of the Aerial Design and Systems Planning Group on its formation in 1948, in which capacity he was responsible for the design of aerials and associated equipment for communications, broadcasting and television. His contributions to *Wireless World* include articles on the Wrotham aerial system.

N. C. STAMFORD.

C. GILLAM.

N. C. Stamford, M.Sc., M.I.E.E., recently appointed education officer of the Institution of Electrical Engineers in succession to W. H. Taylor (see below), was lecturer in electrical engineering in the University of Manchester from 1933 to 1944. In that year he was appointed principal of Marconi College, with additional responsibility for education and training in Marconi's W.T. Company. He subsequently became deputy education and training officer to the British Electricity Authority.

W. H. Taylor, B.Sc., A.M.I.E.E., recently appointed controller of Education and Personnel Services to the General Electric Company, was education officer of the Institution of Electrical Engineers for six years from 1947.

Dr. Alfred N. Goldsmith, a co-founder and director of the Institute of Radio Engineers, has relinquished the editorship of the *Proceedings of the I.R.E.*, which he has held since 1913. In recognition of his services he has been appointed Editor Emeritus and given the Founder's award. He is succeeded by John R. Pierce.

Richard Arbib, managing director of Multicore Solders, is on a two-months' tour of the U.S.A. and has visited the Chicago Radio Parts Show (May 17th-20th). The British Industries Corporation, distributors for a number of U.K. manufacturers, including Multicore, had a stand at the Chicago show.

Sir Arthur Fleming, C.B.E., D.Eng., Hon.M.I.E.E., who was director of research and education with Metropolitan-Vickers for many years before assuming a similar position with the parent company, Associated Electrical Industries, has received the honorary degree of Doctor of Law of Manchester University.

Col. J. Reading, M.B.E., B.Sc.(Eng.), M.I.E.E., an assistant engineer-in-chief, Post Office, has been appointed chairman of the council of the Institution of Post Office Electrical Engineers and of the board of editors of the institution's journal. He was for many years secretary of the institution. Col. Reading joined the equipment branch of the Engineering Department of the Post Office in 1925 and returned to the Post Office in 1946 after war service. He was for some time chief signals officer at the War Office.

E. D. Hart, M.A., A.Inst.P., A.M.I.E.E., who was for many years with Marconi Instruments, and, since 1952, has been head of the Technical Department of Mullard's equipment division, has been appointed deputy director of the Scientific Instrument Manufacturers' Association. He is chairman of the Joint Advisory Committee on Radio Communication and Radar Measuring Instruments set up by R.C.E.E.A., R.E.C.M.F. and S.I.M.A. The new secretary of S.I.M.A., following Mr. Peacock's resignation (see below), is Miss G. E. Moss, B.A., formerly clerk to the council.

A. G. Peacock, B.Sc., A.Inst.P., has resigned the secretaryship of the Scientific Instrument Manufacturers' Association and has joined the board of Mervyn Instruments, manufacturers of scientific and industrial electronic equipment, of St. John's, Woking, Surrey. He is perhaps best known as the honorary exhibition secretary of the Physical Society.

P. A. Thorogood, G4KD, has accepted the invitation of the Radio Society of Great Britain to organize the eighth Amateur Radio Exhibition which is to be held at the Royal Hotel, Woburn Place, London, W.C.1, from November 24th to 27th. Mr. Thorogood, who has organized the Electrical Engineers' (A.S.E.E.) Exhibitions, is chairman of the London u.h.f. group of the R.S.G.B.

C. E. Hay has been appointed by Communication Systems, Ltd., to fill the newly-established post of technical director. He has been transferred from the parent organization, Automatic Telephone and Electric Company, which he joined in 1945 from the Ministry of Aircraft Production.

G. W. Cussans, flying radio officer with the British Overseas Airways Corporation, has been elected chairman of the Radio Officers' Union for 1954. He was a sea-going operator with Marconi Marine before joining Imperial Airways (predecessor of B.O.A.C.) in 1936. From 1945 to 1948 he was senior instructor at Hythe, Southampton.

OUR AUTHORS

D. N. Corfield, whose article on valves for Bands III, IV and V appears in this issue, spent a short period in the research laboratories of Ericsson Telephones before going to Standard Telephones and Cables in 1927, where he was concerned with carrier telephones and repeater equipment. He was for four years chief engineer of the subsidiary company Kolster-Brandes and since the war has been in charge of the Brimar Valve Application Department. Mr. Corfield is a member of the committee responsible for building the Television Society's u.h.f. 405-line transmitter installed at Norwood. He has been active as an amateur transmitter, G5CD, since 1923.

Charles B. Bovill, who reviews in this issue the development of the French 819-line television system, has been working in France for some time on the Decca Navigator chain of stations. He has been with Decca since 1946. His radio career began in 1933 when he joined the Gramophone Company on the development of broadcast receivers. In 1936 he went to the Air Ministry Aeronautical Inspection Directorate Radio Department and two years later joined Marconi's Aircraft Division acting as liaison engineer between the company and Coastal and Bomber Commands of the R.A.F. In 1942 he was commissioned in the R.A.F.V.R. and was officer in charge of the Air Operational Research Group of the Inter-Services Research Bureau.

H. G. M. Spratt, contributor of the article in this issue on magnetic recording tape, was, until recently, manager of the Magnetic Tapes Division of the Minnesota Mining and Manufacturing Company. Prior to that he was for a short time assistant chief engineer at Marconi Instruments and during the war was engaged on radio and radar in the Ministry of Supply. For seven years before the war Mr. Spratt worked on the development of high-definition television at E.M.I. and Philco. He started his career as a heavy engineer designing motors and generators.

OBITUARY

J. E. Nickless, M.I.E.E. (G2KT), who was for fifty years with Bullers, Ltd., and was the company's technical adviser on radio components (he retired in 1948), died at the age of 75 on May 2nd. He was well known in amateur circles and was a vice-president of the Southend and District Radio Society.

IN BRIEF

Broadcast Receiving Licences current in Great Britain and Northern Ireland at the end of March totalled 13,436,793, including 3,248,892 for television and 226,667 for car radio. The month's increases were 75,868 for television, 7,631 for sound only and 3,158 for sets fitted in cars.

Physical Society Show.—Both exhibitors and visitors to the Physical Society's annual exhibition will welcome the proposal to hold next year's exhibition in a larger hall. In spite of the co-operation of the governors of Imperial College, the growing interest in the show has made the space available at the college inadequate. It is expected that the 1955 exhibition will be held in the Royal Horticultural Hall, London, S.W.1, towards the end of April.

1954 Amateur Show.—It has been decided by the Radio Society of Great Britain to hold the eighth Amateur Radio Exhibition at the Royal Hotel, Woburn Place, London, W.C.1, from November 24th to 27th. The emphasis will be on "transistors and emergency equipment for portable and mobile use."

Electrical "Noise."—A five-day summer school on the theory of electrical conduction and noise will be held at the Centre for Continued Studies, Primrose Hill, Selly Oak, Birmingham, 29, from September 27th to October 1st. Particulars of the course, for which the fee is £5 (excluding meals and accommodation), can be obtained from the Director of Extra-Mural Studies, The University, Edmund Street, Birmingham, 3.

Electronics in Industry.—Some typical applications of electronics to mechanical handling equipment will be shown and, in some cases, demonstrated by a few of the 200 exhibitors at the Mechanical Handling Exhibition, which opens at Olympia on June 9th for eleven days. Among the organizations known to be featuring electronic control gear are:—The British Electrical Development Association, B.T-H., English Electric and Goring Kerr. A preview of the exhibition will be given in the June issue of *Mechanical Handling* which is organizing the show.

Home Service Coverage has been further improved by the installation of two permanent 2-kW transmitters at Scarborough, Yorks (1151 kc/s), and Ramsgate, Kent (1484 kc/s). They replace temporary transmitters which have been in use for some time.

Wireless Dinner Club.—At the annual general meeting and dinner of the British Wireless Dinner Club, which has a membership of 500, Maj. Gen. C. H. H. Vulliamy, C.B., D.S.O., was elected president in succession to A. V-M. C. W. Nutting, C.B.E., D.S.C. The new vice-president is H. Bishop, C.B.E., director of technical services, B.B.C.

Ten-Year Index.—The annual indexes to the four parts of the *Proceedings of the Institution of Electrical Engineers* for the years 1942-1951 have been collated and published as a collective index by the Institution. In addition to indexing every author, speakers in discussions and every key word in the titles of papers, the ten-year index includes a subject index in which titles of papers are collected under forty broad headings. The 500-page index costs 25s.

INDUSTRIAL NEWS

Transmitters for three television stations (both vision and sound), with associated aerial systems, have been ordered from **Marconi's** by the Danish broadcasting authority. They are to be installed at Copenhagen, Odense and Aarhus. The 625-line vision transmitters are to be amplitude-modulated while f.m. will be used for sound.

Cable Ship Radio.—The new cable ship *Recorder* (3,300 tons) for Cable & Wireless, Ltd., which was recently launched at Newcastle-upon-Tyne, will be equipped with Kelvin-Hughes radar and echo-sounders and Marconi radio-communication and sound amplifying gear.

B.B.C. and British Movietonews used **Leevers-Rich** magnetic recording gear when covering the Royal Australasian Tour. The recorders used by Movietonews are fitted with a synchronizing device, which, by means of a pulse recorded on the tape during the filming, ensures that when the tape is transcribed to the film perfect synchronism with the picture will be maintained.

"**Navigator,**" the demonstration motor yacht of the Decca Company, is on a two-months' cruise of North European ports. She is equipped with the three types of radar (45, 12 and 159B) and the latest Decca Navigator (Mark V), which is capable of receiving the transmissions from nine chains working on different frequencies. Some 3,200 radar installations for 780 ship-owners plus installations in vessels of the Royal Navy and 25 Commonwealth and foreign navies, have been undertaken by Decca. Navigator installations now total over 2,200.

South African Enquiry.—W. L. Procter (Pty.), Ltd., of 63, Strand Street, Cape Town, distributors of high-fidelity radio and audio equipment and components would like to receive catalogues from British manufacturers. Their London representatives are: William Dunn & Company, Ltd., 12-15, Finsbury Circus, London, E.C.2.

Clare Instrument Company, of Rickmansworth, Herts, which was recently formed by J. de Gruchy, has opened a London office at 39, Victoria Street, S.W.1 (Tel.: Abbey 1816). A multirange instrument incorporating the principles of protection described by Mr. de Gruchy in our September, 1953 issue, will be produced by the company.

The Engineering Division of **International Aeradio, Ltd.,** has moved from Bovingdon Airport to new premises adjoining the I.A.L. Printing and Publishing Division at Hayes Road, Southall, Middlesex (Tel.: Southall 2411).

Aerialite, Ltd., has opened a sixth depot—at 19, Blythswood Street, Glasgow, C.2. (Tel.: Central 2299.)

Radio-communication equipment and navigational aids are to be installed by **Marconi Marine** in the six vessels being built for the fleet of the Sugar Line, Ltd. Marconi equipment is also to be installed in the Union-Castle Line's new 7,450-ton motorship *Tintagel Castle* and the 9,000-ton motor tanker *Regent Royal* of the Regent Petroleum Tankship Company.

French Television Progress

Plans for Extending the Service

By CHARLES BOVILL, A.M.I.E.E., M.Brit.I.R.E.

The 819-line test card used by La Radiodiffusion Television Française.

SOME three years ago it was unusual to see a television aerial in France, although there were regular broadcasts from stations in Paris and Lille. To-day, however, aerials are to be seen on the roof-tops of very many houses, both in the towns and in the country, and even the smallest radio shops display television sets for sale.

The sudden increase in the popularity of this form of entertainment is generally considered to be largely due to the success of the Coronation relay, which was seen by millions of French people, very many of whom had never seen or been previously interested in television. Another factor which has stimulated interest is the very good quality of the 819-line system, which is now the established French standard. French people have appreciated the fact that this is a very high definition system which cannot be superseded for some years to come, and they feel that a receiver can be invested in without danger of it becoming out of date. Moreover, the close spacing of the lines enables very pleasing pictures to be obtained from large-screen tubes.

When the 819-line system was first proposed it was looked upon as a dangerous step to take and technicians were apprehensive on account of the many problems which its use incurred. One of the main difficulties anticipated was serious phase distortion in the system due to the wide bandwidth which the high-definition system employs. This can occur in many parts of the chain between the studios and the transmitter aerial. It is therefore greatly to the credit of the engineers concerned, both in the Radiodiffusion Television Française and in the French radio industry, that the difficulties have been largely overcome by the use of ingenious phasing networks, negative feedback arrangements and other techniques, many of which have their origin in radar engineering. In the latest transmitters being built in France, correction is applied at the final modulator stage of the transmitter, an M-derived filter being used for the purpose.

Probably the most critical part of a wide-band television system is in the coaxial cable from the studio to the transmitter. In the case of the Paris station this is relatively long and undoubtedly some phase distortion occurs in it. French television experts state that the best way of judging the amount of phase distortion which occurs in the coaxial, and also the best way of seeing how good the 819-line system can be, is to view from signals transmitted from the Lille station. At this station, a Lille studio broadcast, which involves negligible coaxial cable transmission, can be compared with a relayed programme from Paris which must pass through the long coaxial cable from the studio to the transmitter. This comparative test indicates that if the coaxial cable technique can be improved there is very little wrong with the 819-line system.

Frequency Sharing Troubles

An unexpected problem was met last winter as a result of anomalous propagation conditions which caused interference to reception on the 185.25-Mc/s frequency shared by the Paris and Lille transmitters. This was overcome by using the offsetting technique which detunes the two transmitters by half the line frequency, here about 10 kc/s. The technique was originally developed in the U.S.A. and is now in general use for overcoming the difficulties of operating television stations on common frequencies. To understand the principle of the system, consider first the situation that occurs with perfectly synchronized transmitters. Under these conditions, when there is zero frequency difference between the carriers, there will appear at many reception points a second picture which will resemble the well-known "ghost image." The appearance of the unwanted picture must clearly depend upon the relative phase of the two signals at the receiving aerial, Thus, even with perfect synchronization of carrier frequencies, there will be many localities where reception must be unsatisfactory.

Under practical conditions it is almost impossible to achieve perfect frequency synchronization as there must be some wandering of the frequencies of the two carriers. At the receiver detector this frequency wandering is translated into a heterodyne effect which appears on the screen of the receiver as a series of horizontal bars moving up and down. This effect takes place under conditions of a much greater ratio of wanted-to-unwanted signal and at ranges from the unwanted signal transmitter which are far in excess of those where the form of ghost image is seen. It is therefore an effect which can be most objectionable when even a very small interfering signal is present, such as occurs with abnormal propagation conditions. Furthermore, it cannot be eliminated by such simple expedients as orientation of the receiving aerial.

The problem of the "venetian blind effect," as it is so aptly called, led to the development of the offset system in the following way. Under conditions of a small frequency difference between two carriers there are only a few horizontal bars and the cycles of the beat between the two carriers appear as positively and negatively interfering pictures. As the difference between the carrier frequencies is increased the beat interference pattern becomes one of thin lines which is very much less annoying to the viewer. At the same time the odd and even lines have interfering images of opposite polarity which are cancelled out by the integrating effect of the eye at normal viewing distance. The critical offset frequency will be half the line frequency (10 kc/s with the 819-line system) to achieve the best all-round result. In order that the offset system can function correctly, it is of course necessary to maintain highly stable frequency control at the transmitters, which are working on what is virtually a common wavelength. Practical tests have indicated that a total frequency excursion of up to 2 kc/s, inclusive of both transmitters, is permissible without objectionable interference effects at the receiver. In the case of the Paris and Lille transmitters this means that a frequency stability to within one part of 200,000 is required.

Pair of 30-cm relay aerials with electromagnetic lenses, built by Cie Generale de Telegraphie Sans Fil.

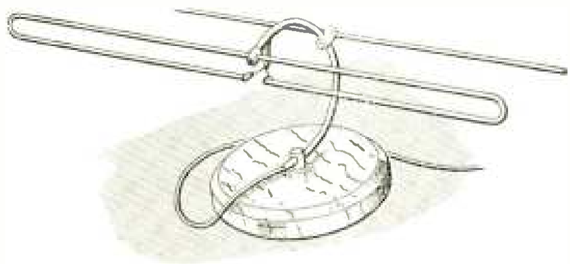
Television relay station in the Paris-Strasbourg chain at Dabo la Hoube in the Jura, constructed by Cie Generale de Telegraphie Sans Fil.

Eiffel Tower Installation

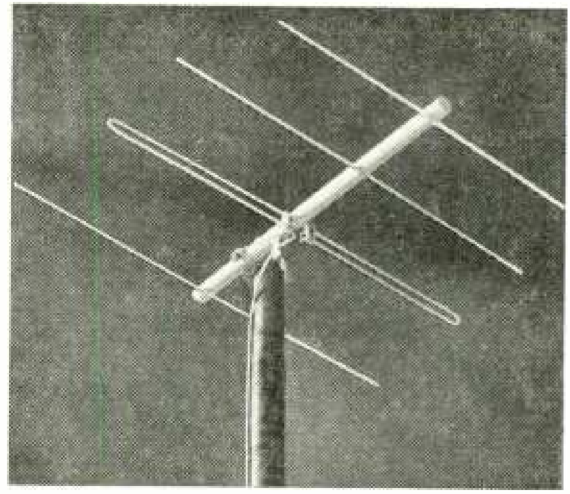
The value of the famous Eiffel Tower to radio has always been considerable from the time that Ducretet sent the first message from its summit in 1898. The massive aerials which for so many years hung from its top gallery to anchor points on the Champ de Mars, and which were used for time signals, have now been removed, and the Eiffel Tower is almost exclusively used for television work, for which it is an ideal transmission site. The 1,000ft elevation of the aerials is unique and enables the signals radiated to have an unobstructed path over a very large area. Not only does it allow the outside broadcast vans to work from considerable distances away, but it also enables relays to be installed which feed the subsidiary stations at Lille and at Strasbourg.

The Paris-Lille relay has been in operation for some time now, but the one to Strasbourg is more recent. It begins with a 3-cm link to Meudon, where the first of ten relay stations is located. From here the remainder of the links operate on a wavelength of 30 cm. The total length of the relay to Strasbourg is about 280 miles.

At present the Eiffel Tower transmitter radiates 12 kW and the equipment is housed in the top of the tower. A new transmitter is now being installed which will enable 150 kW to be radiated, and this will be housed at the base of the tower. The output of this transmitter and also that of the sound transmitter will be connected to a "diplexer," and thence through



Simple indoor television aerial with folded dipole and adjustable director on a marble base.



Typical television receiving aerial for the 819-line system made by Radio Industrie.

a single balanced feeder, over 1,000ft long, to a turnstile aerial on top of the mast, which will radiate both vision and sound signals. The total loss in the feeder will be of the order of 30 per cent. The existing transmitter is modulated at the final stage, but the high-power equipment will be modulated at low level. When the new transmitter is installed the old one will be removed from the top of the Tower and set up as a standby at the base.

These changes to the station will doubtless be welcomed by the engineers who operate the equipment, as throughout the winter they have to mount the last 570ft of the tower on foot to the transmitter room, since the hydraulic lifts, installed many years ago, become unserviceable in cold weather.

Following upon the success of the present high-definition transmitters, further expansion is being carried out, and in the near future new stations will be put into service at Lyon and at Marseilles, and a 200-kW station is being planned for Alsace. In the meantime the aerial mast at the Strasbourg station is being doubled in height in order to increase the field strength in the fringe areas.

The expansion of French television is intended to be in two stages. In the first stage more small relays will be built to serve thickly populated districts, such stations being satellites to the main stations. It is intended to have "branch lines" off the main relay chain from Paris to Strasbourg which will feed relays at Nancy, Reims and Amiens. The main station at Lyon will have a satellite to cover the lower part of the Rhône Valley, and the Marseilles station will have satellites at Toulon and at Nice to cover the south-east coast of France, where the population is relatively dense.

The ultimate plan, which was agreed upon in principle at the international conference at Stockholm in 1952, is for almost complete coverage of France. Owing to the topography of the country, which includes two major mountainous regions, there will be a requirement for a total of 45 stations. The implementation of this plan must depend largely upon funds granted by the Government and from the revenue from licences. At present the French television licence costs 4,350 francs, which is the equivalent of slightly more than £4 6s.

The French television authorities are fully aware of the geographical importance of France for international television relays, and their plans are centred round Strasbourg as the hub of European television relays. In the plan proposed, transmissions from Germany, Switzerland and Italy would enter France at Strasbourg and from there be relayed on to Paris and London. A radio link from Strasbourg to Paris is already being built, and the "inward" relay stations will occupy the same sites as the "outward" relay stations from Paris to Strasbourg.

In eastern France there are many localities where several programmes can be picked up, including the local programme. As there is a difference between the French standard and the European standard, as used in Germany and Switzerland, special receivers are needed—not only for the difference between the 819- and 625-line transmissions and their attendant variation in black-level percentage, but also the sound section of the receiver must be capable of receiving a.m. or f.m. signals. One manufacturer is marketing a receiver of this type aptly named the "Strasbourg," since in this town the Baden Baden transmitter can provide adequate signal strength. On the other hand, the first privately owned television station in Europe, at Saarbrücken, is using the French 819-line standard.

The station to be built for Monte Carlo, which will also be privately owned, will naturally use the French standard, and will probably be providing a regular programme for the Riviera by the end of the year. Both the Monte Carlo and Saarbrücken stations will transmit on frequencies in the 200-Mc/s band.

Indoor Receiving Aerials

Reception of the high-definition programmes has not presented many difficulties, and the normal folded dipole with a reflector and one or two directors is the most popular type in use. This aerial provides the 10-Mc/s bandwidth required and it is coupled to the receiver by a 72-ohm unbalanced coaxial cable. Very many receivers now operate from indoor aerials in the Paris region, and such aerials are becoming increasingly popular since on the 1½-metre wavelength a dipole aerial is of small enough dimensions to be made up as an attractive ornament. For the fringe areas these aerials are supplied with a self-contained pre-amplifier which gives 20 db gain. Interference from motor cars is markedly less on the 185-

Mc/s transmissions than on the 46-Mc/s transmission, which puts out the programme on the old 441-line standard in Paris.

Although France was criticized very strongly by other countries in Europe for adopting the 819-line standard and breaking away from the so-called European standard of 625 lines, recent events and rebroadcasts, such as the epoch-making Coronation relay, have shown that definition conversion can be carried out very satisfactorily and without noticeable detriment to picture quality. Once such techniques are perfected the international exchange of programmes becomes possible, and the question of standardization becomes of secondary importance, since, by the very nature of the wavelengths used for television, international reception must always depend upon local rebroadcasts, except in isolated cases, for which "multi-standard" receivers of the type already described are available. However, this raises the delicate matter of the necessity for standardization for television systems, which is better left alone, not only by the French.

Let it suffice to conclude with a word of admiration for General Leschi, the Technical Director La Radiodiffusion Television Française for having the courage to adopt and to try the high-definition system, and for the French radio industry for supporting it by technical development and making it a success.

Magnetic Recording Tape

Measurement of Coercivity and Remanence

By H. G. M. SPRATT, B.Sc., M.I.E.E.

IN a recent paper[1] on magnetic-tape recording it was clearly shown that, despite the use of h.f. bias, which subjects the tape to several magnetization cycles as it passes the recording head, a truly symmetrical hysteresis loop is seldom, if ever, reached before the tape has left the field. At the same time confirmation was provided of the fact, well known in practice, that the optimum bias current lies well below the saturation level. A valid measurement of coercivity or remanence, however, implies the use of a hysteresis loop which is both symmetrical and extends up to complete saturation in both directions of magnetization. Indeed, quite apart from the standard definitions of these quantities, measurements made under any other conditions would be difficult to repeat and useless for comparison purposes. It might therefore be assumed that such measurements were not only irrelevant but actually misleading when attempting to assess tape quality. Experience shows, however, that knowledge of these quantities is of considerable value in predicting performance, while the curves from which they are obtained may yield additional pointers to behaviour.

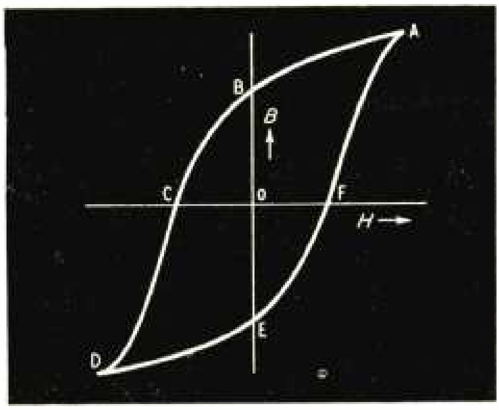
In what follows it is proposed to describe the most convenient method of measuring coercivity and remanence and to indicate the additional information to be derived from the curves. Before doing so, however, the practical importance of these two quantities will be briefly discussed.

In the sphere of magnetic recording the term "coercivity" is undoubtedly the better known of the two. This is because it is common practice for manufacturers to describe their tapes as of low, medium or high coercivity, an excellent idea, marred unfortunately by some confusion as to what constitutes medium and what high. Low-coercivity tapes, rather less popular now than in the past, have values extending up to 150 oersteds and are characterized by low optimum bias currents, easy erasure and relatively poor frequency response. High-coercivity tapes, with coercivity values extending from about 320 oersteds upwards, have exactly the opposite characteristics and are in little demand except for special purposes. Medium-coercivity tapes have coercivities ranging from 220 to 320 oersteds and combine most of the virtues of the other two types without their drawbacks. In practical usage other variables such as mechanical defects and differences in the performance characteristics of recording equipments can easily mask the slight but definite difference resulting from a 10 per cent change in coercivity, e.g., from 230 to 255 oersteds. Nevertheless, an accuracy of measurement within this percentage is essential for comparison purposes.

Remanence values have far less significance for the user than those of coercivity. This is slightly illogical since he is certainly interested in sensitivity and undistorted output capacity, quantities which are dependent upon remanence. Actually knowledge of the remanent flux is more useful still, since total flux, not flux density, determines sensitivity and coating thickness does vary from tape to tape. The bulk of tapes have remanence values lying within the range 400 and 900 gauss.

The necessity for a symmetrical hysteresis loop when measuring coercivity or remanence rules out completely the use of a static or point-to-point plotted B-H curve and demands a dynamic test obtained by applying a steady alternating magnetizing force to

[1] "An Investigation into the Mechanism of Magnetic-Tape Recording." P. E. Axon, *J.I.E.E.* Vol. 99, Pt. III, pp. 109-126 (May, 1952)



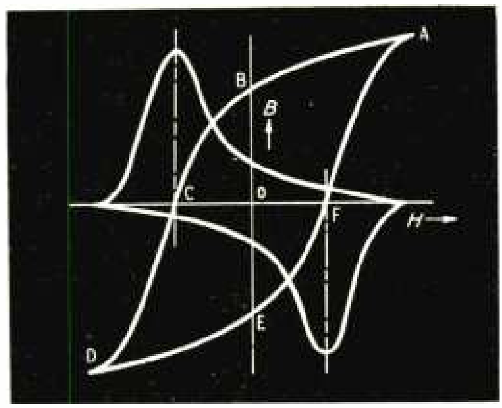


Fig. 1. Typical hysteresis loop under steady state a.c. conditions and (right) Fig. 2. Hysteresis curve together with the time differential curve of flux density (dB/dt).

the tape specimen. The resulting hysteresis loop will then be of the form shown in Fig 1 where the significant values are the magnetizing force OC or OF (the coercivity) and the flux density, OB or OE (the remanence). Obviously in a dynamic test these quantities can be determined only by reading them off a presentation of the loop on a cathode-ray oscilloscope.

To provide such a presentation we must clearly have available a voltage proportional to H for applying to the X-plates and one proportional to B for the Y-plates. As will appear later the first is easily obtained, the second not so easily. There is, however, no difficulty in providing a voltage proportional to dB/dt, the time differential of B, and one recognized procedure, which will be followed here, for obtaining a voltage proportional to B is to take the dB/dt value and integrate it. The integral is, however, less accurate than the differential from which it was obtained as will appear later. Apart from that, the coercivity value can be read off the differential curve —if it is shown—equally well and, moreover, this curve will reveal variations and abnormalities completely hidden in the integrated curve.

In Fig 2 are shown both the integrated curve, i.e., the hysteresis loop again, and the differential curve. The pronounced peaks appearing in the latter obviously correspond to the points of greatest slope in the hysteresis loop. Visual inspection shows, however, that these points of greatest slope are the points where the loop cuts the H axis, i.e., the points giving the value of coercivity. Experience shows that the greatest slope always coincides with this point for a homogeneous ferromagnetic material and is entirely unaffected by increasing the maximum value of H once that value has been raised to the saturating point.

The design of equipment for obtaining both differential and integrated curves will now be considered. If we have an air-cooled solenoid whose length is large and whose winding depth is small compared with its diameter and feed it from an a.c. source, say the 50 c/s mains, the instantaneous flux density in the neighbourhood of the centre will be uniform and proportional to the magnetizing current. A small search coil placed in this region with its axis parallel to that of the solenoid will accordingly have an output voltage which is proportional to the rate of change of this flux density and hence to that of the magnetizing current. If now we place a sample length of magnetic tape inside the search coil, the output voltage will increase as a result of the magnetization of the tape. This voltage value is of little use to us as it stands since we require, not the total voltage, but the increase only. To extract this difference a second identical search coil is placed near, but not too near, the first and connected in series opposition to it. In the absence of the tape the combined output of the two coils will be zero. This balance will, however, be upset by the insertion of the tape, the resulting voltage being that due solely

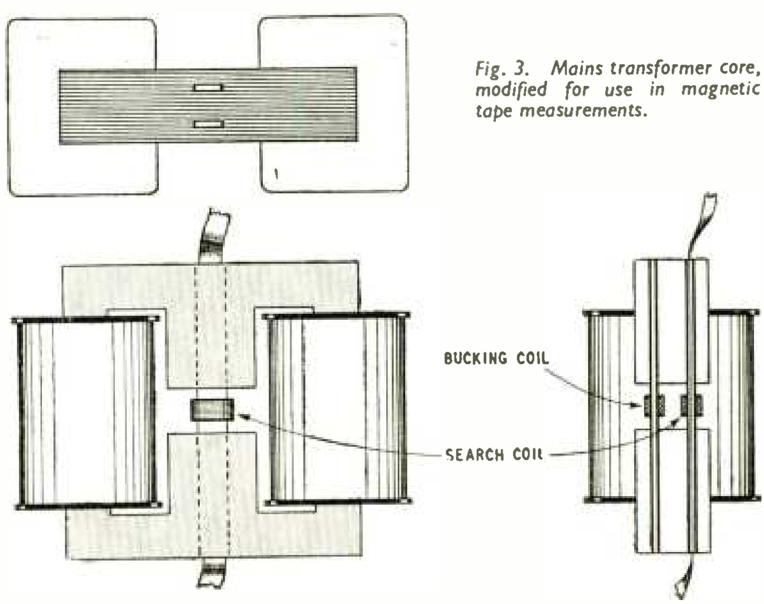


Fig. 3. Mains transformer core, modified for use in magnetic tape measurements.

to the induction in the tape. Theoretically, therefore, in order to present the differential curve on a cathode-ray tube, all that is needed is to apply this voltage to the Y-plate amplifier while a voltage proportional to the magnetizing current, obtained from the voltage drop across a resistance in series with the magnetizing winding, is applied to the X-plate amplifier.

Practical Precautions

In practice it is extremely difficult to design an air-cored solenoid to provide continuously the necessary alternating H of 1,000 oersteds maximum without overheating, but the use of an iron core with a large air gap will solve this problem. A core corresponding to the larger size of radio-receiver mains transformer is quite suitable provided the centre limb is cut away sufficiently to give the necessary gap and some of the inner laminations clipped back to form an aperture down which the tape can be threaded as indicated in Fig. 3. A tube of non-magnetic material of correct cross-section to accommodate three or four samples of standard ¼in-wide tape is introduced into this aperture and the search coil, located in the air gap, surrounds it. The compensating or bucking coil is also placed in the gap but separated slightly from the first. If the closest possible symmetry is desired, two identical apertures can be provided, equidistant from the centre line of the core, one for the tube and search coil, the other for the bucking coil. The magnetizing winding is wound on the two outside limbs of the core.

The search coils should be as small as possible to ensure intimate linkage with the tape flux and uniform flux density across the coil. As, however, they must be wound with several hundreds of turns to provide adequate sensitivity—and probably even then require the help of a pre-amplifier—a wire gauge of 48 to 50 is essential. The leads from the coils must be closely twisted together to prevent stray pick-up and taken to a terminal panel some few inches away from the core.

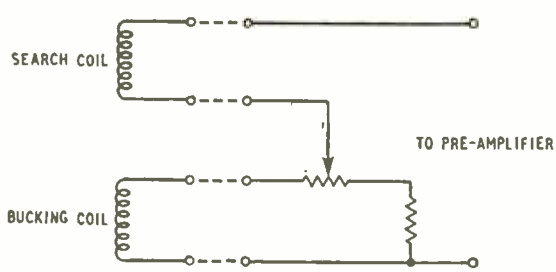


Fig. 4. Circuit showing position of the balancing potentiometer.

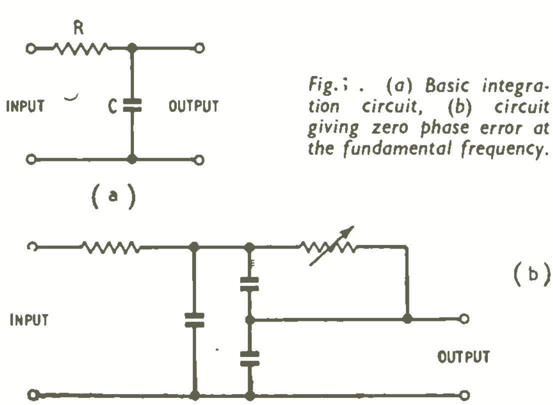


Fig. 5. (a) Basic integration circuit, (b) circuit giving zero phase error at the fundamental frequency.

It is too much to hope that, even if initial balance between the coils is achieved by adjustment of turns, this balance will be maintained permanently. Accordingly, the leads from the two coils should be taken separately to the pre-amplifier, where a small adjusting potentiometer is provided as shown in Fig. 4. Adjustment for balance is made by raising the magnetizing current from zero to maximum with no tape in the unit and full gain in the Y-plate amplifier. Under these conditions there should be no vertical deflection of the trace. Actually, this is likely to prove a council of perfection, even with the help of the potentiometer, owing to slight deviations from 180 degrees of phase between the coils. Final balance will be achieved either by adjustment of coil position or earthing point or the insertion of a piece of lamination into the gap near the compensating coil.

As implied above, provision must be made for full control of the value of the magnetizing current, and this is best effected by driving the magnetizing coils from a Variac transformer. In order to permit earthing of these coils, an isolating transformer should also be included.

The oscilloscope and its amplifiers should be checked for phase error, which will almost inevitably exist to some extent in the low-frequency range employed. A satisfactory test is to apply a 50 c/s voltage to the X-plates and at the same time a small fraction of the same voltage, derived from a resistance potentiometer, to the Y-plate amplifier. The appearance of a closed loop on the screen indicates phase shift in the amplifier and this must be reduced as far as possible by such means as increasing the values of bypass and coupling capacitors. The same procedure should then be carried out on the X-plate amplifier. As regards the type of oscilloscope, a double-beam tube is recommended because of the advantages to be gained by using the second trace as a marker.

Integrating Networks

As already explained, the hysteresis loop is obtained from the differential curve by integration and accordingly all that would appear necessary would be the insertion of an integrating network somewhere between the junction of the search coils and the Y-plates. In fact, care is needed in the choice of the network and as some loss of grain will certainly be involved, an additional stage of amplification will be required. The basic integrating network is the well-known RC combination shown in Fig. 5(a) but if it is used, the value of C will have to be made so large relative to R in order to avoid undue phase error that the insertion loss will exceed 40 db. This network, too, has the particular drawback of introducing a greater phase error for the fundamental frequency than for the harmonics, whereas the reverse is the lesser evil. The rather more elaborate network of Fig. 5(b) can be designed to give zero error at the fundamental frequency and only 0.3 degree at the 3rd harmonic for an attenuation not exceeding 25 db, and is therefore much more suitable for our purpose. Obviously the most convenient place for the integra-

(*Continued on page* 267)

tor and the additional stage of amplification is in the pre-amplifier, where arrangements can easily be made to switch both in and out as required.

It now remains to discuss briefly the two curves which should, of course, be similar to those shown in Fig. 2. Provided $H_{max.}$ is sufficiently high to take the tape up into saturation, both remanence, OB or OE, and coercivity, OC or OF, can be read directly off the hysteresis loop. The coercivity can also be determined, and somewhat more accurately, from the differential curve by measuring the distance between the peaks and the B-axis. Provided all mains pick-up has been removed from the trace and the centring is frequently checked, no difficulty should be experienced in reading to an accuracy within 5 per cent.

As suggested right at the beginning, the values of coercivity and remanence do not strictly apply to the conditions under which tape is normally used: nevertheless they prove in practice extremely useful for comparison purposes. In much the same way the height of the peaks in the differential curve is worth noting. It represents the maximum value of the slope of the hysteresis loop and would accordingly be a direct measure of sensitivity if the operating curve extended to saturation as this does. Even so, in comparison tests a high peak can infallibly be associated with a high sensitivity. It might also be expected that the degree of flatness of the top of the peak would indicate the undistorted output capacity of the tape. Unfortunately, on the normal cathode-ray tube the peaks are never sufficiently wide to show any sensible flatness on the top.

Perhaps the most striking feature of the differential curve is its sensitiveness to inhomogeneity of the magnetic material in the coating. If this coating contains two magnetic materials of different coercivities, it is very unlikely that the hysteresis loop will betray the fact. On the other hand it is equally unlikely that the differential curve will not. The presence of more than one component will be revealed by either asymmetry of the peak or even possibly a subsidiary peak as shown in Fig. 6.

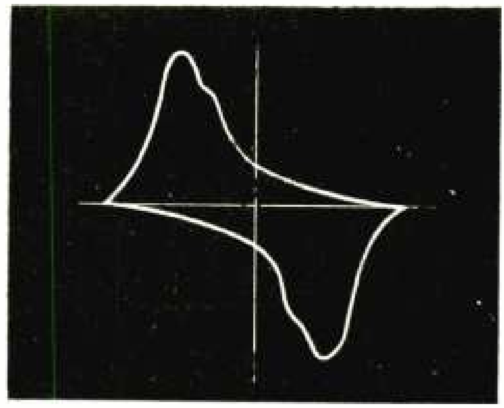


Fig. 6. Distortion of the differential curve due to inhomogeneity of the magnetic material.

It is doubtful whether all useful information extractable from the curves has been covered in this article. That must be left to the user's experience and own particular interests. It only remains to point out that, the more elusive the detail sought, the greater the care needed in balancing the coils and eliminating the last traces of phase error and mains pick-up when the apparatus is finally set up.

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"The Measurement of the Magnetic Properties of Fine Wire," P. T. Hobson, E. S. Chatt and W. P. Osmond. *Elect. Engng.*, Vol. 19, pp. 383-8 (Dec., 1947).

BOOKS RECEIVED

A Textbook of Radar, by the Staff of the Radiophysics Laboratory, C.S.I.R.O., Australia. Second edition, edited by E. G. Bowen, Ph.D., M.Sc. Broad survey of fundamental principles and their practical realization. Chapters are devoted to the applications of radar in navigation and surveying, and to meteorology and the physical sciences. Pp. 617+XIII; Figs. 352. Price 45s. Cambridge University Press, 200, Euston Road, London, N.W.1.

L'Ionosphère, by G. de Maximy. Treatise on the principles of forecasting frequencies for optimum propagation in telecommunications. Pp. 54; Figs. 23. Price 750 Fr. Editions Chiron, 40, rue de Seine, Paris, 6.

Automatic Voltage Regulators and Stabilizers, by G. N. Patchett, Ph.D., B.Sc., A.M.I.E.E., A.M.Brit.I.R.E. Wide survey of electro-mechanical and electronic methods of regulation, including a bibliography of more than 600 references. Pp. 335; Figs. 196. Price 50s. Sir Isaac Pitman and Sons, Parker Street, London, W.C.2.

Television Engineers Pocket Book. Edited by E. Molloy and J. P. Hawker. A compendium of data for dealers and servicemen, including chapters on current practice in television receiver design and fault diagnosis. Pp. 228, Figs. 104, and numerous tables. Price 10s 6d. George Newnes, Tower House, Southampton Street, London, W.C.2.

Introduction to Colour TV, by M. Kaufman and H. Thomas. Description of N.T.S.C. (American) colour television system and analysis of typical receiver circuits. Pp. 140; Figs. 74 Price $2.10. John F. Rider, Publisher, 480, Canal Street, New York, 13.

Highlights of Colour Television, by John R. Locke, Jr. Introduction to principles of colour television as exemplified by the American National Television System Committee's recommendations. Pp. 44; Figs. 29. Price 99 cents. John F. Rider, Publisher, 480, Canal Street, New York, 13.

TV Manufacturers Receiver Trouble Cures. Edited by Milton S. Snitzer. Volume 5 of a series dealing with American commercial receivers. Pp. 109; Figs. 47. Price $1.80. John F. Rider, Publisher, 480, Canal Street, New York, 13.

Specialized Home and Portable Radio Manual. Volume 8. Service data covering R.C.A. receivers issued between June, 1951, and December, 1953. Pp. 96 with numerous illustrations. Price $1.65. John F. Rider, Publisher, 480, Canal Street, New York, 13.

Thyratron Inverter
A Correction

In the circuit of Fig. 7, p. 240, May issue, the top end of the 3-Ω, 1-W resistor in the switching circuit should go to the moving arm of the switch, and not to the "on" contact.

Further Notes on the Midget

Details of Chassis Layout and Circuit Additions for Long-wave Reception

By J. L. OSBOURNE

THIS article gives constructional details of the receiver, theoretical aspects of which were described last month. Details are also given of a method of adding a long-wave band to the receiver, such a band being necessary because there are large areas of this country in which best reception of the Light Programme is provided by the B.B.C. long-wave transmitter on 200 kc/s. The photographs illustrating this article show the cabinet and method of chassis construction adopted by the author for the single and two-band versions and the full circuit diagram of the two-band receiver is given in Fig. 1.

It was originally intended to use a long-wave bandpass filter employing two LC circuits coupled as on medium waves, but such an arrangement has a number of disadvantages. For example, it is necessary to have a tapping point on the second long-wave inductor to feed the crystal, and a change over switch is necessary to select the medium- or long-wave tapping point as desired. One would be extremely fortunate to obtain a commercial inductor with a suitably positioned tapping point and in general hand-wound coils would be used. Moreover, to give a pass band of approximately 10 kc/s at 200 kc/s, a coupling coefficient of the order of 1/30 is necesssary and, if the long-wave inductors have a value of 2.2 mH, the coupling transformer requires primary and secondary inductances of approximately 70μH. Though not impossible, it is difficult to wind by hand two inductors of this value on a small former although, of course, it would be fairly simple to do so using a dust-iron core of the type used for medium-wave tuning inductors. If the long-wave coils have Q values of 100 (a typical practical value) a coupling coefficient of 1/30 is more than three times critical coupling and the frequency response has pronounced "rabbit's-ears." To avoid this, the coils can be damped by parallel resistors, but this reduces the gain. Thus, as pointed out in last month's issue, the addition of the long-wave band is by no means as straightforward as might be imagined.

It was considered unnecessary to go to the lengths detailed in the previous paragraph to obtain reception on a band containing so few signals, and a simple circuit was therefore sought which would permit the use of untapped commercial coils and would not require a coupling transformer. After some experimenting, the method finally adopted is that shown in Fig. 2. The long-wave coils L_5 and L_6 are simply coupled by a small capacitor C_{20} between their "hot" ends; although this circuit has the appearance of a bandpass filter it would be flattery to call it so.

The inductor L_6 is very heavily damped by the detector which is effectively in parallel with it. This damping is more serious than on medium waves because, for a given Q, a long-wave coil has approximately five times the dynamic resistance of a medium-wave coil. In fact the effective Q of L_6 is probably less than 1/6th of its nominal value because of detector damping. On the other hand L_5 is relatively undamped, having only the anode a.c. resistance of V1 (1 MΩ) across it. When two coils of markedly different Q values are coupled, the resulting response

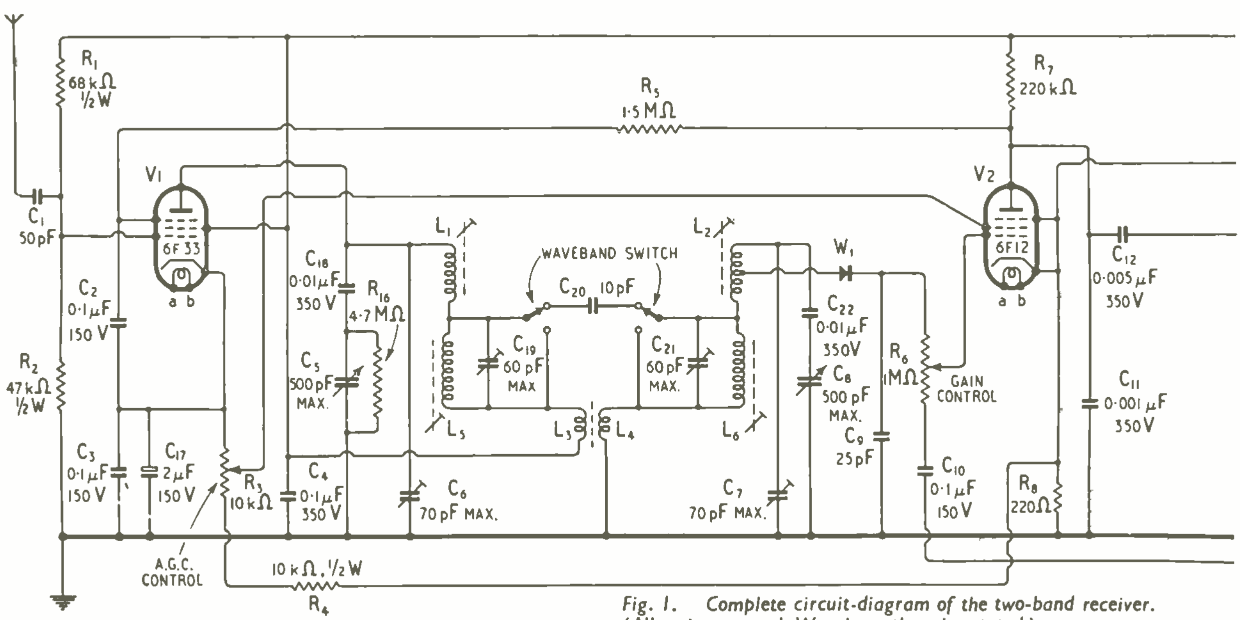


Fig. 1. Complete circuit-diagram of the two-band receiver. (All resistors are ¼-W unless otherwise stated.)

Sensitive T.R.F. Receiver

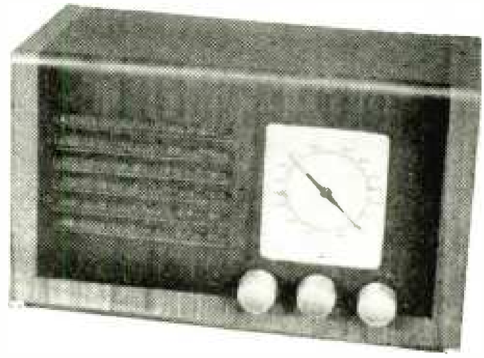
bears little resemblance to the wanted flat-topped curve. The capacitor C_{20} is in effect a matching component and is used in much the same way as the coupling capacitor in the "Modern Crystal Set" described by B. R. Bettridge in the September, 1951 issue of *Wireless World*.

The optimum value for C_{20} was found by experiment to be approximately 10 pF. With this value the sensitivity of the receiver on long waves is of the same order as on medium waves and in the London area it was found possible to receive three signals including the Light Programme at good entertainment level.

The method of waveband selection can be followed from Fig. 1; the long-wave coils L_5 and L_6 are connected in series with the medium-wave coils L_1 and L_2 respectively. In one position of the 2-pole 2-way switch L_5 and L_6 are short-circuited to give medium-wave reception; in the other position the switch connects the coupling capacitor C_{20} between the "hot" ends of L_5 and L_6. The coupling transformer L_3L_4 is in circuit on both wavebands, but it has negligible effect on the long-wave performance because the mutual inductance between the windings (of the order of 1 μH) is so small compared with the inductance of L_5 and L_6 (approximately 2 mH).

A minor modification found necessary in the long-wave receiver is the addition of a 0.001-μF capacitor C_{23} from V3 anode to earth. This is necessary to prevent instability at high settings of the volume control, the r.f. filtering being less effective than on medium waves. The trouble is due to the proximity of the anode lead of V3 to the tuning inductors and can be cured alternatively by screening the lead.

In the original circuit the fixed vanes of one section of the tuning capacitor are at h.t. potential and, with the close vane spacing used in modern components, it was found that sparking tended to occur between



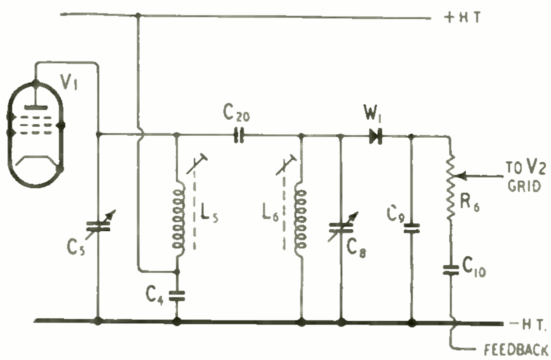
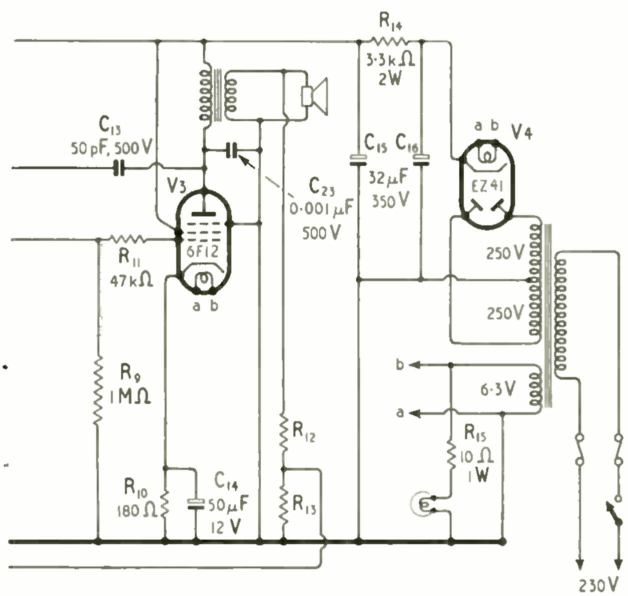


Fig. 2. Essential features of long-wave tuning arrangements.

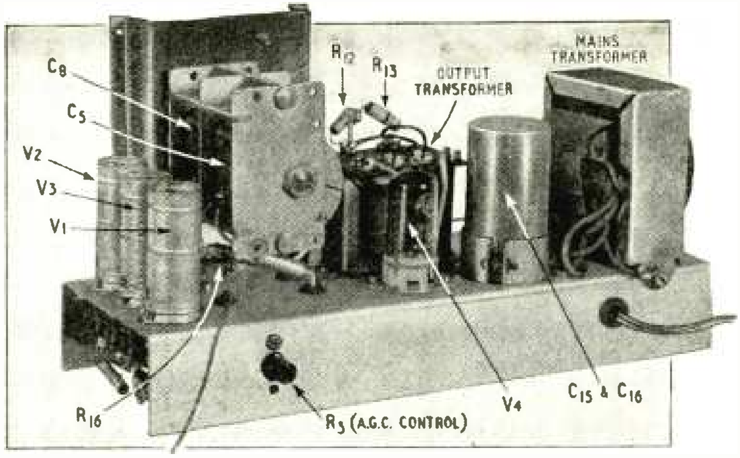
fixed and moving vanes at certain settings of the tuning capacitor, particularly when it was briskly rotated. This is avoided in the circuit of Fig. 1 by the inclusion of a 0.01-μF capacitor C_{18}, the fixed vanes being earthed by the 4.7-MΩ resistor R_{16}, which is too high to give appreciable damping of the tuned circuit. To prevent misalignment a similar component C_{22} is connected in series with the detector section of the tuning capacitor. These additional series capacitors cause approximately 5 per cent. reduction in the maximum capacitance of the tuning capacitors and increase the lowest frequency receivable on medium waves to approximately 580 kc/s. If the full frequency coverage is required, it can be obtained by increasing the number of turns on L_1 and L_2 to 60. Alternatively, curtailment of the band can be avoided by using larger capacitors (say 0.1-μF) for C_{18} and C_{22} but the smaller capacitors were used by the author to conserve space.

A tendency has been noted in a receiver constructed to the circuit shown last month to oscillate at a very low frequency when tuned to a very strong signal and with a high volume control setting. The receiver does not always exhibit this behaviour and, when present, it occurs only on the strongest signals, disappearing on slight mistuning and on reducing the output volume. This has been traced to the variations in h.t. voltage which occur at high volume settings (the maximum undistorted output of the receiver is less than 1 watt). These variations affect the gain of earlier stages and set up steady oscillation. This



effect can be eliminated by connecting a small electrolytic capacitor (C_{17}) from V1 cathode to earth. Any capacitance greater than 2 μF is adequate and the voltage rating need not exceed 150 volts.

The dial lamp is a 6.3-volt 0.3-amp. type operated from the l.t. winding of the mains transformer via a 10-Ω, 1-W resistor R_{15} which drops the voltage available at the lamp to approximately 4. This reduces the brightness of the bulb, but the tuning scale is still adequately illuminated. The series resistor was included to give the bulb a long life; the author has used this technique for some time and has some bulbs which are still giving satisfactory illumination after more than five years' operation.

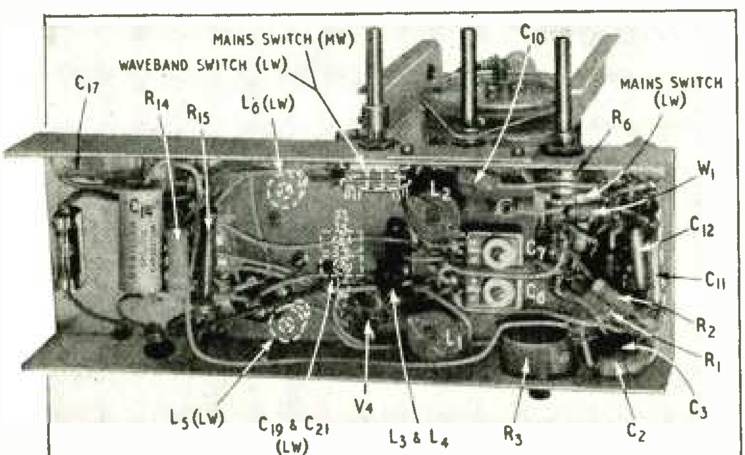


Principal components mounted above the chassis.

The accompanying photographs illustrate the method of construction used by the author for the single- and two-band models, the additional components required for long-wave reception being indicated in dotted lines. The receiver is housed in a cabinet measuring 5in × 5¾in × 11½in (outside measurements). The chassis measures 3½in × 1⅞in × 10½in, the front-to-back measurement being 1 inch smaller than the corresponding internal measurement of the cabinet, to leave room for the loudspeaker and the tuning drum drive. The chassis is spaced from the front of the cabinet by a folded piece of aluminium which supports the tuning capacitor, the tuning scale and the indicator lamp.

To keep hum at a low level, the three valves are grouped at one end of the chassis and the mains transformer is mounted at the other, the intervening space on the top of the chassis being occupied by the rectifier, smoothing capacitors, output transformer and tuning capacitor. Under the chassis, almost all the components associated with V1, V2 and V3 are mounted on the valve-holder tags or on two 5-way tag strips mounted on either side of the line of valves. The 50-μF cathode decoupling capacitor C_{11} is, however, rather bulky and is secured to the tags of a 7-way tag strip underneath the mains transformer. This tag strip also serves to terminate the l.t. winding and to support the resistor R_{15}. All the inductors and trimmers are located in the centre of the chassis near to the waveband switch. To facilitate alignment these are all adjustable from underneath the chassis. The a.g.c. control is mounted on the rear flange of the chassis and, when the chassis is in position in the cabinet, the adjusting screw projects through a hole in the back of the cabinet. A.g.c. can therefore be adjusted without removing the back from the cabinet. Once set, however, the a.g.c. control needs very little attention. The author's receiver has been in use for several months and during that time there has been no need to touch this control.

In the single-band model the three knobs control the volume, tuning and a rotary mains on-off switch, but in the two-band model the on-off switch is combined with the volume control and the third knob controls the miniature Yaxley-type waveband switch. This is a 3-pole, 2-way type of which two poles are used. The additional coils and trimmers required for long-wave reception are accommodated under the chassis near the waveband switch as shown in dotted lines. Fairly small components are necessary to fit into the space available and the trimmers are a pair of miniature compression-type capacitors of 60-pF maximum capacitance mounted on a steel strip attached to the chassis by stand-off pillars. The long-wave coils are Osmor Type QA6.



Underside of chassis showing modifications and positions of additional components for long-wave reception.

Long-wave alignment should be carried out after the receiver has been aligned for medium-wave reception as described in last month's issue. Long-wave alignment should then be carried out in the following way. Adjust C_{19} and C_{21} for maximum output with a modulated input at 350 kc/s and the tuning capacitor set to maximum capacitance, and adjust L_5 and L_6, for maximum output with a modulated input at 150 kc/s. Finally repeat the initial adjustment at 350 kc/s.

The quality of reproduction of this receiver is extremely good and, in fact, the excellent response to frequencies above 5 kc/s is an embarrassment during medium-wave listening after dark, each heterodyne whistle being reproduced with uncomfortable clarity. Constructors with an interest in experimenting might care to try the effect of increasing the value of C_{13} to reduce the high-note response ; it might even be an advantage to use a 300 or 500-pF variable capacitor to act as a variable tone control.

Radio Receiver Measurements

International Recommendations on Methods of Testing Sound-broadcasting Receivers

PUBLICATION 69* of the International Electrotechnical Commission, like others in its series, expresses "as nearly as possible, an international consensus of opinion" on its subject, and the national committees represented on the I.E.C. are pledged to bring their own countries' rules into harmony with the recommendations "in so far as national conditions will permit."

Comparing the scope of this document with the British Standard Glossary of the same subject, recently reviewed†, one observes that it includes a number of characteristics omitted from BS.2065—notably hum, square-wave tests, stability of tuning, automatic frequency correction, acoustic feedback and radiation—and in the single matter of frequency response characteristics it even specifies conditions for acoustical measurement; in spite of this, the treatment is on the whole simpler. It owes a great deal to the American I.R.E. "Standards on Radio Receivers," a number of clauses being almost word for word. But there are some rather surprising differences; for example, the standard dummy aerial, which, although based on the form that has long been familiar, shows some changes in component values. This, however, is only the beginning of the section on dummy aerials, which are dealt with much more thoroughly than usual. Not only is provision included in the type shown here for correcting the output resistance of one signal generator, and for two-signal tests with 1 : 1 and 10 : 1 ratios, but additional units are specified for simulating indoor aerials over two ranges of frequency, car aerials, and pick-up by mains. Procedure for frame-aerial receivers is laid down in detail.

The standard 30 per cent modulation at 400 c/s is retained, and so is the 50 mW standard output, but 5 mW and 500 mW are allowed as alternatives to meet special conditions.

The method of hum measurement provides data from which behaviour on supply mains of different waveforms can be predicted: along with pure d.c. or sinusoidal a.c. is applied 2 per cent audio frequency varied over the whole of the a.f. range, and a curve is drawn of hum output against this frequency; mains-frequency harmonics in the output are also noted, and tests are repeated with different levels of unmodulated carrier wave present, to show modulation hum.

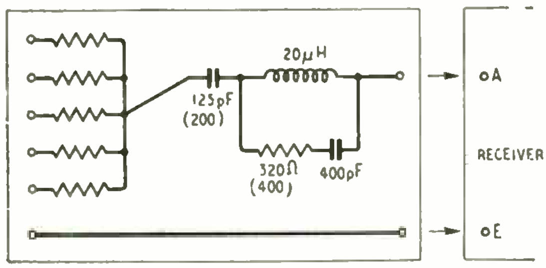
In contrast to the considerable amount of detail on these and other subjects, the methods of measuring harmonic distortion (total and individual) are dismissed in five lines, with no diagram. It might be expected that this brief treatment would provide room only for broad principles, so it is surprising to read that "During the measurement the loudspeaker has to be in its normal position."

The two common methods of intermodulation measurement are indicated, along with a note that disagreement among the principal workers in this field precludes rigid standards at the present time.

It is a pity that the wording of this international technical document should sometimes be so slipshod. For example, in Clause 21.3: "In the case of a loudspeaker for which the magnetic field is produced by a D.C. current, only the current in the speech coil should be considered for hum measurements." One might ask, what if the loudspeaker has not got a case? And, seeing that "D.C." presumably stands for "direct current," what is the significance of "D.C. current"? Wherever the words "the case of" occur (which they do frequently) the sense would be improved by striking them out. But these details apart, what exactly does this particular instruction mean? The French version fails to supply a clue, for this sentence is omitted from it! Unfortunately, badly expressed and ambiguous instructions are by no means rare.

Nevertheless, this publication does bring together a series of measurements well calculated to determine the practical capabilities of receivers within the terms of reference, with due regard (except, possibly, in the acoustic measurements) for what is reasonably practicable in equipment; and it is to be hoped that it will help to eliminate unnecessary differences in the basis of reckoning receiver performance. The fact that we have had to wait until now for an international recommendation on a.m. broadcast sound receivers emphasizes the need, as regards f.m. and vision receivers, for early and close collaboration between workers in all countries, so that differences can be eliminated before they have become too firmly rooted.

M. G. S.



The I.E.C. standard artificial outdoor aerial for 0.15-26.1 Mc/s differs from the American I.R.E. specification by two component values (I.R.E. values shown in brackets) and by the addition of five resistors for matching to one or two signal generators. Their values are such as always to bring the total generator output resistance to 80 Ω, regardless of whether one or two generators are in use.

* "Recommended Methods of Measurement on Receivers for Amplitude-Modulation Broadcast Transmissions" (First Edition). Central Office of the I.E.C., Geneva, Switzerland. 1954. Price: S.Fr.10.

† BS.2065 : 1954. See *Wireless World*, April 1954, p. 188.

Valves for Bands III, IV and V

Half Way Between Ordinary Electrode Structures and Disc-Seal Techniques

By D. N. CORFIELD* D.L.C., A.M.I.E.E

RECEIVING valves for Bands III, IV and V generally differ from those used in lower frequency bands because it is essential for the r.f., mixer and i.f. stages to give more gain in order to achieve a similar signal-to-noise ratio. Television receivers for Band I generally have an i.f. not exceeding 20 Mc/s, a pentode mixer and a single pentode r.f. stage, and a signal-to-noise ratio between 6 and 8 db is achieved in good designs. This figure may not be obtained, however, on all channels in Band I unless a modern type of r.f. pentode is used. Earlier types of r.f. pentode such as the 8D3, 6F12, Z77 and EF91 developed during the war have a single cathode connection, with the result that their input impedance is about 8.9 kΩ at 45 Mc/s but only 3.8 kΩ at 67 Mc/s. This value is below the critical damping necessary for the bandwidth required, so the gain is lower and the noise worse for Channel V than for Channel I.

Modern r.f. pentodes such as the 6BW7, 6BX6 and EF80 have two separate connections from the actual cathode to the circuit, one being used for the input circuit and the other for the output circuit. This avoids a common cathode impedance in both circuits (inductance of the single lead) which normally couples them together and has the effect of lowering the impedance of the input circuit. As a result of this technique the input impedance of the 6BW7, for example, is 18 kΩ at 45 Mc/s and 6.5 kΩ at 67 Mc/s. These figures are twice as high as those of the earlier types.

Current television receivers designed for use on both Bands I and III use a higher i.f., usually around 34-35 Mc/s, and the improved input impedance of modern r.f. pentodes is desirable here also. This is because it is not a good thing for the circuit damping (necessary for bandwidth requirements), to be provided wholly by the valve, since replacing a valve could change appreciably the i.f. response characteristics.

These points are mentioned because the use of multiple connections is a feature of valves designed for the higher frequencies, although such connections are not necessarily always to the cathode.

The front end of receivers for Bands I and III usually takes the form of a multiple-position tuner comprising an r.f. stage and a mixer/oscillator, the tuned circuits being switched by ganged switches and

* Standard Telephones and Cables.

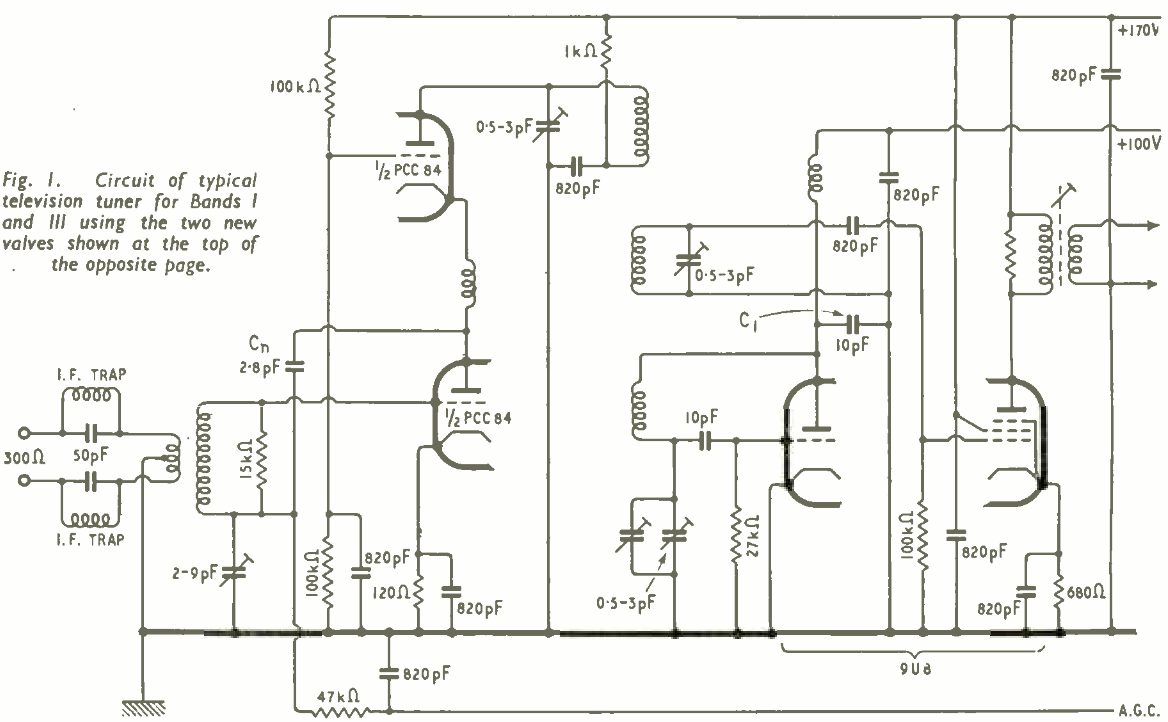


Fig. 1. Circuit of typical television tuner for Bands I and III using the two new valves shown at the top of the opposite page.

rotated on a turret. In order to conserve space and obtain improved performance new mixers have been designed, and these are generally triode pentodes. Typical examples are the 6U8/ECF82 and ECF80 with their a.c./d.c. versions 9U8/PCF82 and PCF80. These valves have much higher triode and pentode slopes than the types of triode pentode with which we are familiar. The 6U8, for example, has a triode slope of 8.5 mA/V and a pentode slope of 5.2 mA/V. The high triode slope ensures ready oscillation and the high pentode slope good conversion conductance as a mixer. Apart from the heater the two units are quite separate and this tends to reduce the possibility of oscillator radiation *via* the mixer portion.

The r.f. stage for such tuners does not use an r.f. pentode but a double triode in a "cascode" circuit. Triodes will always give lower noise than pentodes because of what is known as partition noise. The cathode current of a pentode comprises two portions, the anode current and the screen current, and both contribute to the noise but only the anode current to the useful signal. A pentode has, as a first approximation, three times the noise it would have if used connected as a triode. There are, of course, some snags in using triodes as r.f. amplifiers and they normally need to be neutralized in order to achieve stability. The cascode system is a trick which creates a stable circuit from two triodes.

Fig. 1 shows a typical tuner circuit for Bands I and III. The lower triode of the first valve is used with an earthed cathode and the upper one with an earthed grid. The lower section has a fairly high input impedance but gives little gain except for the step up in the input transformer because it is working into the cathode impedance of the other section, which is very low. This upper section gives quite a good gain and the overall result is a gain from the aerial input to the mixer grid of about ten times (23 db). There is often a small coil between the anode of the first triode and the cathode of the second one, and this is for peaking the frequency characteristic of the circuit above 200 Mc/s to improve the gain. A small neutralizing capacitor is connected from the anode of the first section to the series-tuned grid circuit; this is not primarily for the purpose of obtaining stability but for improving the signal-to-noise ratio. Valves suitable for this circuit are the PCC84/7AN7, 6BQ7A, 6BK7A and 6BZ7; these give a noise ratio of about 7 db.

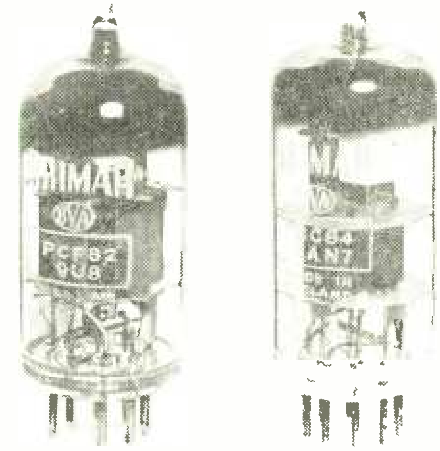
The mixer circuit is conventional except that a negative temperature-coefficient capacitor C_1 is required across the oscillator tuned circuit, otherwise the frequency drift is excessive. The maximum drift on Band III allowable in this country is rather less than in the U.S.A. and on the Continent because we use a.m. sound as against interchannel f.m. A proposed B.R.E.M.A. figure is 50 kc/s maximum.

Conventional British multi-channel tuners use very tiny coils for the circuits; some, in fact, are just straps across adjacent switch contacts. Their Q is, therefore, poor and so is the L/C ratio, the C being mainly valve capacitance and strays. As a result the frequency stability is not very good.

Oscillator Drift Problem

One possible approach to the oscillator drift problem is exemplified in a Band III to Band I convertor designed by the author. The oscillator uses a trough tuned line, electron-coupled oscillator fashion. The triode grid is tapped two-thirds of the way up the line and the cathode one-third of the way up, the heater lead being taken back inside the line. The two tuning capacitors, one variable (bandspread) and one fixed (bandset), are across the hot end of the line and the mixer is coupled to the oscillator cathode. Such a tuned circuit has a drift of 20 kc/s from cold and a drift of 100 c/s per volt for h.t. variations. Lines of this type need not be of any particular shape or size and can be bent, and if they are not required to be continuously tuned the capacitors can be switched in discrete steps. The author has used this type of tuned circuit for years in a receiver covering both the 2-metre amateur band and the 90-Mc/s f.m. band, and in fact it is not difficult to arrange this form of circuit to cover a frequency range of 3 to 1.

Valves for Bands IV and V require higher slopes and lower noise factors than for Band III. This can only be achieved by closer electrode spacings and



New valves for Band III television tuners. On the left the 9U8 PCF82 triode-pentode frequency changer and on the right the PCC84 7AN7 double-triode cascode r.f. amplifier.

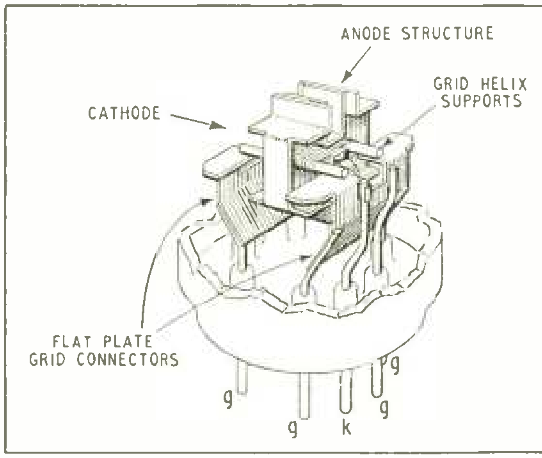


Fig. 2. Electrode structure of the 6AM4 triode, intended for earthed-grid operation up to 1000 Mc s. The grid is connected to five base pins (one not shown) through two flat metal sheets, which not only provide a low-inductance path to earth but shield the cathode and heater connectors from the anode. Flat strip is also used for the anode and cathode connectors.

multiple connections to the essential electrodes. An example of such a valve is the 6AM4 which is an earthed-grid r.f. amplifier or mixer for use up to 1,000 Mc/s. Since the common electrode is the grid this uses five separate grid connections. In order to reduce the lead inductance the structure is mounted horizontally right down on the glass base (see Fig. 2). The slope of the valve is 9.8 mA/V.

Table I gives some idea of the increased difficulties of manufacture resulting from attempting to obtain similar performance at higher and higher frequencies. A quite modern type, the 12AT7, is given for comparison purposes. The 6AM4 has a grid-cathode clearance of only one-thousandth of an inch and the grid is wound with 1¼-thou' wire with a gap of two thous between turns. The reduction of grid-cathode spacing is necessary in order to maintain the required value of mutual conductance, and the grid-anode spacing has to be similarly reduced to keep the amplification factor in proportion. More turns per inch and thinner wire on the grid helix are an outcome of the generally smaller electrode structure. The valve will give a noise factor of about 6 db as an r.f. amplifier in Band IV and about 9 db as a mixer, and Fig. 3 at the bottom of the page shows a circuit including both these applications.

The corresponding oscillator valve is the 6AF4, which has a slope of 6.6 mA/V. It has two grid connections and three anode connections, as it is normally used with the cathode choked and the grid or anode earthed. More expensive valves, because of their construction, are the disc-seal types also known as lighthouse, planar, pencil or rocket valves. The grid, anode and, in the case of tetrodes, screen grid are brought out to discs or rings which can be clamped into the circuit and thereby provide a continuous and therefore infinite number of connections. These give even better performances than normal valves but in their present form are unlikely to be used in Bands IV and V for domestic television.

Crystal Mixture

A type of mixer commonly used for these bands is the crystal mixer, the most popular being the silicon type although germanium ones are also available. These mixers are somewhat critical of heterodyne voltage and give a conversion loss of about 6 db. A convertor can be made for Band IV with a noise factor of about 7 db if considerable care is taken. This figure can only be achieved if the first stage of the i.f. amplifier has very low noise, and this is usually obtained by using a cascode or neutralized triode for the first i.f. stage. It is also essential that the heterodyne voltage is free from noise and spurious frequencies. Since the noise output from the crystal is proportional to the crystal current generated by the applied heterodyne voltage, the presence of anything other than the frequency required (± a few cycles ideally) merely increases the noise without improving the signal. This is one effect responsible for poor noise figures in crystal mixers, particularly when the oscillator is operating at harmonic frequency or is generated by a lower frequency crystal, but it can be reduced by the insertion of a sharp filter or high-Q break between the heterodyne source and the mixer.

On all high frequency bands care must be exercised in the coupling between stages, particularly that between the aerial feeders and the first stage, and it should be remembered that the coupling that gives the maximum gain rarely gives the best signal-to-noise ratio. The lowest noise is usually obtained when the coupling is tighter than that required for normal gain.

Mention was made earlier of the importance of a low-noise r.f. stage to reduce the effect of mixer noise, and here it is worth noting the effect on noise factor of adding r.f. stages in front of a receiver in Band IV. With a noise factor about 6 db in the receiver, the addition of a disc-seal pre-amplifier of 20 db gain reduces this to 3 db while a further pre-amplifier brings it down to 2 db.

This article is based on a lecture recently given by the author to the Television Society.

TABLE I.—CRITICAL DIMENSIONS IN U.H.F. AND V.H.F. TRIODES

Valve Type	grid-cathode clearance	grid-anode clearance	grid turns per in.	grid wire size
12AT7 (double triode)	0.003in	0.015in	156	0.002in
PCC84/7AN7 (double triode)	0.00275in	0.013in	147	0.0015in
6BQ7A (double triode)	0.002in	0.017in	200	0.001in
6AM4 (single triode)	0.001in	0.008in	295	0.00125in

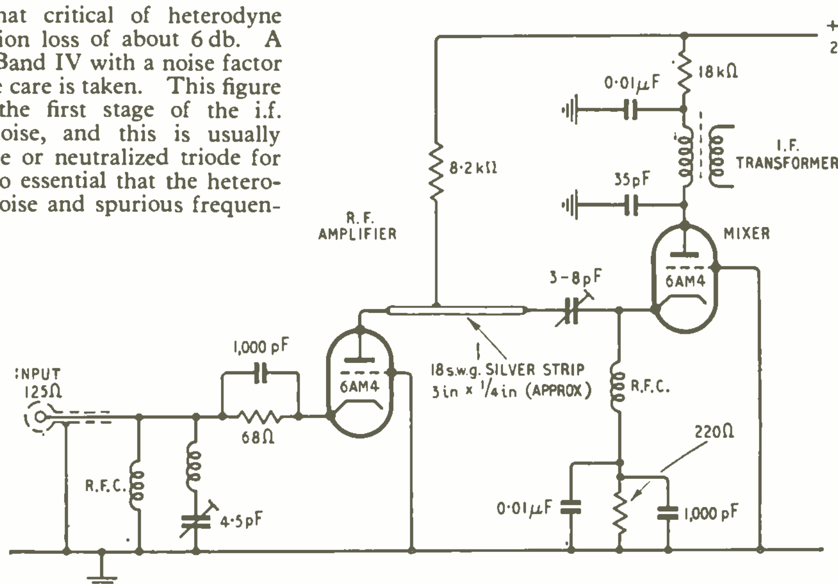


Fig. 3. The 6AM4 triode used as an r.f. amplifier and as a mixer in a Band IV receiving circuit (70 cm). The oscillator (not shown) is coupled inductively to the silver-strip line.

Piezoelectric Crystals

Survey of Physical Properties and Their Practical Exploitation

By S. KELLY*

BEFORE 1939 only two types of piezoelectric material were generally available; these were quartz and Rochelle sait. Quartz plates were used principally as resonators and oscillators, and Rochelle salt was the activating unit in crystal gramophone pickups. Since the end of the war an increasing number of piezoelectric materials have been made available, usually accompanied by cryptic initials which often mean less than nothing to the practising radio engineer unacquainted with chemical jargon; and he should not be blamed for misconceptions, especially when the various claims for different types of crystals appear to be mutually contradictory. Most of these new crystals have been developed with specific engineering applications in view and can be divided into two major classes: (a) as resonators, (b) as electro-mechanical transducers.

The underlying physical principle of these two types of crystal is identical, and the differences are of degree and application rather than fundamental. It is the purpose of this article to try to sort the sheep from the goats and at the same time establish some form of pedigree of the crystals used as electro-mechanical transducers, in particular those which are used in the manufacture of gramophone pickups.

Crystal Materials.—Quartz is still the major source of plates for precise control of frequency. It is interesting to note that bimorph† construction, at present extensively used on electro-mechanical crystal devices, was first introduced by the Curie brothers in their classic investigation of the piezoelectricity of quartz about 1880.[1]

Tourmaline is at present of little more than academic interest, although it has been used as a sub-standard for pressure calibration of microphones.

Ethylene diamine tartrate (E.D.T.) and dipotassium tartrate (D.K.T.) are used as resonators in crystal filters for carrier telephone systems. Their stability is sufficient for this application, and it is possible that they may replace quartz.

Lithium sulphate (L.H.) is used principally as a volume expander in high-frequency (ultrasonic) applications, but is largely being supplanted by ammonium dihydrogen phosphate (A.D.P.). Apart from A.D.P., none of the foregoing crystals finds any commercial use as transducers in gramophone pickups or microphones.

There are, therefore, only three general types of crystal available for use in commercial transducers. These are:—

(a) Sodium potassium tartrate (Rochelle salt),
(b) Ammonium dihydrogen phosphate (A.D.P.),
(c) Polycrystalline barium titanate (Ceramics).

There is a fundamental difference between the first two crystals and the third in that the former are single crystals grown from a solution, whereas the latter is an aggregate of micro-crystals sintered to shape. By virtue of the asymmetry of the basic crystal structure a voltage will be generated across two electrodes of a correctly oriented slab when a force is applied to it (usually but not always perpendicular to the faces which are furnished with electrodes). In the case of barium titanate ceramics in which the crystals are completely randomly oriented, the charges on the individual micro-crystals will cancel. By subjecting the fired and "electroded" slab to a high potential gradient the domains of favourably oriented micro-crystals grow at the expense of the others, and ultimately approximately 7 to 10 per cent of the domains are aligned in the correct direction.

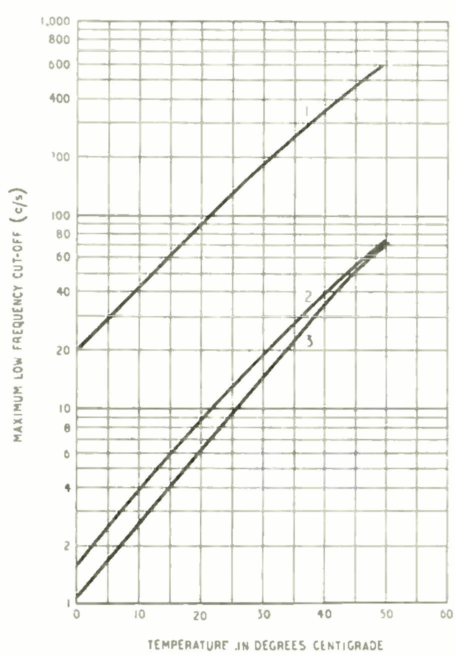


Fig. 1. Variation in low-frequency cut-off due to change of conductance with temperature in three grades of ammonium dihydrogen phosphate.

A.D.P.—Ammonium dihydrogen phosphate was developed at the beginning of the war to meet the need for high-power under-water transducers. It has a higher voltage sensitivity ("*g*" coefficient, discussed later) than Rochelle salt, but a very low dielectric constant, with the result that most A.D.P. crystal units are designed to work into a 5-MΩ load. This high value of load resistance can be reduced to a value of 1 MΩ and still maintain a satisfactory low-frequency

* Cosmocord, Ltd.

† A bimorph is essentially a mechanical transformer, consisting of two slabs of crystal material cemented together, with electrodes connected so that one element expands (for a bender type of crystal) or shears (for a torsional type) in one direction, while the other element contracts or shears in the opposite direction. The amplification of movement is $(L/T)^2$ where L is the length and T the thickness of the bimorph.

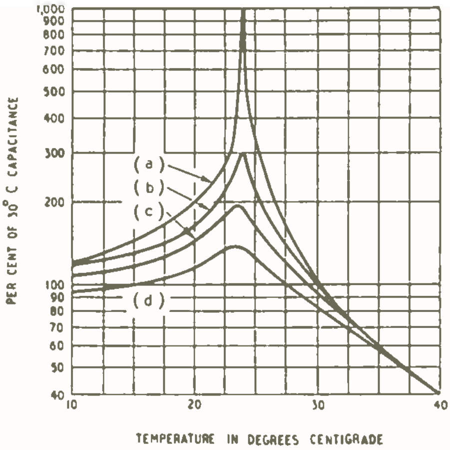


Fig. 2. Change of capacitance in Rochelle salt element with temperature. (a) X-cut plate, no restraint ; (b) torque bimorph, no restraint ; (c) bimorph mounted in pickup ; (d) bimorph set in casting resin.

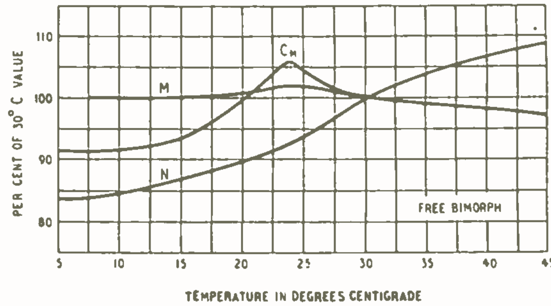


Fig. 3. Variation with temperature of effective mass (M), compliance (Cm) and the equivalent mechanical-electrical transformation ratio (N) in a free bimorph of Rochelle salt.

response by shunting the pickup with a condenser of about four times the crystal capacitance; but the voltage sensitivity of the pickup will also be reduced by the same factor (×4). The capacitance is quite stable with temperature and pickups have successfully withstood the test of immersion in boiling water for half an hour with no apparent deterioration in performance.

There is, however, a snag! At frequencies below resonance, the crystal transducer behaves as a generator in series with a capacitance terminated with a resistance. In the case of Rochelle salt and barium titanate the conductance, G, is sufficiently small for it to be neglected, but in the case of A.D.P. the value is relatively high and variable, being a function of the purity of the crystal and the temperature. It is usual to express this conductance in terms of the low-frequency cut-off rather than an absolute value, and the cut-off frequency is that at which $G=\omega C$. This is the familiar −3 db point on RC-coupled amplifiers.

The graph, Fig. 1, shows the variation of low-frequency cut-off (−3 db point) with temperature for three different grades of A.D.P. These curves are taken under open circuit conditions and because of this disability and the low dielectric constant, A.D.P. is not often used as a transducer in pickups.

Rochelle Salt.—This compound has the highest electro-mechanical coupling coefficient of any commercially available piezoelectric material. It has a reasonably high dielectric constant, a low density and a fairly low Young's modulus, all of which combine, as we shall see later, to make a highly efficient wide-frequency-range bimorph. The capacitance versus temperature anomaly which occurs at the Curie point of 23.8 deg C can be a nuisance for some applications, but is not very important for gramophone pickups. Fig. 2 shows the variation of capacitance with temperature for Rochelle salt under four conditions; curve (a) is for a single shear plate, as cut from the virgin crystal, with no restraint, (b) is for a torsional type bimorph, again with no restraint, and curve (c) is the same crystal fitted into a gramophone pickup with correctly applied viscous damping and restraining members, and curve (d) is with the crystal firmly clamped. In the latter case the crystal was cast in a block of cold-setting Araldite "D" of approximately 1 inch cube. The above graph shows that the effect of the capacitance anomaly is strictly a function of the conditions under which the crystal is used.

Fig. 3 shows the variation of the other constants with temperature; M is the effective mass, C_m compliance, and N the transducer ratio, all referred to 30 deg C. Except at very low frequencies the load impedance is considerably greater than the crystal impedance. The average value of the crystal used in present-day gramophone pickups is 1,500 ρF at 80 deg F (27.5 deg C) and this corresponds to a capacitive reactance of about 1 MΩ at 100 c/s. The crystal capacitance will be greater than nominal between 55 deg F (14 deg C) and 80 deg F, and the variation of low-frequency performance will be within 3 db over this temperature range.

Humidity does not present any serious problem with present-day commercially available pickups, although a limiting temperature of 45 deg C is imposed from practical considerations. At a temperature greater than 55 deg C the Rochelle salt will disintegrate in its own water of crystallization. The life of a crystal at 45 deg C can be considered infinite. At 55 deg C it is of the order of 18 months, at 60 deg C it is about 14 days and at 65 deg C it is about 30 minutes. The above figures were taken with normal production crystals fitted into hermetically sealed production type pickups. The ultimate life of a Rochelle salt pickup under normal used conditions is determined by the care and control exercised in the initial fabrication of the crystal to the point when it is hermetically sealed. If the crystal is not hermetically sealed, the life is only a few hours under humidity conditions of 95 to 99 per cent relative humidity and if the crystal contains any excess moisture at the time of sealing, its life will be reduced. Normally, in the crystal fabrication shops, temperature and humidity are controlled at 21 ± 1 deg C, 45 ± 2 per cent r.h. Under these conditions plain unprotected crystals can be stored indefinitely. Fig. 4 shows the relation between temperature and humidity for onset of dehydration, and beginning of solution, these being determined by (1) the point at which dehydration can be observed after 168 hours subjected to the conditions shown in the graph, and (2) in which the insulation resistance drops below 10,000 MΩ under the conditions specified. These curves are for unprotected, uncoated crystals.

Barium Titanate.—All the foregoing crystals (including quartz) can be grown from solution under carefully controlled conditions at temperatures between 25 deg C and 400 deg C, according to the type of crystal.[3] The melting point of barium titanate is of the order of 1,500 deg C, and to the present date it has not been possible to grow pure barium titanate monocrystals larger than 1 or 2 mm side in commercial quantities. Barium titanate elements are, therefore, produced by a sintering process in which the carefully prepared primary materials (usually barium carbonate and titanium dioxide), together with various admixtures, are either slip-cast as in traditional pottery manufacture or mixed with a binder such as Bentonite and pressed to form on a tableting machine. The "green" slab is then fired in a sintering furnace at a controlled temperature which results in the material becoming a homogeneous solid mass. The consistency of the barium titanate at the sintering temperature is little stiffer than jam, and unless care is taken considerable distortion usually takes place especially if elements are of large area, unsupported, or of thin cross-section: the shrinkage is large and where precise dimensions of the finished product are required the fired slabs must be ground to size. (Part of the secret of successful manufacture of barium titanate is in obtaining the correct temperature for the correct length of time, the rest being careful chemical control, applied force and classic learning.) The resultant slab is an aggregate of micro-crystals of barium titanate randomly oriented. Whilst each individual crystal is piezoelectric they mutually cancel and the material behaves as a dielectric of high permittivity, but if the plate is subjected to a high unidirectional potential gradient for a period and this potential is then removed, the material will appear to be piezoelectric, and the magnitude of this phenomenon will be a function of the polarizing potential gradient and time.

Fig. 5 shows the variation of coupling coefficient versus polarizing potential gradient for pure barium titanate when applied for about 1 hour at room temperature, the polarizing voltage may be reduced to about half of this value if applied at just above the Curie temperature (about 120 deg C) and allowed to cool to lower than 50 deg C with the potential still applied: but it is usual to apply the maximum field consistent with the elements not breaking down during the polarizing process.

Above the Curie temperature (120 deg C) the crystal has a cubic form, the eight corners of the cube being barium atoms (each barium atom is shared between eight adjacent cells). One oxygen atom occupies the centre of each of the six sides, and since each is shared with the adjacent cell there are three oxygen atoms. The titanium atom is in the centre of the cell and is relatively free to move within it. It will normally be in a "potential well" adjacent to one or other of the oxygen atoms, but if the thermal energy is sufficient it may jump from the neutral position of one oxygen atom to any of the other five in a completely random manner. At temperatures below 120 deg C, the titanium atom will move permanently towards one of the oxygen atoms, the cell will assume tetragonal form (actually the length will increase by about 1 per cent in the direction of the titanium atom movement). If the titanium atoms in sufficient adjacent cells are locked in the same direction a domain will be formed and will be ferro-electric. The crystals (and therefore the domains) are randomly oriented in the sintered aggregate and no residual polarization will occur, application of a unidirectional bias will result in more and more domains aligning themselves in the direction of the electrical field as it is increased. At maximum field strength (just below the breakdown point) about 10 per cent of the domains are aligned in the direction of the field, and the plate has expanded by about 6 parts in 10,000 in that direction. On removal of the polarizing field it will be found that the majority of the domains remain aligned in the preferred direction.

Application of alternating potential to the plate will cause it to alternatively expand and contract, the absolute value of this mechanical variation being proportional to the applied voltage. The mechanical movement is probably caused by the growth and contraction in the preferred direction of the aligned domains at the expense of their neighbours, rather than any reversal in the domains themselves. The mechanical strain is quite considerable and can be well in excess of the elastic strength of the material. It is interesting to note that crystals firmly cemented (with a thermo-setting resin) to a heavy metal support and then polarized inevitably shatter when the polarizing field exceeds about 20-25 volts per 0.001in.

Various additions are made to the pure barium titanium oxide to improve its properties. The addition of strontium will reduce the Curie point, whilst the addition of lead will increase it. One particular artifice is to add zirconium, which increases the low-temperature transition point to a limit of approximately 45 deg C and which will give an enhanced "*g*" coefficient. This can be very important to gramophone pickup manufacturers, because it will result in a

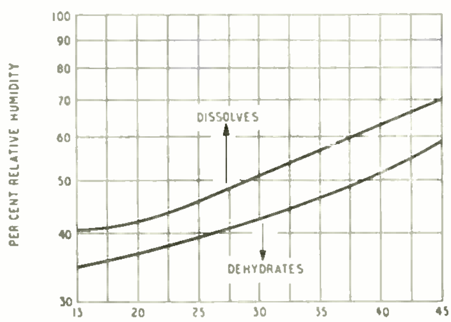


Fig. 4. Temperature and humidity in relation to the onset of dehydration and solution in Rochelle salt.

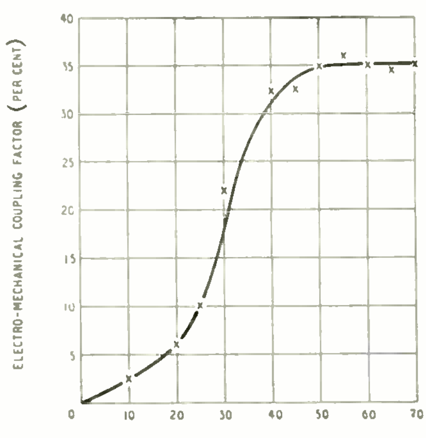


Fig. 5. Relation between potential gradient of polarization and electro-mechanical coupling factor in barium titanate.

sensitivity gain of approximately 3 db at temperatures below 45 deg C, but if the crystal is subjected to temperatures above this limit the coupling will revert to the lower value.

As stated before, the asymmetry of barium titanate disappears above the upper Curie point (about 120 deg C) and if a pre-polarized barium titanate aggregate is subjected to temperatures above about 80 deg C it will tend to lose its polarization. It has been found that minor quantities of impurities adversely affect the life of barium titanate, in some cases reducing the sensitivity by 50 per cent in a matter of weeks or months; the effect is quite unpredictable and to eliminate it requires most careful chemical control. The addition of lead or calcium has the effect of "locking" the domains so that the stability of the crystal is considerably improved, especially when used as a driver. The manufacturers will usually guarantee the sensitivity of the element to deteriorate by not more than 10 per cent over a period of one year.

The maximum coupling coefficient figures for pure barium titanate of 0.35 measured under laboratory conditions are not realized in practice, a value of about 0.2 being usual. This is due to two causes: (a) an admixture of lead or calcium, and (b) either by reversed polarizing or subjecting the crystal to elevated temperature for a short while, in order to stabilize the element. Fig. 6 shows the temperature dependence of barium titanate. The anomaly at about +5 deg C shows up as a hysteresis loop of the dielectric constant, dissipation factor and voltage output ("*g*" coefficient). It will be seen from the middle curve that if the unit is polarized at a temperature lower than the discontinuity (Y) and the temperature is increased, the "*g*" coefficient will decrease to some value, and then if the temperature is reduced below the discontinuity point the lower value of "*g*" will be obtained (Z). The addition of zirconium will increase the temperature of discontinuity to a maximum of approximately 45 deg C, whilst the addition of lead will reduce it to about −20 deg C. Calcium will reduce the discontinuity temperature to still lower values.

Unlike Rochelle salt and A.D.P., ceramic bimorphs at present available are in bender form only. The coupling coefficient (and hence the conversion efficiency) is much lower than Rochelle salt and A.D.P. but barium titanate has the advantages of a higher working temperature than Rochelle salt, a high permittivity (about five times that of Rochelle salt and 100 times A.D.P.) resulting in a lower electrical impedance than other crystals for a given size of plate, and a stable capacitance temperature performance together with improved humidity resistance characteristic. It is not by itself completely proof against humidity, in that the insulation resistance of the bimorph will be reduced under conditions of high humidity due to absorption of water vapour, although the crystal can easily be dried out.

Crystal Coefficients.—Crystals are anisotropic, that is the various electrical and mechanical properties are different in different directions of the crystal and are not constant in all directions as are those of isotropic materials. Of the 32 known crystal classes, 20 will show piezoelectric effects (which are due to lack of symmetry of the crystal), and depending on the crystal asymmetry they may have from 3-21 elastic constants, 0-18 piezoelectric constants, and 1-6 dielectric constants.[1] Crystallographers refer these constants to the X, Y, and Z rectangular axes, and where crystals are cut at oblique axes (for instance, zero temperature coefficient cuts of quartz, etc.) transformation equations have been evolved by means of which the new constants can be calculated in terms of the standard constants.[1]

TABLE 1

Comparative Table of Electromechanical Materials

Crystal and Mode	Strain out / Field in d	Dielectric Constant[1] κ	Field out / Stress in g	Elastic Modulus Y	Coupling Coefficient $k=\sqrt{d.g.Y}$	Specific Gravity	Frequency Constant[2] $\sqrt{Y/4\rho}$	Maximum operating temp. °C.
Rochelle salt (30°C.)								45
X-cut expander	165	200	0.093	31.0	0.69	1.77	2100	
Y-cut expander	27	9.2	0.33	10.0	0.30	1.77	1180	
A.D.P.								120
Expander	24	15.3	0.177	19.3	0.29	1.80	1630	
Quartz								550
Expander and thickness	2.3	4.5	0.058	80	0.10	2.65	2700	
Lithium sulphate								75
Thickness	16.0	10.3	0.175	46	0.36	2.06	2360	
D.K.T.								110
Expander	11.0	6.5	0.192	25	0.23	1.99	1770	
E.D.T.								100
XY-cut expander	11.3	8.2	0.156	26	0.22	1.53	2050	
Tourmaline								1000
Thickness	1.93	6.6	0.033	160	0.10	3.1	3600	
Barium titanate								100
Thickness	190	1700	0.0125	110	0.56	5.7	2200	
Expander	78	1700	0.0052	110	0.22	5.7	2250	
Multipliers—								
M.K.S.	10^{-12}m/V		V.m / Newton	10^9 Newton / m²			c/s. m.	
c.g.s.	10^{-10}cm/V		V.cm. 10^{-3} / dyne	10^{10} dyne / cm²			kc/s. cm / 10	

[1] Relative to vacuum.

[2] The density ρ should be given in kg/m³ in the M.K.S. system and is obtained by multiplying the specific gravity by 1000. The frequency constant is then obtained in c/s. m = kc/s. mm.

Note: Expander units are used for making bimorphs.

The various constants have now been more or less standardized and are shown on Table 1, which lists the major piezoelectric crystals currently available for commercial use. This table relates only to expander modes, expansion and compression of crystal elements taking place either parallel or at right angles to the applied electric fields, and covers only the more useful expander modes of these crystals.

The dielectric, piezoelectric and elastic constants are interrelated and are given below; in order to prevent misunderstanding of the terms "stress" and "strain," the following definition is used in this article:—

When a solid body is in equilibrium under a given system of externally impressed forces, its state of deformation is called a "strain," while the forces, which necessarily occur in equal and opposite pairs, give rise to a "stress."

"d" Coefficient, Column 1.—This expresses the strain obtained for an applied electric field strength and practically is the ratio of expansion of the plate for the voltage applied. The direction of the expansion (i.e., a contraction is a negative expansion) is directly dependent on the sign of the applied field. It is usually in a direction perpendicular to the applied field although in special cuts such as the "L" cut in Rochelle salt it can be parallel to it. This condition holds whether the applied voltage is direct or alternating. The instantaneous increase in length of the crystal will be directly proportional to the instantaneous applied voltage. In the case of ferro-electric crystals such as Rochelle salt at temperatures between the Curie points of −18 deg C and +23.8 deg C, and barium titanate, it is not strictly true because of the phenomenon of ferro-electric hysteresis, but for a practical application, especially at low field strengths, this can be neglected.

Permittivity (Dielectric Constant) κ, *Column* 2 is the dielectric constant referred to a vacuum, and is independent of the intensity of the electric fields normally encountered, except in the case of Rochelle salt between the Curie points of −18 deg C and +23.8 deg C where the material is ferro-electric and is voltage sensitive. The Rochelle salt values given are for weak fields and are applicable where the crystal is used as a voltage generator such as a gramophone pickup or microphone.

"g" Coefficient, Column 3. This coefficient represents the open circuit voltage per unit applied force. If a unit step function of force is applied the instantaneous voltage developed will be proportional to this force, but this voltage will then decrease in an exponential manner, with time, dependent on the leakage resistance across the terminals and the capacity of the crystal (see Fig. 7). As a matter of interest, under conditions of very low humidity and extreme care being taken with the insulation and mounting of the crystal, Rochelle salt bimorphs have still shown 60 per cent of their peak voltage several minutes after the step function has been applied. When an alternating force is applied, the instantaneous open circuit voltage is proportional to the instantaneous applied force. This is one of the most important coefficients in the design of transducers, because it specifies the maximum available voltage under known working conditions.

In the case of a gramophone pickup the maximum available force is of the order of a 5×10^{-2} Newtons and for a microphone is usually about 10^{-5} Newtons (a Newton is 10^{5} dynes). This constant thus gives a direct comparison of the voltage sensitivity of the various materials, always assuming, of course, that the plates of the various materials being compared are identical in size.

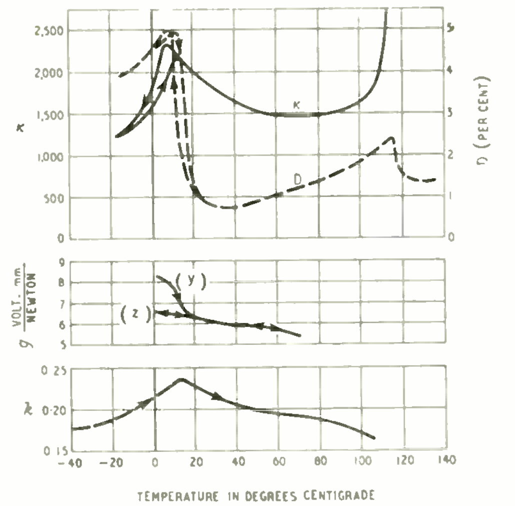


Fig. 6. Temperature dependence in barium titanate of dielectric constant (κ), dissipation factor(D), voltage output coefficient (g) and electro-mechanical coupling coefficient (k).

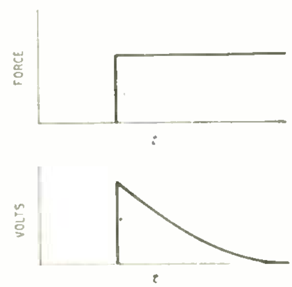


Fig. 7. The voltage developed by a step function of force will decay due to the finite resistance of the crystal.

Young's Modulus, Column 4. This is for the particular crystal cut stated. It is an important coefficient because it will decide the low-frequency impedance of the final crystal unit, in general a low value of Y is preferred.

Coupling Coefficient k, Column 5. By definition, a transducer is a converter of one form of energy to another and in the case of crystals the two forms of energy are electrical and mechanical. The electrical constants of the crystal will therefore be a function of the mechanical loading applied to it and *vice versa*. For example, if the crystal is firmly clamped so that it cannot possibly move and the dielectric constant of the crystal is measured, one obtains the minimum electrical capacitance of the crystal. If the tightness of the clamp is reduced some additional energy will be stored in mechanical form and the measured dielectric constant will have increased. Ultimately, where the crystal is completely free to move, the maximum quantity of mechanical energy will be stored and this is commonly called the free dielectric constant. The ratio of the clamped and free dielectric constants is determined by the coupling coefficient *k;* it is defined as the square root of the ratio of total energy stored in mechanical form to the total electrical energy absorbed by the crystal. The following equation gives the rela-

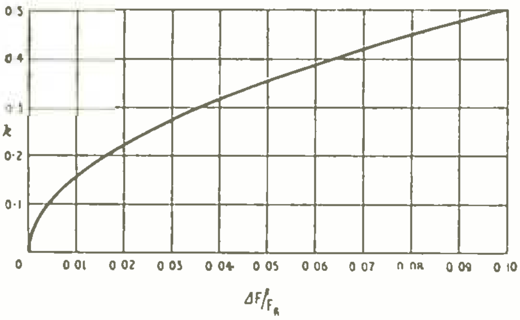


Fig. 8. Derivation of coupling coefficient from the relationship of the resonant frequencies of the freely suspended crystal.

tions where the values d, κ and Y are as defined above:—

$$k = \sqrt{\frac{\frac{d}{\kappa}}{4\pi Y}}$$

An alternative way of obtaining the coupling coefficient is:—

$$k = \sqrt{d.g.Y}$$

The simplest method of measuring this parameter is by measuring the resonant and anti-resonant frequencies of the crystal; and the relation between the coupling coefficient and these frequencies with an accuracy sufficient for practical purposes is:—

$$k = 1.58\sqrt{\frac{\Delta F}{F_R}}$$

where F is the resonant frequency and ΔF is the difference between the resonant and anti-resonant frequencies. The graph of Fig. 8 plots this equation. Several precautions must be taken during the measurements. The crystal must be freely suspended, preferably at its nodal point and the source impedance of the electrical generator must be extremely high and preferably resistive in order that electrical loading effects be reduced to negligible proportions.

When comparing the "goodness" of two different crystal materials, this coefficient is usually the first to be considered. In the case of barium titanate, the final efficiency of the product is controlled to a large extent by the manufacturing processes rather than an inherent quality of the crystal, as in classic crystals such as Rochelle salt or quartz, and the coupling coefficient is the parameter often used for quality control of the various production processes.

Columns 6 and 7 show the density and the frequency constants, whilst Column 8 is the maximum operating temperature. The frequency constant relates the resonant frequency and length of the freely suspended crystal when in longitudinal vibration.

As before stated, the table relates to single plate units, but for pickup engineering applications the mechanical impedence of these plates is too great; the bimorph construction is usually used in order to achieve reasonably low working mechanical impedances.

(To be concluded)

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[1] "Oeuvres de Pierre Curie." Gautier-Villars (Paris) (1908), pp. 200-205.

[2] "Piezoelectric Crystals and their Application to Ultrasonics." W. P. Mason (van Nostrand), pp. 165-189.

[3] "Crystal Growth." H. E. Buckley (Chapman and Hall), pp. 43-71.

[4] "Piezoelectricity." W. G. Cady (McGraw Hill), pp. 17-21.

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[6] "The M.K.S. System of Units." T. McGreevy (Pitman.)

SMALL-CRAFT RADIO

The converted 60-ft lifeboat "Aries," which, with a crew of four, is making a double crossing of the Atlantic, has been fitted with Admiralty-type communication equipment. Sub. Lt. E. Skelton, R.N.V.W.R. (G3JOQ), is shown in this Wireless World photograph at the controls of the 15-W m.f. (330-550 kc/s) section of the Type 619 transmitter. The 40-watt h.f. section (1.5-16 Mc/s) is on the right and in the centre is the receiver, Type CAT, which covers 60 kc/s to 32 Mc/s in eight steps. The power pack is under the desk. The installation was carried out by Rees Mace who also fitted a Pye PTC117 a.m. radio-telephone transmitter-receiver operating on 121.5 Mc/s in the wheelhouse for communication with aircraft.

LETTERS TO THE EDITOR

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

Relaxation Oscillators

IT is pointed out to me by W. T. Cocking that I was in error in saying that a certain dynatron characteristic had d.c. negative resistance.* He reminds me that d.c. resistance can only be negative when the ratio of applied direct voltage to direct current is negative, as it can be in those dynatrons whose anode current is negative over a certain range of anode voltage (but not in the example I showed). Over this range of negative current, the a.c. resistance is first negative and then positive, and if the valve is operated in the positive-a.c. negative-d.c. region it delivers d.c. power to the load and anode-voltage source.

I entirely agree that this is the only strictly correct interpretation of "d.c. negative resistance," and it seems that I myself was caught in one of the meshes of the trap I have so often warned others about—the anomalous terms with which our craft is littered. As a sop to common usage (or perhaps through sheer forgetfulness!) I wrote "d.c." when I ought to have stuck to my principles and made it "z.f." Appeasement is a rotten policy!

The distinction I was trying to show between the dynatron and most other negative-resistance devices (transitron, back-coupled valves, etc.) is analogous to that between "d.c. amplifiers" and "a.c. amplifiers." "A.c. amplifiers" have reactive couplings which prevent them from holding indefinitely a changed steady output current or voltage caused by a similar but smaller change at the input. Transitrons and back-coupled valves likewise have reactive couplings that prevent a positive increase in steady potential from causing a steady negative increase in current. The negative resistance of a dynatron, on the other hand, is analogous to the amplification of a "d.c. amplifier." In the same way that my expression "d.c. negative resistance" was wrong, so is everybody's "d.c. amplifier." Apart from the fact that most so-called d.c. amplifiers are not *current* amplifiers at all, the ratio of steady output current (or voltage) to input is, in general, not equal to the amplification.

Even if no one was actually misled by my common but wrong use of "d.c.," I ought to have called the peculiar dynatron characteristic "z.f. a.c. negative resistance"—to signify a.c. negative resistance at frequency indefinitely close to zero. I hope that would satisfy even the rigorous mathematicians!

E. F. Good raises an objection to the last paragraph of the same article, in which I included sinusoidal RC oscillators in the relaxation category. While sharing with him and apparently other readers a feeling that this is not quite right, I am unrepentant. First, because in this matter I was following B. van der Pol, whom one would hesitate to contradict on the subject of relaxation oscillators; and, secondly, because if one denies that RC sinusoidal oscillators are relaxation oscillators one is faced with the awkward obligation of specifying precisely when they turn into relaxation oscillators as the negative feedback is progressively increased.

"CATHODE RAY."

* "Relaxation Oscillators," *Wireless World*, April, 1954, p. 195.

Marine V.H.F. Telephony

WITH reference to your Editorial in the February issue of *Wireless World*, may I call your attention to a letter written by me to the Editor of *Wireless Engineer* and published in October, 1940, on the use of double modulation on v.h.f. transmissions?

I suggest that it should be fairly simple to provide for marine v.h.f. transmitters to be modulated either in the f.m. or a.m. mode as required, and many receivers are now available which can be switched to receive either f.m. or a.m. as required.

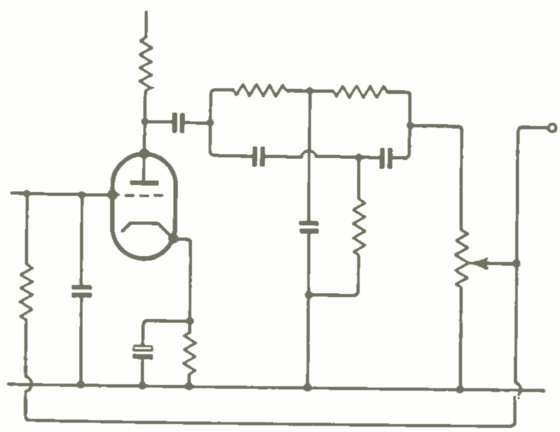
It is interesting to note that this double-modulation method of providing stereophonic or binaural broadcasting is now being used in the U.S.A., as reported in *Electronics*, February, 1954, issue.

I am rather surprised that the B.B.C. has not made use of this method to permit either binaural transmission from the Wrotham station or to enable receivers capable of receiving on a.m. only to sample the advantage of v.h.f. broadcasting.

Port Moresby, Papua. W. C. GEE.

Williamson Tone Compensating Unit

JOHN J. CLARK suggests (April issue, p. 177) that the slope can be varied by adjusting the loop gain, but as C. Robinson points out (May issue, p. 224), the suggested modification will affect the overall gain of the



amplifier. One way to overcome this defect is to take the output from the potentiometer tap, so that the proportion of the output fed back to the input remains constant, whilst the gain within the loop varies. This gives a constant overall gain for most settings of the potentiometer, but varies the rate at which the gain falls off near the "cut-off point."

Whitton, Middx. G. A. ASKEW

Undecoupled?

WHY should L. Bainbridge-Bell (May issue) pick on "decoupling to" for his criticism? There are hundreds of other equally offensive (to the grammarian) terms in the electronics world, let alone in others. He also infers that "decoupling to cathode" is somehow worse (grammatically) than "decoupling to earth." Indeed, if we have an h.t. supply of zero a.c. impedance, we could profitably decouple a screen-grid h.t. supply to h.t.!

The difference between "couple" and "decouple" is simply one of purpose. A coupling capacitor (*sic*; no steam engines in my equipment!) does not *remove* a.c. fluctuations from an anode, whereas a decoupling capacitor would (since we always make our measurements with respect to earth). Does Mr. Bainbridge-Bell's "grid leak" allow the inside of his valve to spill all over the chassis? What memorandum about gramophones does a "gramophone record" contain? Would a "four-stroke" make a cat purr?

On another topic, with regard to "Cathode Ray's" helpful suggestions concerning baby alarms; why trouble the poor baby-sitter all the time. For most of the infant's needs, a "tele-film," shown on a screen near the cot, to be triggered by the baby-cry-analyser, of the infant's mother making suitable goo-goo noises is all that is needed. Only for very urgent needs would the baby-sitter's viewing be disturbed at all.

Cambridge. KEITH A. M. HARDISTY.

Plug-and-Socketry

MAY an overseas reader express an unavoidably delayed opinion on the article by C. Lister in your February issue? Party No. 1 seems to have the better system of names. The fact that the pins of some chassis or panel mounting plugs are recessed out of harm's way does not turn such plugs into sockets. The pins of others are not recessed and the mating cord socket remains wholly outside the panel when contact is made. Surely Mr. Lister has forgotten that household necessity, the "long cord," which comes out when an appliance is to be used at some distance from the nearest wall socket. In this case Party No. 2 would have a plug fitting into a plug. If Mr. Lister dislikes "*n*-pin plug" he could always say "*n*-contact plug," but one feels that objection to the former on the grounds of redundancy is rather like being horrified at every split infinitive.

Mr. Lister has my warm approval, however, in ventilating this matter. Though only an occasional buyer, I am often irritated at the inadequate or misleading descriptions of their wares given by some of your advertisers. One employs the term "motor" in two senses, (a) motor only, and (b) motor plus turntable, in the same advertisement. Again, if a meter or fuse-holder is not panel mounting, should it be allowed to hang freely from the chassis at the ends of its leads? "Surface mounting" or "flush mounting" gets rid of that uncertainty which is the real gravamen of my reproach. There is no way of knowing how many actual or potential customers in this country are affected but, doubtless, few would notice the redundancies were it not for the three weeks' wait and half-crown that it costs to find out by air mail what the advertiser really means. Manufacturers' catalogues are not always helpful even when they are available.

Dunedin, New Zealand. S. G. EMSLIE.

Television Convertors

THE Band III convertor described by G. H. Russell in your May issue offers an attractive solution to the conversion problem, but it seems doubtful if such a simple device could give an adequate performance in most areas. No amount of filtering in the convertor could cut out direct pick-up of a strong Band I signal by a sensitive receiver tuned to it, unless the receiver were very well screened. Few commercial sets are, and patterns due to beating between carriers would be inevitable.

Furthermore, with two local oscillators running, one in the convertor and one in the set, an almost infinite number of beats can be found to exist between their harmonics, sufficiently close to the carrier in Band III, Band I or the i.f., to cause patterning.

Oscillator stability is a big problem in Band III frequency changers, and if the two oscillator drift errors add, which is not unlikely, very poor tuning stability would result.

A far less hazardous conversion would be to change the Band III signal straight down to the receiver i.f. and to link-couple it into the first i.f. transformer of the i.f. strip, switching from Band I to Band III simply by switching the h.t. from one "front end" to the other. Some adjustment of the tuning of this transformer would be necessary to restore the i.f. curve to its original shape, but this should not prove difficult.

Salford, Lancs. R. WARD.

Die Castings

I WAS very interested to read your account of the B.S.I. Certification Scheme for zinc alloy die castings which appeared in the April issue. This scheme should encourage the wider use of high-quality die castings in industries such as your own.

Your comparison between zinc alloy die castings and cast iron may, however, give your readers a wrong impression, since the tables published in BS1004 give figures for the tensile strength of zinc alloy die cast test pieces ranging from 16 to 20 tons per square inch. These figures compare more than favourably with the average tensile strengths of ordinary iron castings, which range from 10 to 12 tons per square inch.

The value of zinc alloy die castings lies not only in the high strength of the material, but in the intricate shapes which can be mass-produced with high dimensional accuracy. The new Licence Scheme will no doubt encourage many manufacturers in the telecommunications industry to make further use of certified zinc alloy die castings.

RONALD W. BAILEY,
Oxford. Zinc Alloy Die Casters Association.

"Cascode"

THE recently developed series-connected twin-triode r.f. amplifier which, with the advent of Band III frequencies has a particular application in television receivers, is repeatedly referred to, in and out of the literature, as a cascode circuit. This confuses with the original cascode circuit by Wallman, which used parallel-connected triodes to h.t.

The new circuit affords a distinct advantage to the original by the extended grid base obtained by series connection, minimizing cross-modulation of the vision and accompanying sound signals. Also the original cascode employed a frequency-selective neutralizing circuit, whereas the grounded cathode triode of the series-connected amplifier generally includes a neutralizing capacitive bridge, with balance independent of frequency.

These differences would indicate the need for a more positive identification of the new circuit. "Extended Base Cascode" would identify one merit, but does not embrace the second.

The American 6BQ7 when used similarly is identified as a "Driven Grounded Grid R.F. Amplifier" which is to be commended more than the loosely used cascode identity.

Colwyn Bay. S. L. FIFE.

Transistor Applications

THE exploitation of any new device is nowhere more rapid than in the U.S.A., and the transistor is no exception. According to the April, 1954 *Electronics* a transistor pre-amplifier is now embodied in a hand-type moving-coil microphone, its use lifting the output to about the level of that of a carbon type. It is said that the background noise is considerably reduced.

A carrier telephone system which employs some 300 transistors has been installed in a rural area. It covers 26 miles or so of country, includes three terminal units and, several repeater amplifiers, and the use of transistors is said to reduce the size of these equipments to 1/10th and the power requirements to 1/20th of that of valve equipment.

New Licence Regulations

Amending Transmitting and Receiving Licences

UNDER the 1949 Wireless Telegraphy Act, and its extensions covering the Channel Islands and the Isle of Man, the Postmaster-General is empowered to make such regulations as are necessary to licence transmitting and receiving stations. No such regulations regarding fees had been made until April 5th when two Statutory Instruments* covering broadcast receiving licences and sundry transmitting licences were laid before Parliament. They are scheduled to come into operation on June 1st. Co-incident with the introduction of these new fees the P.M.G. has revised some of the regulations covering the issue of licences.

So far as broadcast receiving licences are concerned the main changes are in the fees payable. As has already been announced in Parliament, television receiving licences are to cost £3 per annum. In the past an hotel has been licensed as a single household, irrespective of the number of rooms equipped for radio reception, but the new regulations provide for licences for hotels at £1 (sound) and £3 (sound and vision) for each room equipped.

On the transmitting licence side there have been many changes. In general the technical requirements are more stringent except that for amateurs there has been an easing of restrictions. There have been a number of changes in the charges for transmitting licences—both increases and decreases—which, incidentally, are based on the estimated administrative costs for the various classes of licence. It is the intention of the P.M.G. to issue the new licences on the first renewal after the introduction of the new regulations and charges on June 1st.

Mobile Radio

To ensure that these new Statutory Instruments are fully discussed in the House of Commons, Capt. L. P. S. Orr, M.P., who is chairman of the Mobile Radio Users' Association, has announced that he is putting down a Prayer for their annulment. The question of the legality of the original charge for mobile radio licences is, as already reported,† being contested by one user who has served a writ on the Post Office. It is also claimed that some of the regulations laid down in the licences are contrary to the provisions of the Wireless Telegraphy Act.

Now for the details of the new transmitting licences. Brief descriptions are given in S.I. 1954/439 of seventeen different types of licence, but this is not a complete list, for there are in addition a number of special licences; in fact there are some cases where there is only one licence in existence. In other cases, such as that for the radio control of industrial equipment and telemetering, new licence regulations are in course of preparation.

On perusing the provisions of the new "private mobile radio licence," which will supersede the business radio licence, the technical requirements appear to be more stringent. On investigation, however, it will be found that the technical limitations laid down, which were not included in the old licence, are, in fact, a reiteration of the P.M.G.'s specification issued to manufacturers for the type-approval of their equipment. The licence charges have been reduced from £5 to £3 per transmitter and a composite licence for all the stations in a network will be issued. It is something of an anomaly that whereas ambulance services come under the "private mobile radio" category and will pay the £3 fee, there is a separate "police and fire service" licence for which the fee is £2 p.a. for each fixed station, irrespective of the number of mobile transmitters used.

Amateur Sound and Vision

Instead of the previous arrangement whereby charges for amateur sound transmitting licences varied according to the power of the station (10 W, £1; 25 W, 30s; over 25 W, £2 p.a.) the new regulations provide for a uniform fee of £2 p.a. The initial charge of 10s or £1 according to the radiated power will no longer be made. Operators may not at present use portable equipment or operate from an alternative address without first applying to the Post Office and the charges for "P" or "A" operation have been 10s each. Under the new regulations operation from a temporary alternative address or location is covered by the main licence. Provided the periods of "P" or "A" operation do not exceed four consecutive weeks the Post Office will not need to be notified.

A "sound mobile licence" which is supplementary to the main amateur transmitting licence will in future be available for £1 and this will permit the licensee to operate in a vehicle or vessel. Amateur equipment, whether mobile or fixed, may not be used at sea or within any estuary, dock or harbour.

The P.M.G. is introducing the award of a certificate (Amateur Radio Certificate) which will be granted to those who pass the City and Guilds Radio Amateur Examination and a 12-w.p.m. morse test. Holders will be permitted to operate a transmitter under the supervision of a licensed operator without themselves holding a licence.

A licence to operate an amateur television station will in future cost £2 instead of £3, and as at present, it limits transmission to visual images. An operator may send his call in morse but to radiate sound he will also need an amateur sound licence.

A licence for the radio control of models is provided for in the new regulations. This costs £1 for five years. The operator will not have to pass a test.

There will in future be a "training establishment licence" (£2 for five years) which will permit the establishment of a transmitting and receiving station for "wireless telegraphy" which, within the meaning of the Wireless Telegraphy Act, covers radar.

* S.I. 1954/438 "The Wireless Telegraphy (Broadcast Licence Charges) Regulations" (4d) and S.I. 1954/439 "The Wireless Telegraphy (General Licence Charges) Regulations" (6d), H.M.S.O.
† *Wireless World*, March, 1954, p. 124.

The Diode Rectifier in Valve Voltmeters

By M. G. SCROGGIE, B.Sc., M.I.E.E.

Limitations of Use Imposed by Specified Maximum Error

THE majority of valve voltmeters for alternating voltages use a diode rectifier followed by what may be called a current amplifier or direct-voltage valve voltmeter. A previous article[1] reviewed the whole design of this rectifier circuit, including methods for dealing with its non-linearity, which of course is of chief importance at low voltages. The present article is confined to causes of error other than non-linearity, and has especially in view (though not exclusively) use at frequencies lower than r.f. At such frequencies one reasonably expects a fairly high standard of accuracy to be attainable. On the other hand, the sources of voltage being measured are unlikely to be low-loss tuned circuits, and, as was emphasized previously, when a non-resonant source is being measured the error due to diode loading is appreciable with much less source resistance than is often supposed, especially when one is accustomed to using the instrument across r.f. tuned circuits. For 1 per cent error, say, a diode voltmeter with a load resistance of 1 MΩ is actually worse than an ordinary 1,000-ohms-per-volt metal-rectifier meter on a 50-V or higher range!

With an ordinary voltmeter, the source-resistance error can be calculated from the voltmeter resistance. In one way of looking at the matter, this resistance and the resistance of the source of voltage form a potential divider as in Fig. 1, and the voltage actually read (assuming the meter otherwise free from error) is $\frac{R_m}{R_m + R_s}E$ instead of E. An error of x per cent is caused by R_s when it is x per cent of $R_m + R_s$, or (assuming x is reasonably small) very nearly x per cent of R_m. If R_m were 50,000 Ω, for example, and the maximum source-resistance error tolerated were 1 per cent, the maximum source resistance that need not be corrected for would be just over 500 Ω.

An alternative viewpoint that shows the same result is to suppose that the voltage to be measured is due to a constant current I flowing through the source resistance. It is therefore equal to IR_s. When the meter is connected, the resistance through which I passes is R_s and R_m in parallel, i.e. $R_mR_s/(R_m + R_s)$. The ratio of voltage read to voltage before the meter was connected is therefore $\frac{R_m}{R_m + R_s}$ as before.

If one seeks to apply this calculation to a diode voltmeter the question at once arises, where is R_m? And if the voltage being measured is across a tuned circuit there may also be doubt about R_s. One thing that must *not* be done is to work on the assumption that R_m is the load resistance of the diode, i.e. the resistance across which the rectified voltage is developed —R in Fig. 2. In general one cannot regard the rectifier as equivalent to an ordinary resistance, for during the greater part of each cycle of the input voltage the diode is non-conducting so that the rectifier as a whole is an open circuit and imposes little or no load on the voltage source, while during the remainder of the cycle it is conducting and passing a relatively heavy current into the capacitor C. Notwithstanding this, however, it is found that in the special case of the source of voltage being a resonant circuit the damping effect of connecting the rectifier across it is equivalent to that of an ordinary resistance. The reason is that the flywheel effect of the stored energy in the resonant circuit maintains its pure voltage waveform in spite of the great variability of the load across it.

Effective Input Resistance

It is sometimes stated that the value of this equivalent resistance, which we shall call R_i—the effective input resistance of the rectifier, or the resistance which, if substituted for the rectifier, would draw from the voltage source the same amount of energy during each cycle—is half the diode load resistance (R). But it is not always made clear at the same time that this is not even approximately true if the input voltage is small or the source-resistance error is large, and that it applies only to the series-diode circuit, Fig. 2(a). R_i varies with input voltage, because at very small inputs a diode is far from being a perfect rectifier. Throughout this article, however, we shall assume that the input is sufficient (say at least several volts) for the performance of actual diodes to be not greatly different from that of an ideal diode having infinite resistance when the anode is negative with respect to the cathode and either zero or a constant small resistance when it is positive. If for the moment we also assume that the Fig. 2(a) circuit is used, with no source resistance, then V_r, the rectified output across R, is equal to the peak value of the sinusoidal input voltage. Since the forward resistance of the diode is assumed zero and its backward resistance is infinite, R is the only power-dissipating element in the circuit, the power being V^2_r/R. This must be equal to the input power, which by definition of R_i is E^2_{rms}/R_i. Since the peak value, $E_{max} = \sqrt{2}\,E_{rms} = V_r$, $E^2_{rms} = V^2_r/2$, so $R_i = R/2$. In practice this theoretical value is a reasonably good approximation when the input voltage is at least a few volts and there is no series resistance other than a low-resistance diode—in other words, conditions are such that V_r is not more than one or two per cent less than E_{max}.

In Fig. 2(a), R is shut off from E by the non-conducting series diode for almost the whole of every cycle, but in the shunt-diode circuit, Fig. 2(b), a.c. is driven through R by E all the time (the impedance of

[1] *Wireless World*, March 1952, pp. 89–94.

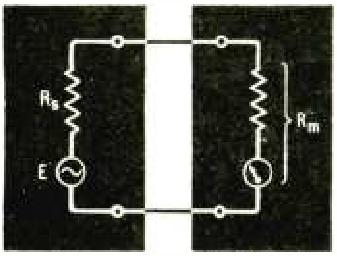


Fig. 1. Diagram representing a source of voltage as an e.m.f. E in series with internal resistance R_s, being measured by a voltmeter with resistance R_m.

C being assumed negligible), so R_i in this case is equivalent to R/2 in parallel with R; i.e., R/3.

To prevent the alternating voltage across R in the shunt circuit from being passed on, some kind of simple filter is usually employed, perhaps the commonest being as in Fig. 2(c) or (d). If the impedances of C_1 and C_2 are negligible in comparison with the resistances, it can easily be found in the same way—by reckoning the d.c. and a.c. resistances in parallel—that in Fig. 2(c) $R_i = \frac{R_1 R_2}{R_1 + 3R_2}$, and in Fig. 2(d) it is $\frac{(R_1 + R_2)R_2}{R_1 + 3R_2}$. In both circuits it is assumed that there is no current path between the output terminals other than those shown. To make the output in Fig. 2(d) equal to the r.m.s. value of sinusoidal E, $(R_1 + R_2)$ must be about equal to $\sqrt{2}\,R_1$, in which case $R_i = R_1/3.83 = R_2/1.59 = (R_1 + R_2)/5.42$. And if in (c) $R_1 = R_2$, $R_i = R_1/4 = R_2/4 = (R_1 + R_2)/2$. All these, of course, are subject to the assumptions made; with large input voltages the actual R_i tends towards these figures, but around bottom-bend level the whole matter becomes far more complicated. In general, R_i is greater (loss smaller) at small input voltages in the series circuit (a), and less in the shunt circuit, than large-voltage values. At high frequencies the additional losses in the capacitances may be serious and would have to be taken into account in any accurate evaluation of R_i.

The importance of R_i is that when it comes across a resonant circuit it reduces that circuit's dynamic resistance (which we shall call R_r). The voltage developed across the circuit by a given e.m.f. or current is proportional to the dynamic resistance. So the ratio of voltage with the rectifier connected to the voltage without the rectifier is $R_iR_r/(R_i + R_r)$ to R_r, or $R_i/(R_i + R_r)$ to one. In other words, the calculation is exactly the same as for an ordinary meter, Fig. 1, R_i now taking the place of R_m, and R_r the place of R_s. For example, if a series-diode voltmeter with a load resistance R of 3MΩ were used to measure the voltage across a resonant circuit with a dynamic resistance of 80 kΩ, R_i would be 1,500 kΩ, so the factor by which the voltage was reduced by the meter would be approximately 1500/1580 = 0.95; i.e., 5 per cent error.

The desirability of making R_i large is especially great in the valve voltmeter used to indicate Q in the usual type of Q meter measurement, for this damping error directly affects the readings and is not cancelled out as in the reactance-variation method.

Peak Clipping

So much for measurements on resonant circuits. From now on we shall assume that the source of voltage can be represented, as in Fig. 1, by an e.m.f. E in series with a resistance—the source resistance R_s. Such a source has no stored energy to meet the relatively heavy demand at the positive peak of each cycle, when the diode is conducting; consequently the positive peaks—which are what the diode voltmeter measures—are clipped short and the readings are low. If R_s and the forward resistance of the diode (r_a) were nil, C or C_1 in all the circuits in Fig. 2 would charge up to the full peak value, E_{max}. To do this, the portion of each cycle during which the diode conducted would have to be infinitesimally small and the current infinitely great, so even a very small value of $R_s + r_a$ is sufficient to modify the situation considerably. If we restrict the error due to it to, say, 1 per cent, so that V_r is only 1 per cent less than E_{max}, the period of diode conduction cannot extend far each side of the positive peak; and since during this brief period C has to take in enough charge to feed R for the whole cycle, the charging current is bound to be relatively heavy. To restrict the voltage dropped in R_s by this heavy current to 1 per cent of E_{max}, it is

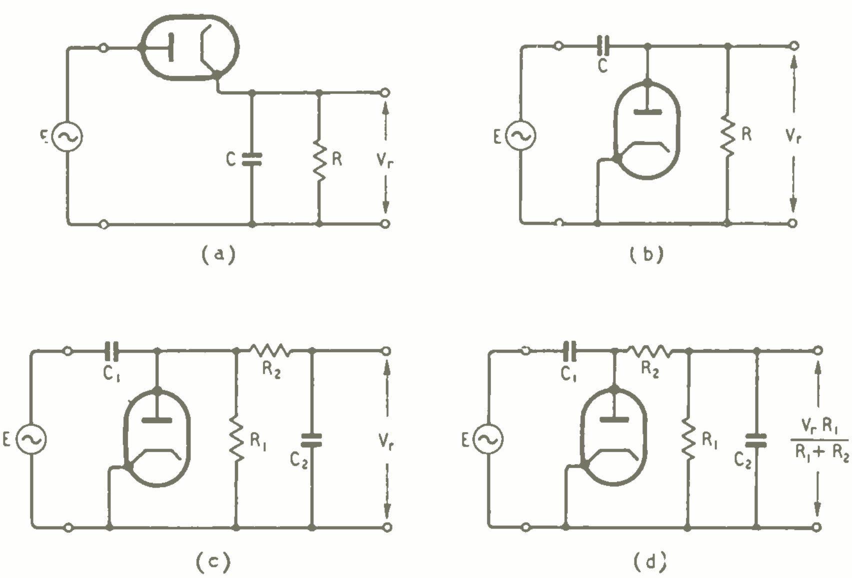


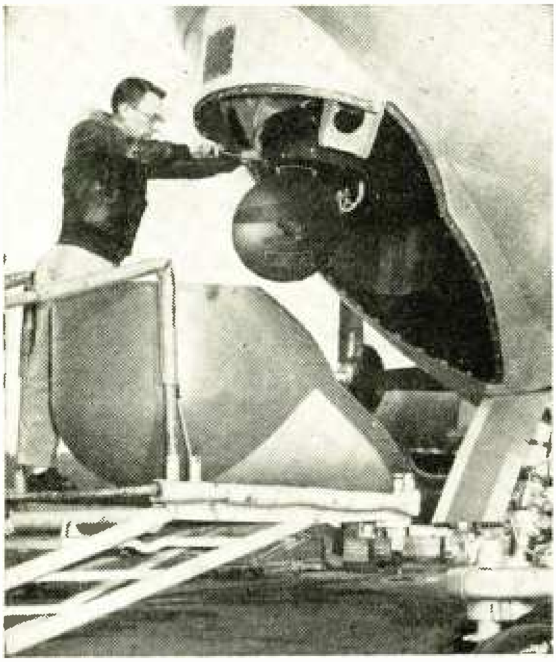
Fig. 2. The four types of diode rectifier considered. (a) is the series-diode type, (b) the simple shunt-diode, and (c) and (d) are shunt-diode circuits with two varieties of simple filter for removing the a.v. component from the output.

obvious that R_s must be very small compared with R, which carries a far smaller current.

In the article previously referred to there was a curve, due to D. A. Bell[2], showing how the "efficiency of rectification," V_r/E_{max}, varies with R_s/R. Although one could see from this curve that an efficiency of 99 per cent (i.e., error 1 per cent) necessitated R_s being a very small fraction of R, the scale was such that it was very difficult to see even roughly how small. One object of the present article will be to remedy this by showing the upper part of the curve on a larger scale. Another object is to take account of the value of C on the small errors. But the main object is to extend the information, hitherto available only for the series-diode circuit, to the shunt circuit and the variants shown in Fig. 2. While a very large amount of information has been published on the series circuit, the shunt circuit seems to have been almost ignored. Admittedly the series circuit performs better in nearly every respect, but for use in measuring instruments it is not generally so convenient as the shunt circuit. Even data about Fig. 2(b) do not really meet the need, because in order to keep the following amplifier from being overloaded by a.c. the circuits used in practice are more likely to be (c) or (d), and what then is the load resistance?

(To be Concluded)

[2] *Wireless Engineer*, Oct. 1941, pp. 395-404. Actually a similar calculation had been presented, slightly differently, by F. M. Colebrook eleven years earlier (*Wireless Engineer*, Nov. 1930, pp. 595-603).



Aerial scanner of R.C.A. lightweight search radar being installed in plastic nose radome of Boeing 80-ton "Stratofreighter." Now a standard fitting in these aircraft, it can be used to locate storm fronts, as a collision warning device and as a navigational aid, by showing up prominent land features. Two display indicators are fitted, one shared by pilot and co-pilot and the other for the navigator, who also controls the equipment's various functions.

News from the Clubs

Birmingham.—June meetings of the Slade Radio Society include a talk on "Receiver Design" by G. Nicholson (11th) and another on "Servicing Car Radio" by W. E. Lewis (25th). The second of the season's events for the Harcourt Trophy will be a midnight d.f. test on the 12th/13th. The society meets at the Church House, High Street, Erdington, on alternate Fridays at 7.45. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

Brighton and District Radio Club continues to meet each Tuesday at 7.30 at the Eagle Inn, Gloucester Road, Brighton. The club transmitter (G3EVE) is on the air on 80 and 160 metres (phone and c.w.) on some Tuesdays. A quantity of components has been acquired and it is proposed to start an "assisted constructional scheme" to help young members in building their equipment. Sec.: T. J. Huggett, 15, Waverley Crescent, Brighton, Sussex.

Hastings.—The Hastings and District Amateur Radio Club will again be exhibiting at the Hobbies and Crafts Exhibition in the New Pavilion, Falaise Road, Hastings, during the town's Carnival Week (July 3rd-10th). The club station, G6HH/A, will be manned during the exhibition from 10.00 to 22.00 each day except Sunday, July 4th, and will operate in the 80-metre band. Amateurs are invited to arrange schedules. Sec.: W. E. Thompson, 8, Coventry Road, St. Leonards-on-Sea, Sussex.

QRP.—The QRP Society is organizing a campaign to encourage the use of low power by all stations participating in local nets. The society considers that there is no justification for stations to use 150 watts when 5W will adequately cover the neighbourhood. The society would like to hear from clubs interested in QRP with a view to organizing contests and trials. Sec.: J. Whitehead, 92, Rydens Avenue, Walton-on-Thames, Surrey.

Commercial Literature

Measuring Instruments, including signal generators, valve-voltmeters, Q-meters, frequency meters, bridges and microwave test equipment, described in a 1954 catalogue of 200 pages, handsomely bound and illustrated, from Marconi Instruments, Longacres, St. Albans, Herts. A functional diagram accompanies the description of each instrument.

Power Resistors, wire-wound, with values from 10 to 30,000 Ω and power ratings from 10 to 40 watts. Leaflet from R.M. Electric, Team Valley, Gateshead 11, Co. Durham.

Lead-through Capacitors, Hi-k miniature ceramic types, for Band III and IV television tuners. Also Hi-k ceramic disc capacitors for decoupling in television receivers. Two technical bulletins from The Telegraph Condenser Company, North Acton, London, W.3.

Slotted Angle Strips in steel for Meccano-type construction of racks, frames, etc. Leaflets from Dexion, Triumph House, 189, Regent Street, London, W.1.

Voltage Stabilizer with output voltage continuously variable between 200 and 240 volts and maintained to within 0.25%. Input voltage variation possible is −17½% to +6½%. Leaflet from Servomex Controls, Crowborough Hill, Jarvis Brook, Sussex.

Miniature Soldering Irons of the pencil type made by Oryx. One model, for 6-volt operation, gives a high bit temperature of almost 400°C; another, already supplied for 6-, 12- and 24-volt working, is now available for 50 volts. Leaflet from Anglo-Netherland Technical Exchange, 3, Tower Hill, London, E.C.3.

Encapsulation of small units in suitable potting resins: a service offered by Lion Switchgear and described in a leaflet from their Works at Hanworth Trading Estate, Hampton Road, Feltham, Middx.

Components and Accessories; an information folder for insertion in their catalogue from Webb's Radio, 14, Soho Street, London, W.1.

High-Fidelity Audio Amplifier of 12 watts output, substantially flat from 2 c/s to 160 kc/s, with negative feedback of 26 db and distortion of less than 0.1%. Also a pre-amplifier and remote control unit for use with it. Specifications on a leaflet from Pye, St. Andrews Road, Cambridge.

French Components Show, 1954

Preponderance of Electronic and Television Equipment

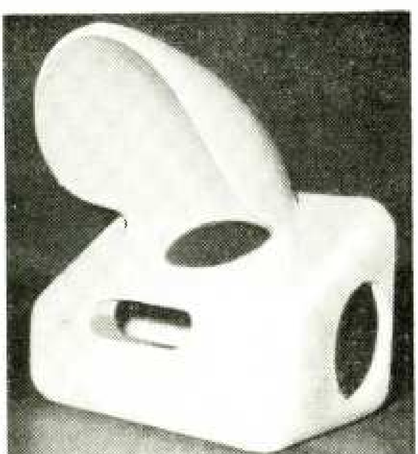
By E. AISBERG*

SINCE the world's first components exhibition was staged in Paris in 1934, the area covered by the "Salon de la Pièce Détachée" has grown from 600 to 6,000 sq. metres. Like its British counterpart, the R.E.C.M.F. show, the French Salon confines itself to components, accessories and measuring instruments produced by the home industry.

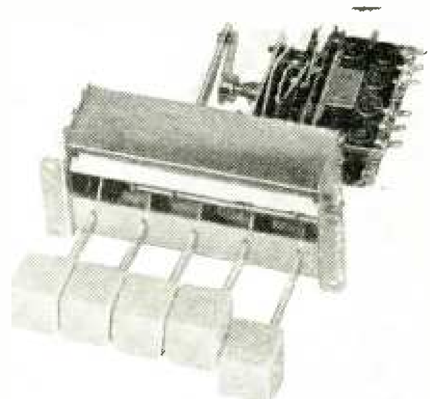
Three main tendencies were in evidence this year. First and foremost, equipment for professional and industrial use took pride of place. What was at one time essentially a radio show has become an exhibition of general electronics. No doubt the heavy demands imposed on the French industry by the armed Services are responsible for this tendency, and, as a result, technical considerations are becoming of greater importance than purely commercial ones. Now that supplies are plentiful, choice is determined largely by quality, but of course price is important in components for broadcast receivers, both sound and vision. Lastly there is a trend, more and more in evidence, towards the production of many new television components.

Sound Broadcast Equipment.—Since March 28th the Paris f.m. station, which had previously been conducting low-power experimental transmission, has been regularly at work on 96.1 Mc/s with a power output of 20 kW. The coming of f.m. has been responsible for some novelties amongst components. Several coil manufacturers have produced special assemblies for the 90-Mc/s frequency band, as well as wide-band i.f. transformers and windings for discriminator circuits.

* Editor, *Toute la Radio*.



"Rabbit's-ear" dual loudspeaker with one operative and one passive unit. (Elipson).

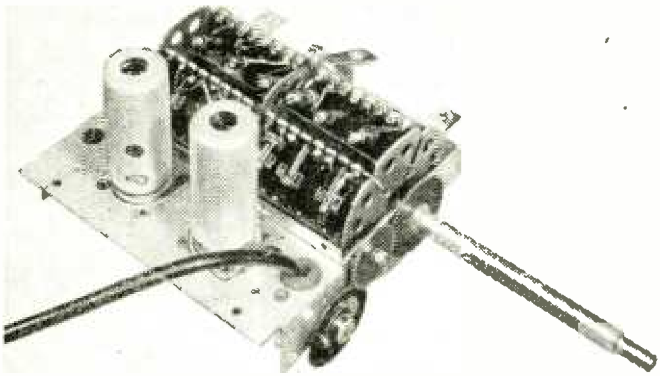


Device to enable a rotary switch to be push-button operated (S.T.A.R.E.).

Loudspeakers designed to handle a wide range of audio frequencies were well in evidence. Besides the usual electro-dynamic types several manufacturers have introduced dual units with concentrically mounted electro-static or piezo-electric units capable of reproducing audio frequencies up to 15,000 c/s. The coming of f.m. was not the sole cause of the development of such loudspeakers; they are required also for the reproduction of high-quality microgroove records. If the manufacturers of television receivers would only take the trouble to give proper attention to the a.f. portions of their sets, viewers could take full advantage of the wide-band sound transmissions which accompany the pictures. Most French televisors, alas, are provided with rather rudimentary a.f. amplifiers and small loudspeakers and so are incapable of reproducing more than a narrow band of audio frequencies.

Before we leave loudspeakers another interesting novelty must be mentioned. This is an instrument with a focusing baffle shaped like a rabbit's ear. In addition to a normal, energized reproducer there is a second one, exactly similar but mounted horizontally. The latter receives no audio input; actually, its speech coil is short-circuited. The purpose of the "parasitic" speaker is to absorb the resonance peaks of the other to some extent. Since it is precisely similar to the energized one, it has the same resonances and the currents in its speech coil serve to damp the movement of the cone.

Television Equipment.—The new television components show, on the one hand, a tendency to simplify manufacturing processes with a view to price reductions, and on the other a desire to enable the user



Dual moving-coil and piezo-electric loudspeaker. (Musicalpha) and (left) Six-channel television tuner. (Vidéon).

to receive several stations, possibly with different standards of definition.

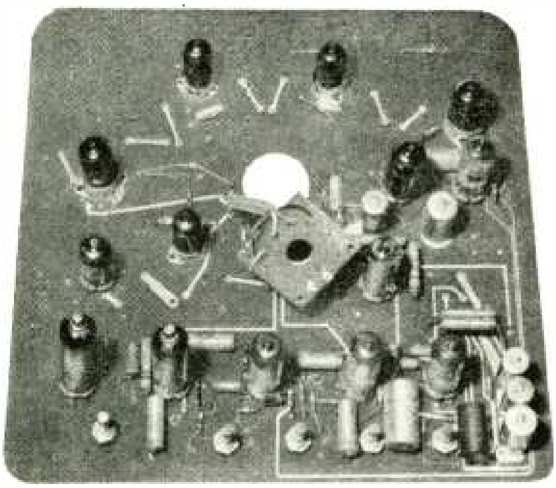
Printed-circuit technique has now for the first time been used in the manufacture of television receivers. The French term *circuits appliqués* is perhaps more accurate. Two manufacturers showed assemblies made by cementing a plate of copper, 0.03 mm to 0.05 mm thick, to an insulating backing and removing unwanted metal by chemical methods.

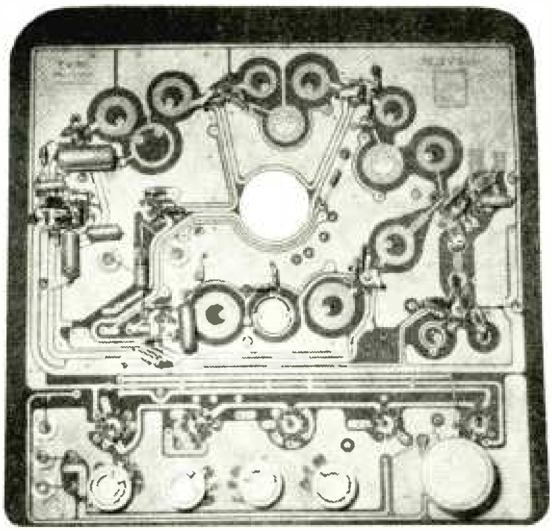
A complete TV receiver chassis constructed in this way may contain no more than a few dozen soldered joints, as against the thousand or so called for by ordinary wiring methods. Deflector coil assemblies are also made by the applied circuit method. Much use also is made of the new magnetic materials for TV purposes.

Cathode-ray tubes shown had screen diameters ranging from 36 to 66 cm, anything less than 36 cm being of no account. Tubes with 43-cm screens are already in mass production and the large-scale manufacture of 54-cm tubes will soon be under way. Wide-angled tubes with deflection up to 90 deg are becoming common.

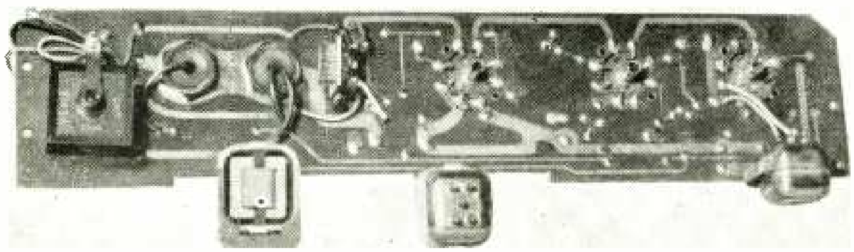
Two types of "rotactor" (rotary switching coil units) enabling reception to take place on any one of several channels were exhibited. They are equipped with readily interchangeable coils.

Several standards of definition have to be taken

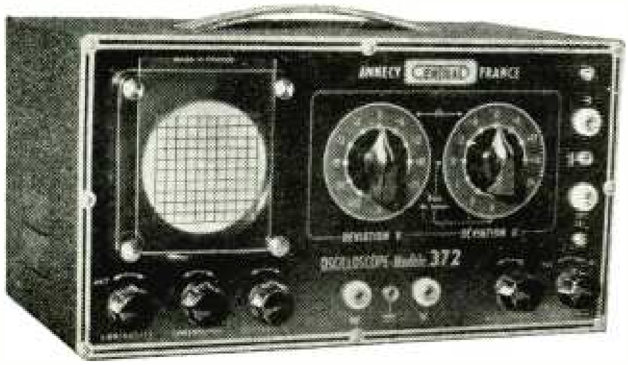




Front and back views of printed circuit panel for a television receiver. (Visseaux).



Printed circuit amplifier panel for a magnetic recorder. (Aréna).



Servicing oscilloscope with 3-in. c.r. tube. (Centrad).

into account in France. In addition to the 819-line transmissions on the official French standard, 441-line transmissions will continue until 1958. Again there are many viewers in the regions near the eastern frontier who receive the German 625-line transmissions. One thus finds television measuring instruments, pattern generators and the like, designed to deal with this multiplicity of scanning systems.

Measuring Instruments.—Amongst these there is a large variety of new instruments designed to meet widely different needs. There are galvanometers so completely water-tight that they can be used submerged in several metres of water. More and more instruments are seen with scales of up to 270 deg. With the higher and higher sensitivity that is being achieved a microammeter with a full-scale deflection for a current of 1 μA comes as no surprise.

One ingenious means of improving the oscilloscope must be mentioned. It consists of a fluorescent scale engraved on a sheet of Perspex, which is placed in front of the screen. The screen is illuminated from the side and the brilliance can be varied at will.

Electronic Equipment.—In France, as elsewhere, the semiconductors are beginning to figure prominently in the field of electronics, germanium and silicon diodes being in common use. Several firms showed transistors, though these are not as yet generally available.

An ingenious device is a d.c. "transformer" which enables direct voltages to be increased or decreased at will. The appliance contains a 2-position switch. In one position the switch connects a bank of capacitors in series; in the other it connects them in parallel. The capacitors may thus be charged in parallel and discharged in series and the voltage increased. It can be decreased by charging in series and discharging in parallel. The principle is an old one; but this practical application is new and the device is completely reliable.

To sum up, the Salon must have made a very satisfactory impression on any technical visitor. Quality, reliability and ingeniousness were its outstanding characteristics, all of which serve to exemplify the liveness and virility of the industry.

HONG KONG HARBOUR RADIO

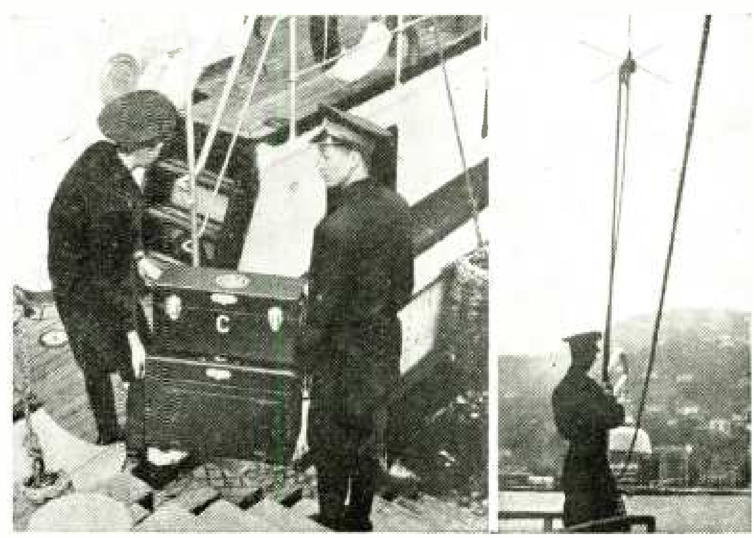
A V.H.F. radio-telephone system has been installed at Hong Kong to provide direct communication between ships in the harbour and subscribers on the Hong Kong telephone exchange. In addition to providing this facility the new system affords direct communications between moored ships and greatly assists loading and unloading operations.

The ship-to-shore radio link is provided by a portable battery-operated f.m. transmitter-receiver, which is taken on board from the pilot's cutter as soon as the ship enters the harbour and set up in some suitable position.

To facilitate operation the network is divided into several groups, each group being allotted two wavelengths, one for transmit and one for receive, and all groups work through a permanent land station linked by cables to the main telephone exchange.

Ship stations operate from a 12-volt battery and the equipment for each comprises a calling decoder, portable aerial mast, transmitter, receiver, desk controller and all necessary cabling; the gear can be set up on board and working in a matter of minutes.

All the equipment was made by the General Electric Company of England and the service is operated by Cable and Wireless.



One of the G.E.C. mobile radio-telephones being taken aboard the pilot's cutter for transference to a ship entering the harbour. On the extreme right is shown a ground-plane aerial set up aboard ship in Hong Kong harbour for ship-to-shore communications.

Cavity Resonators

Empty Boxes Instead of Coils and Capacitors

By "CATHODE RAY"

IN microwave equipment, the parts that correspond to wiring at lower frequencies are commonly referred to as "plumbing," from the obvious resemblance of waveguides and associated metalwork to the pipes with which builders in this country decorate the outsides of houses. The precision of manufacture and installation has to be a good deal higher than in domestic plumbing, however. After having been accustomed to making electrical connections from A to B by means of almost any old piece of wire, the constructor's graduation to microwaves comes rather painfully. Whether the same can be said of the theory side is perhaps a more open question. Anybody who has been brought up to think exclusively in currents and circuits probably finds it very difficult to imagine how electricity can be sent along a pipe. If, however, he had begun with microwaves, which would have meant thinking in fields from the start, the idea of currents travelling along wires might have appeared strange and difficult. Supposing I had a very limited time in which to do my best for someone who knew nothing at all about electricity, I think I might choose waveguides rather than wires. Even though speaking tubes are no longer standard equipment in the really modern home or office, so that an actual demonstration might be difficult to arrange, it is easy to imagine how they work. And if one can visualize sound waves going along pipes, why not electromagnetic waves? Communication by wire is a much more surprising phenomenon

Acoustic Resonant Cavities

It is the same with resonant cavities. We radio people are so used to our tuned circuits being made up of coils and capacitors that we are baffled when asked to accept an empty copper box as a tuned circuit. But if we could start again with no electrical knowledge at all, surely it would be the coil and capacitor that would be baffling, rather than the cavity? After all, everyone is accustomed to acoustical resonant cavities. Even the washer-up can hardly have failed to notice that while a bottle is being filled with water the sound, produced by the resonant cavity formed by the unfilled portion of the bottle being shock-excited by the impact of the water, rises in pitch as the cavity becomes smaller. And I suppose we have all played tunes by acoustically shock-exciting our mouths—another form of resonant cavity—by tapping our teeth with a pencil or blowing air between our lips and simultaneously varying the size of the cavity. By slightly modifying the blowing technique we can obtain much clearer notes, caused by continuous oscillation in the cavity, commonly referred to as whistling. To whistle a low note we have to make the mouth cavity larger than for a high note. If anyone asks about dental cavities, the answer is that in a well-kept mouth they should always be small enough for their resonant frequency to be above audibility.

Another example of acoustic resonant cavity, introduced to most of us at an extremely tender age—probably on first visiting the seaside—is a shell held to the ear, which, like an electrical tuned circuit, selectively amplifies the frequencies to which it resonates, causing otherwise barely audible sea noises to roar forth impressively. And when listening to speech or music, one can, by making a cavity with the hands close to the ear, distort the sounds in just the same way as a too-resonant audio amplifier or loudspeaker.

The classical example, which so far I have not been privileged to witness, is the famous tenor lifting his empty glass after dinner and shattering it with one strong sustained note sung at its resonant frequency. But in this country such behaviour, even by famous tenors, is probably considered bad form, and one would have to go abroad to stand any chance at all. However, with so many less spectacular but perhaps more instructive demonstrations right at hand, there is really no need.

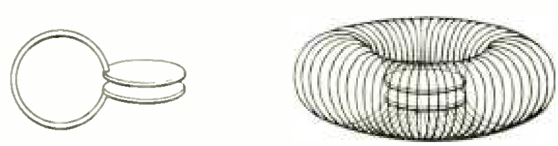
Now of course the fact that enclosed or nearly enclosed spaces have acoustical resonance does not prove that they also have electromagnetic resonance, nor does it explain how such electromagnetic resonance (if any) takes place. But we do know that there is a very close analogy between the generation, transmission, propagation and reception of sound waves, and of electromagnetic waves, so at least our examples of acoustic resonant cavities should lead us to expect something corresponding in electromagnetics; and by tracing the analogy between sound and electromagnetic waves we ought to be able to get some idea of how electromagnetic cavities resonate. To make this approach it is necessary to have a fairly comprehensive mathematical knowledge of sound waves, and their differences as well as resemblances to electromagnetic waves. Anybody who has such knowledge will probably be able to follow this line for himself without the doubtful benefit of my assistance. The rest of us will be content with the general picture.

Another approach is from what we know about transmission lines, resonant stubs and waveguides. Anyone who has grasped the theory of these three items can go on to resonant cavities on the basis that cavities are to waveguides as resonant stubs are to transmission lines. One learns that long lines, made up of uniformly distributed inductance and capacitance, transmit electromagnetic waves, and that certain comparatively short lengths, either short-circuited or open-ended, resonate, and are equivalent to tuned circuits (but in general are much better, in terms of

Q. Similarly, a pipe or waveguide, provided its diameter is large enough in relation to the frequency, transmits electromagnetic waves; and a certain length of waveguide (such as a half wavelength) acts as a high-Q resonator. A closed length of waveguide is one possible form of cavity. And, just as waveguides have different "modes" of wave transmission, so cavity resonators have different modes of oscillation. Cavities, then, are best considered as an extension of the study of waveguides, especially as regards the question of modes.

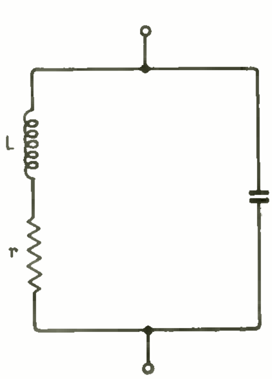
The shapes of cavities are by no means only the same as commonly used types of waveguide. One possible, and in fact highly efficient but not usually convenient, shape is spherical. A very usual one, again not related to waveguide shape, is the toroid or American doughnut; for example, in klystrons, where it is termed the rhumbatron.

Still another approach, short-circuiting the study of waveguides, is by way of ordinary inductance-capacitance or LC-tuned circuits. The rhumbatron just mentioned is sometimes introduced as a development of a tuned circuit consisting of a single-turn coil and a single pair of capacitor plates, as in Fig. 1(a). By putting together a sufficient number of turns in parallel around a circle, as at (b), one forms a rhumbatron. Although this view may be better than nothing if a knowledge of waveguides and wave propagation is lacking, it doesn't get us very far. And it may be misleading in that the inductance and capacitance are not really separate, even in this shape, and obviously are not if the shape is a sphere, cube or cylinder. It is therefore hopeless to try to analyse a resonant cavity, as one can an ordinary tuned circuit, by measuring L its inductance; C, its capacitance; and r, the resistance which, if connected in series with L, would account for all the losses (Fig. 2). On the other hand, it is quite easy to find a cavity's resonant frequency. Actually, it has many resonant frequencies, but "the" resonant frequency, if not more particularly specified, is taken as the lowest. And it is fairly easy, by means of the frequency-variation method, to measure the Q



(a) (b)

Above : Fig. 1. One way of looking at the toroidal-shaped resonant cavity (b) used in klystrons is as an extension of a single-turn coil and a single-pair-of-plates capacitor (a). In fact however the inductance and capacitance are not completely separate, even in this shape.



Right : Fig. 2. However a resonator is made up, it can be represented by this equivalent circuit. The values L, C and r usually depend on frequency and on what are reckoned as the terminals of the resonator.

of a cavity. The one remaining item needed to specify its performance as a resonator is its impedance, measured at resonance, when it is equivalent to a high resistance—the "dynamic resistance." This is more difficult, but can be done if the points between which the resistance is reckoned are indicated.

These three things, usually written as f_0, Q and R_d respectively, together with the terminal points of R_d, are sufficient to specify any kind of tuned circuit, whether its inductance and capacitance are distributed or lumped. If lumped, then L, C and r can easily be found from f_0, Q and R_d, because

$$f_0 \simeq \frac{1}{2\pi\sqrt{LC}} \quad \text{(when Q is not small)}$$

$$Q = \frac{2\pi f L}{r}$$

$$\text{and} \quad R_d = \frac{L}{Cr}$$

If they are distributed, as in a stub or cavity resonator, the values of L, C and r found from these equations are the component values of the equivalent lumped tuned circuit.

Why we use Cavities

Just in case anyone may not be quite clear why people should bother with cavities instead of the good old coil and capacitor (or, alternatively, bother with a coil and capacitor when it seems that an empty screening can is sufficient) let us dispose of that point before going any farther.

The advantage of the coil and capacitor is that their construction enables a comparatively large amount of inductance and capacitance to be got into a small space. Thereby it is practicable to tune to Droitwich (200 kc/s) in even a "ladies' handbag" portable set. Theoretically it is possible to tune to Droitwich with a resonant cavity, but its dimensions would have to be of the order of half a mile, which would create some practical difficulties, notably in the matter of manual tuning control. Even at the London television frequency (45 Mc/s) a cavity-tuned receiver would resemble a battery of Lancashire boilers. The conventional tuned circuit meanwhile is still entirely convenient at this frequency. But at the much-discussed Band III frequencies (around 200 Mc/s) one is beginning to feel a shortage of turns when trying to arrange step-up or step-down ratios. And if we had to go to Bands IV or V, in the upper hundreds of megacycles, this difficulty would become so acute that a semi-distributed construction such as the "butterfly" circuit would probably be adopted. An alternative is the stub or short resonant line, already mentioned, but this is not particularly compact by present-day standards: at 600 Mc/s a quarter-wave stub is 12½ cm long—say 5in. A cavity is still less convenient, because it has to be wide and deep as well as long. It comes into its own in the thousands of megacycles, where lumped tuned circuits are right out of it, and stubs in turn are beginning to be difficult because their short-circuiting ends, which are supposed to be almost negligibly small compared with the length, no longer are.

The higher the frequency, the greater the tendency to radiate. Although radiation from a coil can be prevented from going far enough to cause trouble, by shutting it up in a metal can, it is not thereby prevented from being a loss to the coil. Apart from the difficulty of getting few enough turns at very high frequencies, therefore, the coil is out of it because of excessive radiation losses. For the same reason tuning stubs always take the coaxial form, in which the outer conductor completely screens the inner*; not the parallel-wire type, which radiates. When the frequency is so high that the length of a coaxial stub is so short that its outer diameter cannot be incomparably smaller still and at the same time give adequate clearance between low-resistance conductors, then one might as well drop the inner conductor and make it a cavity, for the dimensions will not be unreasonably large.

And so we are left with an empty metal box. It acts as its own screening can, so the radiation loss is practically nil. The only dielectric concerned is the air inside, so the dielectric loss also is practically nil. (If we were really fussy we could pump the air out; sometimes this has to be done anyway, if the resonator is part of a valve.) The only conductor concerned is the metal of the box, which is nearly always copper; and since the currents flow only on the inner skin† the inner surface of high-class cavities is polished and silver-plated. All these things having been properly attended to, the losses are extremely small, and the Q values are fantastic by conventional tuned-circuit standards—30,000 and more is not unusual. Of course, a cavity is not usually made just for the sake of being set into oscillation; it is expected to work for its living, and the load to which it is coupled pulls down the overall Q. But for best results it ought not to be pulled down too much; in this respect the cavity is like any other tuned circuit.

Although Q is often expressed (as we have already done) as the ratio of inductive (or capacitive) reactance to equivalent series resistance, this is just a special case of the general definition, which takes the form of the ratio of energy stored to energy lost. The energy stored in a cavity resonator is stored in the electric and magnetic fields inside, so other things being equal is proportional to the volume. The energy lost is lost in the inner surface, so other things being equal is proportional to the area of that surface. One would expect, then, that the highest Q would be obtained in the shape that has the largest ratio of volume to surface area; which is the sphere. In practice the cylinder is little if any behind the sphere, and is obviously easier to make.

Field Patterns

In such a very introductory look at cavities I really don't think we had better delve deeply into the business of modes; it can all be found in the books on microwaves, which are full of diagrams looking like latitude and longitude lines on hemispherical maps of the world. The full lines are electric lines of force, and the dotted lines are magnetic lines of force, and all of them are as imaginary as lines of latitude and longitude. They just show the directions and roughly the relative intensities of the fields at chosen instants during the cycle of oscillation. In a conventional tuned circuit the electric and magnetic departments are kept almost completely separate, in the capacitor and coil respectively, but in a cavity they share the same space. The analogous fact in an organ pipe or other acoustic resonant cavity is that the air inside vibrates to and fro (velocity wave) *and* is alternately compressed and expanded (pressure wave). And just as an acoustic cavity resonates at one series of frequencies from end to end, and another from side to side, the electromagnetic cavity resonates at various series of frequencies depending on the mode. In both acoustic and electromagnetic kinds of cavity, a standing-wave pattern is set up at resonance, and the mode is the particular pattern. Hence all the pretty diagrams. Anyone who has studied loudspeakers knows that the cone can vibrate in a large number of different modes, at different frequencies. The modes of vibration of a flat plate can be shown visually by sprinkling it with fine powder, which is thrown off the vibrating parts on to the stationary parts, forming what are called Chladni's figures (Fig 3).

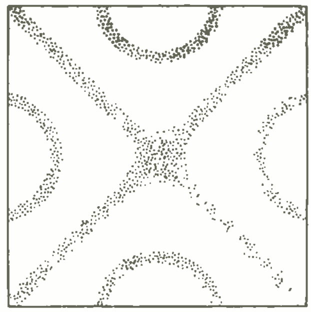


Fig. 3. One example of Chladni's figures, in which the pattern into which powder sprinkled on a plate forms itself when the plate is set into vibration shows the mode of vibration. The dark or powdery parts are the nodes, where there is no vibration.

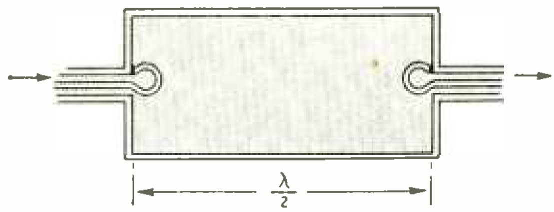


Fig. 4. Rectangular resonant cavity with input and output coupling loops.

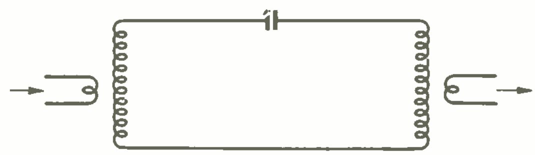


Fig. 5. Circuit equivalent to Fig. 4.

In a two-conductor line, whether parallel-wire or coaxial, both electric and magnetic lines of force are transverse; that is to say, at right angles to the direction of travel. The electric lines stretch between the two conductors and the magnetic lines encircle them. But in a waveguide, where there is no second conductor, one lot of lines is partly along the pipe. The British custom is to divide all modes into two main classes, according to which lot of lines this is. In America they are classified according to which lot it isn't. Thus modes which have electric lines going along the guide are in the British system called E modes. In America they are called TM (transverse magnetic). Actually both lots of lines are transverse, but only the magnetic lines are exclusively so. The other class of modes is called H (for magnetic field) or TE (transverse electric). Individual modes in each class are distinguished by little numbers, e.g. H_{01},

* "Some Coaxial Problems," *Wireless World*, Dec., 1953, p. 571.
† "Skin Effect," *Wireless World*, Nov., 1953, p. 537.

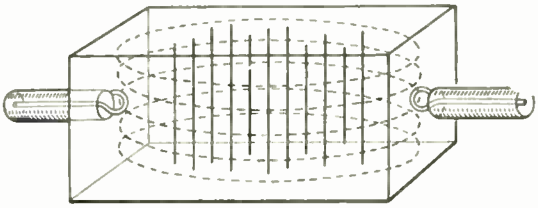


Fig. 6. The dotted loops are magnetic lines of force and the verticals within them are electric lines of force characteristic of the lowest-frequency mode of oscillation set up as in Fig. 4.

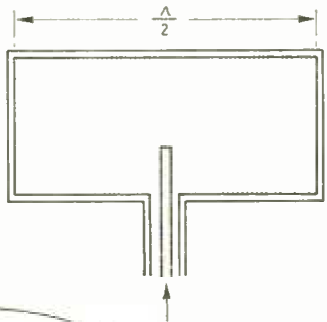


Fig. 7. Electric probe coupling for setting up the same mode of oscillation as in Figs. 4 and 6.

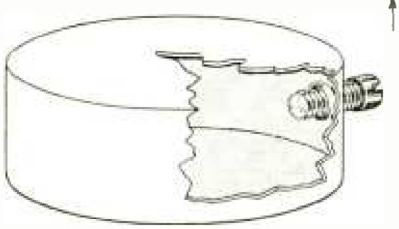


Fig. 8. Screw plug device for varying the resonant frequency of a cavity.

according to the number of half-waves in the field pattern across the main dimensions. This is where I refer you to the books for details.

Important Modes

Resonant cavities, unlike waveguides, do not have a continuous wave movement in one direction; there is a standing wave pattern, and these patterns or modes are classified in the same way as for waveguides, except that one more number is needed—to indicate how many half-cycles there are of standing wave. Although there are innumerable possible modes, it is only the very few of lowest "order" (and therefore frequency) that are used; the others are merely a nuisance. A good deal of the design of a cavity resonator is a matter of discouraging unwanted modes, so as to make sure that at any one time it oscillates with one intended pattern at one intended frequency. Here again there is the acoustical analogy. If you, like me, have a member of the family who is learning to play a wind instrument, you will know what I mean. Such instruments, it seems, require skill to ensure that the column of air therein does not vibrate in some undesired mode, instead of or in addition to what is wanted.

In both musical and electromagnetic instruments, a good deal depends on how the driving or exciting unit is coupled to the resonator. In microwave plumbing, one can place a probe (which is like a tiny rod aerial) in the direction along which the electric lines of force are wanted, or a loop in such a position as to encircle magnetic lines where they are wanted. Fig. 4 shows a rectangular cavity magnetically coupled to a source via a coaxial line at one end and to a load at the other, making a system equivalent (at the resonant frequency) to the circuit in Fig. 5. The input loop in Fig. 4 starts an electromagnetic wave with the magnetic lines going through the loop, and therefore at right-angles to the paper. The corresponding electric lines are from top to bottom. When the wave reaches the far end it is (except for energy taken out by the coupling there) reflected. The magnetic field is reflected without change of phase so the round trip is a whole wavelength and the reflected energy arrives back in phase with what is just being delivered by the loop. Most of it is reflected again; and so forth, until the build-up in the cavity is very large. Since some of the magnetic field at the outlet end passes through the loop there, it generates an e.m.f. and so starts a wave along the outlet line. The field pattern in the resonator is represented conventionally as in Fig. 6; the mode is H_{011} or TE_{011}. If the cavity were twice as long, or the frequency twice as high, it would be H_{012}, because there would be two half-wavelengths from end to end.

Because the electric lines are vertical, an alternative way of establishing resonance of the same mode is shown in Fig. 7. The total distance from the probe to the end walls and back is only half a wavelength, but the electric field is reversed in phase on reflection, so the reflected wave again arrives in phase. No load is shown here, so presumably the cavity is very sharply resonant indeed, and the input impedance would go through very violent changes of magnitude and phase if the frequency were varied through f_0.

There are two other methods of exciting cavities: through a slot, or little open window between the source and the cavity; and by shooting electrons through the cavity. This last method is very important, as we shall see.

An aspect of the subject yet to be mentioned is tuning. Obviously one way of tuning a cavity is to vary its length. One can think of a cylinder in a petrol engine as a resonator tuned rapidly to and fro over a wide range of frequency. We would be well advised to do no more than think about it, because as a practical arrangement it would not be very efficient. Steel piston rings, though no doubt excellent as a gas and oil tight joint, would not be conspicuously satisfactory for microwaves. However, suitable cylinder and piston combinations are in fact used as resonators for wide ranges of tuning. More often quite a small range is sufficient, and then a popular method is a screw plug (Fig. 8). The acoustic analogy might lead one to suppose that screwing the plug in, by reducing the volume of the cavity, would raise the resonant frequency. It might do so, but on the other hand it might lower it; all depending on whether it occupied space formerly dominated by electric or magnetic field. If electric field, then the result would be the same as if part of the space between capacitor plates were filled with metal—the capacitance would be increased and frequency lowered. Screwing a plug into the haunt of magnetic field, on the other hand, is like copper-slug tuning in coils—the inductance is reduced and frequency raised.

Applications

The uses of cavities? Obviously, for general tuning purposes. But there are one or two rather interesting special uses. Cavities can hardly be mentioned at all without bringing to mind the cavity magnetron,

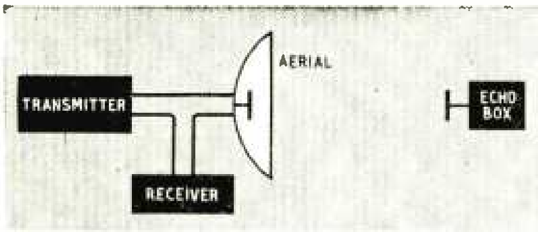


Fig. 9. Echo box method of checking the frequency and overall efficiency of a radar set.

which might quite well be called the valve that won the war. I gave some account of this last year,* along with the klystron,† which also incorporates one or more resonant cavities. In both of these the cavities are thrown into resonance by controlled electrons flying past or through them.

Another use is as a wavemeter. For rough tuning over a wide range there is the piston type, and for fine tuning the plug or plunger controlled by a micrometer movement. The enormously high Q enables the resonant frequency to be very precisely indicated. But, in contrast to the conventional absorption wavemeter, one must beware of responses at unwanted modes.

The high Q comes in very useful for testing radar sets. The higher the Q the longer the oscillations in the resonator take to die out after the power has been cut off. With a Q of the order of 30,000, they go on for quite a long time—at least several microseconds. That may not strike one as being an unendurably long time, but a wavelength of 3 cm means 10,000 cycles per microsecond. Briefly, the procedure is to set up a cavity resonator with a little dipole receiving aerial at a fixed distance from the radar aerial (Fig. 9). Each pulse from the radar, if it is working on the correct frequency (the frequency to which the cavity or "echo box" is tuned) sets the box into oscillation. At the end of the pulse the oscillations die away exponentially and are picked up by the radar receiver. Since each microsecond delay between pulse and received signal appears as a range of 164 yards on the receiver, the time taken for the oscillations to die away to the just-detectable level is known, and of course the longer this is the better the radar set as a whole, for it increases with transmitter power, receiver sensitivity, and efficiency of feeders, aerial, etc.

Speed of E.M. Waves

My last example of the use of a cavity resonator is a very special one. Some years ago, Dr. Essen of the National Physical Laboratory used a resonant cylinder about 7in long to measure the speed of electromagnetic waves in a vacuum with great accuracy. The dimensions of this cylindrical cavity were made correct within one hundred-thousandth of an inch, and the result of the measurement was given as 299,792.5 ± 3 km/s. Since there is no reason to believe that the speed of electromagnetic waves at the frequency of the measurement (10,000 Mc/s) is any different from those at 500,000,000 Mc/s, this is accepted also as a measurement of the speed of light. Certainly it agrees well with accurate direct measurements of the speed of light. The speed is so enormous that the early methods necessitated a distance of many miles. Now seven inches is enough.

* "Valves for Microwaves," *Wireless World*, Sept., 1953, p. 417.

† "More Valves for Microwaves," *Wireless World*, Oct., 1954, p. 479.

Transistor Stagnation

DEVELOPMENT of transistors is being held up by the unwillingness of possible users to co-operate with the manufacturers, according to B. R. Bettridge in a recent lecture to the Brit. I.R.E. Engineers were tending to sit down and wait for the super-device they felt was just around the corner, he said, instead of getting down to experimental work with existing transistors and making demands for specific improvements. Consequently the manufacturers were not very sure in which directions to guide their development work and the awaited improvements were slow in coming. The whole situation was a vicious circle which could only be broken by the users thoroughly exploring the potentialities of the transistor and pointing out the best lines of development.

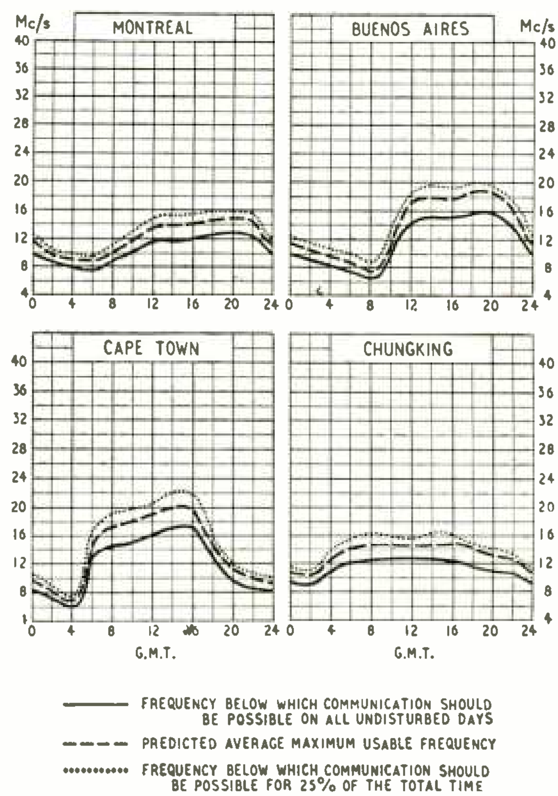
Mr. Bettridge spoke about the use of other materials besides germanium for transistors, but said there were difficulties in manufacturing them in the form of single crystals.

Short-wave Conditions

Predictions for June

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

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



Physical Society's Exhibition

Electronic Techniques in Research and Measurement

This report is followed by surveys of recently introduced valves and allied devices; also of test and measuring gear. These surveys cover exhibits at both the Physical Society's and R.E.C.M.F. shows. Some products appeared at both, so no distinction is made in the surveys between the two exhibitions.

RESEARCH

THE transistor has stimulated research into semi-conducting materials and the possibilities of finding substitutes for or perhaps even better substances than germanium for this and other applications of solid-state electronics. Germanium belongs to Group IV of the periodic table of the elements with a chemical valency of 4, and on theoretical grounds it has been predicted that intermetallic compounds of elements from the groups above and below with valencies of 5 and 3, which solidify in a zinc-blende structure similar to germanium should exhibit comparable electrical properties.

One of the principal difficulties in making electrically significant compounds is the maintenance of exact molecular proportions during the alloying process. The Services Electronics Research Laboratory showed examples of miniature vacuum furnaces and methods of controlling the reaction, and also a series of representative specimen compounds.

Provisional constants for some of these compounds are as follows:—

	Energy gap (eV)	Melting point °C	Electron mobility cm/sec per V/cm
Aluminium antimonide	1.65	1,060	100
Gallium arsenide ..	1.2	1,280	3,500
Gallium antimonide	0.71	725	700
Indium phosphide ..	1.2	1,050	—
Indium arsenide ..	0.48	950	14,000
Indium antimonide	0.18	525	50,000
Germanium ..	0.72	960	3,600

It will be seen that gallium arsenide has properties similar to germanium and may be expected to be less sensitive to temperature since the energy (gap) required to free an electron-hole pair from the crystal valency bond is greater.

The exceptionally high electron mobility and the low energy gap of indium antimonide suggest that it should be very useful as a thermoelectric generating material, and better than germanium as a material for measuring flux density by means of the Hall effect.* A demonstration was given with a small specimen of this material embedded in potting resin, which gave full-scale deflection on a Pye "Microvolter" when rotated in the earth's magnetic field.

An exhaustive study of the dielectric properties of ceramics formed by various proportions of the oxides of magnesium, silicon and aluminium has been made by the Research Laboratory of B.T.H. In the most favourable proportions the losses (tan δ) are as low as 0.0001-0.0005 at 3,000 Mc/s; the dielectric constant is about 6. Conducting glasses made with vanadium oxide and other admixtures and having resistivities at room temperature of the order of 10^{4} were also shown by B.T.H.

A sensitive method of measuring frequency fluctuations is embodied in the "periodmeter"† which was shown by H.M. Underwater Detection Establishment. Time intervals between zero transits of the wave under examination are displayed on an arbitrary time base as successive vertical deflections, and the shape of the envelope gives useful information on the nature and components of any frequency irregularity. The resolution is 1 c/s in 10 kc/s and one oscillogram showed that the equipment is capable of giving accurate information on magnetic tape speed, well below the generally accepted limits for fluctuation in recorders. It has also been applied to the measurement of the mean frequency of noise in a narrow band, and to the detection of pulse signals in noise.

Apparatus for the measurement of very weak sounds (of the order of 7 phons) was demonstrated by G.E.C. Research Laboratories. It has been designed primarily for the investigation of hum produced by fluorescent lighting chokes. A soundproof double box, lead-lined, is used to contain the choke under test and a sensitive microphone, and a special pre-amplifier in which the anode current of the first valve is only 60 μA has been developed to reduce the electrical noise level. This amplifier is in tubular form so that it can be used for general measurement with minimum disturbance of the sound field.

The National Coal Board are investigating a method developed in the Physics Department of King's College, Newcastle, of detecting the presence of air in fire-damp drained from pit workings by measuring the velocity of sound through the gas by a pulse technique. The position of the pulse on a c.r. tube display is arranged to indicate all mixtures on a horizontal trace and an alarm relay is operated when the air content lies between 50 and 100 per cent. A commercial gas analyser working on the same principle is made by Sir Howard Grubb, Parsons and Company.

An unusual application of electro-acoustics methods is to be found in the "apidictor" shown by the research department of Wayne Kerr Laboratories. A microphone and switched selective amplifier are used to monitor the sounds made by bees in a hive and to give information on the health of the queen and the imminence of swarming without disturbing the life of the colony.

Other research items noted in passing were a d.c. mercury pump (A.E.R.E.) in which transverse current and a magnetic field at right angles force the liquid upwards in accordance with the classical "left-hand rule"; and an e.h.t. supply unit (A.S.R.E.) in which the valve heaters are energized by capacitive feed from the anodes through miniature r.f. transformers which can be suspended in the wiring in multiplier circuits

* See *Wireless World*, Nov., 1950, p. 415.

† *Wireless Engineer*, Nov., 1953, p. 274.

NON-INDUSTRIAL ELECTRONICS

THE counting and sizing of microscopic particles, such as blood corpuscles and dust, is a job which plainly calls for electronic techniques. The most popular method seems to be to place the particles on the slide of an ordinary microscope and scan them with a flying-spot cathode ray tube "looking" down through the eyepiece; a photocell on the other side of the slide then transforms the light modulated by the particles into pulses, and these are passed to an electronic counter during the period of one frame. Instruments working on this principle were shown by Mullard and University College, London. To avoid the possibility of a large particle being counted several times as a result of being on more than one scanning line, both instruments use a double scanning spot with an extra photocell. When the first of the two spots encounters the particle a pulse is counted in the normal way, but when, on the next scanning sweep, both spots encounter the particle the pulse from the second photocell is used to cancel the output of the first one, and so on. Size analysis of particles is accomplished in the University College instrument by a pulse-width discriminator which only accepts photocell pulses of certain durations, and in the Mullard instrument by increasing the separation of the two spots so that the second "inhibiting" spot only comes into action with particles of a certain size.

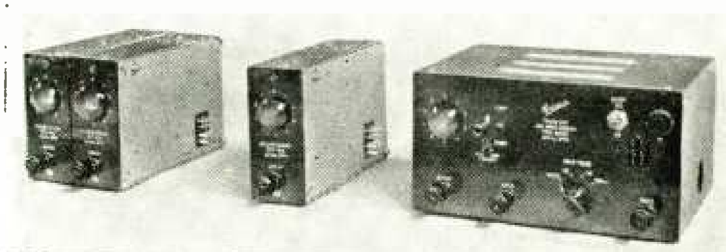
Another type of particle which can only be counted by electronic means is that produced by radioactive materials, and in this field the scintillation counter is becoming increasingly popular because of its great sensitivity—up to 80 times that of a Geiger-Muller counter. Burndept were showing an interesting example which was fitted with a lead collimator round the detecting crystal to give directional properties. With this the counting rate falls to one half of its peak value when the counter is moved as little as 5½ degrees from the source of radiation. For the actual process of counting, as distinct from detecting, Ericsson Telephones were demonstrating a versatile equipment based on their well-known Dekatron tube. This is designed on the "add-on" unit principle so that any number of decades, each incorporating a Dekatron, can be plugged together to count up to whatever figure the user requires.

A new method of displaying the electrical activity of the heart which is now becoming increasingly popular is the vectorcardiogram. This gives a two-dimensional picture by presenting on one diagram recordings made simultaneously across two planes of the heart. In the vectorcardiograph shown by the Cambridge Instrument Company the amplified signal from one set of electrodes is connected to the Y plates of a c.r. tube and the signal from the other electrodes to the X plates, the result on the screen being a complicated loop somewhat akin to a Lissajous figure. This trace gives the properties of magnitude, sense and direction of the heart voltage, while the time scale is provided by a recording camera. Ordinary electrocardiograms can also be displayed.

Another interesting Lissajous-type display on a cathode ray tube was given by a number and letter generator shown by the Admiralty Signal and Radar Establishment. This presented the face of a clock, with moving hands giving the actual time and with the letters A S R E in the middle. The basic generator waveform was an ordinary sine wave produced by an RC oscillator. From this four secondary sine waves were derived, each displaced 90° in phase, and from these in turn came eight sets of half sine waves (positive and negative) and four sets of sine waves of twice the original frequency, making 16 waveforms altogether With these it was claimed that all figures and all the letters of the alphabet could be produced.

(Right) Ericsson counter with "add-on" decades.

(Below) Vectorcardiograph with recording camera by Cambridge Instrument Company.



(Right) Mullard flying-spot particle counter.

INDUSTRIAL ELECTRONICS

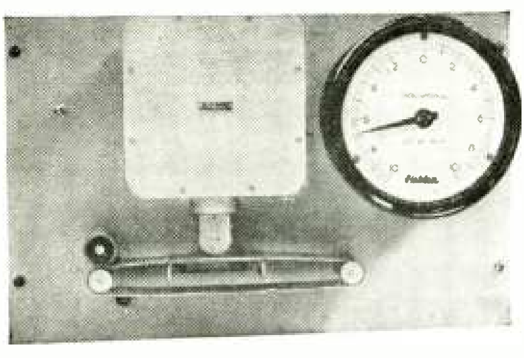
THE precision tachometer for measuring rotational speeds of aircraft engines, made by Plessey, is essentially an electronic counting device using Dekatron cold cathode tubes to give four decades. Electrical pulses from the engine shaft are registered on the counter tubes for a period of precisely 1 second, the marker pulses for which are derived from 4-kc/s quartz oscillator through two scale-of-two counting circuits followed by three Dekatrons. The display on the four counting Dekatrons is held for 0.7 sec for reading and then automatically set to zero for the next count. Alternatively the display can be held indefinitely until reset by push-button. The instrument is said to have an accuracy of 0.025 per cent.

In the Labgear (Cambridge) electronic tachometer (D4105) speeds up to 150,000 r.p.m. can be measured Normally the time datum is derived from 50-c/s mains, but terminals are also provided for an external 1-kc/s oscillator. Timing intervals of 0.1, 1 and 10 sec, and 1, 2, 10 and 20 minutes can be used, and the instrument is basically a combination of the D4102 automatic timer and D4104 Dekatron basic counter.

For the measurement of displacements, bridge methods involving change of capacitance or inductance are general. Wayne Kerr demonstrated applications of a 3-terminal a.c. capacitance bridge in mechanical engineering problems. Fielden were showing a rubber thickness gauge (continuous sheet micrometer) which makes use of a differential transformer with movable core, actuated by a spring-loaded roller. The bridge is balanced by the standard Fielden pointer servo mechanism and can be supplied as a simple indicator, as an error indicator or as a recorder. Salford Electrical Instruments demonstrated a differential electromagnetic transducer designed for operation from a.c. mains, which could be used for remote position control or for the measurement of displacement and is independent of supply voltage or frequency.

A self-contained industrial servo unit (Type R1219) shown by Ediswan, is mounted on a standard 19-in panel and contains a feedback push-pull amplifier, with provision for internal or external reference voltages, adjustable loop gain, etc., which feeds a total current of 80 mA to the centre-tapped field winding of a Type FA2 Evershed and Vignoles d.c. servo motor. The unit which provides a standing torque of 22 oz-in can be used to drive a variable-ratio transformer in voltage or current stabilizers, for process control or in machine tool pattern follower systems. It was shown connected to a model giving constant tension in a wire, irrespective of winding speed or direction.

Ultrasonic techniques are finding increasing applications in industry, and Mullard were showing, in addition to their high-powered ultrasonic drill, examples of work cleaned with the aid of high-frequency vibration. By irradiating the cleaning liquid with ultrasonic waves, generated with standard Mullard equipment, it was demonstrated that improved results could be obtained in less time. For removing the surface film from optical lenses a magnetostriction transducer working at 25 kc/s is satisfactory, while for intricate engine parts, ball races, etc., a quartz crystal using frequencies of the order of 1 Mc/s is most effective in dislodging dirt from confined spaces.

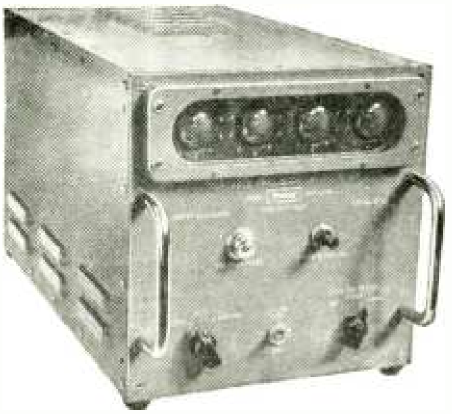


(Above) Fielden continuous sheet micrometer.

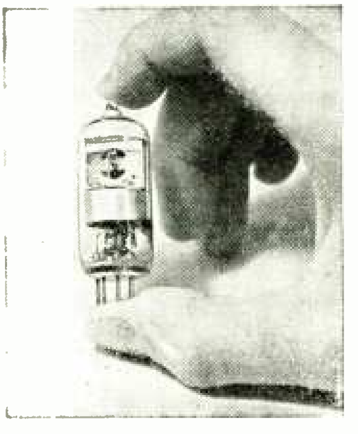
VALVES AND SEMI-CONDUCTORS

MOST manufacturers are now prepared for the coming of Band III television with new valves for the front end of receivers or tuner units. All assume the same type of circuit—cascode signal-frequency amplifier plus frequency changer, as described in our April issue—and all the valves are very similar to each other. For the double-triode cascode stage there are the Mullard PCC84, the Osram B319, the Brimar 7AN7/PCC84 and the Ediswan 30L1, all designed to operate at 90 V h.t. (each section) and with mutual conductances of about 6 mA/V. For the triode pentode frequency changer there are the Mullard PCF80, the Osram LZ319, the Brimar 9U8/PCF82 and the Ediswan 30C1. All eight valves have 0.3-A heaters for connecting in series heater chains.

Another sign of the times was the appearance of several ranges, or partial ranges, of valves for a.m./f.m. receivers. Amongst these were a number of multiple valves intended to serve several purposes. With the Brimar 6U8 triode pentode, Osram B309 double triode and Mullard ECC85 double triode, for example, one half would be an r.f. amplifier and the other a self-oscillating mixer. With the Brimar 6T8 and Mullard EABC80, both



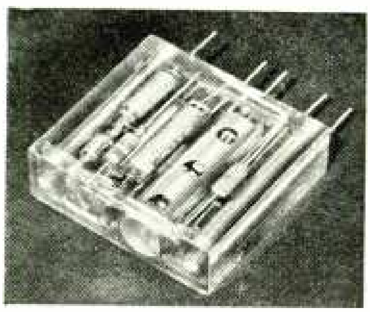
(Left) Portable precision tachometer (Plessey).



(Right) G.E.C. tunable magnetron showing form of cavities.

triple-diode triodes, two of the diodes would be used in an f.m. ratio detector, the third as an a.m. detector and the triode section as an a.f. amplifier.

The design of low-power tunable magnetrons of the conventional type for operation at frequencies of the order of 10,000 Mc/s becomes difficult because of mechanical complications. G.E.C. were showing that a simple type of magnetron can be devised to give adequate output for most low-power applications by the use of electron interaction with space harmonics of the resonator field. The valve (type VX3238) has a simple form of anode with two resonant cavities, mounted within a glass bulb through which it radiates directly into an output waveguide. It operates with the same voltage and magnetic field as a magnetron with ten to fourteen cavities of the usual type. By adjusting an external cavity coupled to the valve a tuning range of at least 400 Mc/s can be achieved with a single control and with a power of not less than 100 mW. Pulse operation is possible and a peak power of the order of 1W may be obtained at a peak current of about 50 mA. G.E.C. also had another low-power tunable magnetron



Example of Wayne Kerr "potted" circuit element with provision for dissipating heat from encapsulated valve.

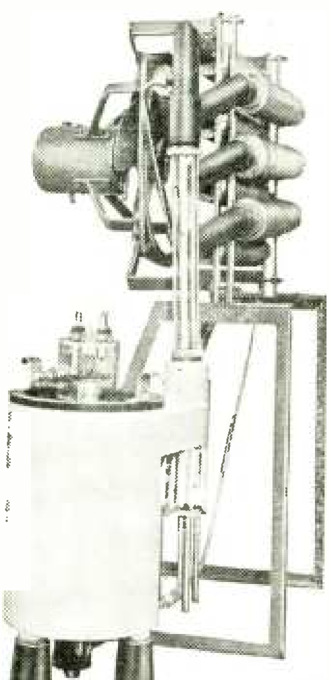
(type VX3809) with an interdigital anode structure. It operates at an anode voltage of 700-800V and gives an output power of 4-8 watts over a tuning range of 8.8-11.6 cm.

Cooling transmitting valves by water vapour instead of forced air or circulating water is claimed to give greater heat dissipation for a given size of valve. Ediswan were showing two of their "Vapotron" valves with special anode structures rather like copper pineapples for this type of operation. The valve is arranged to bring water to boiling point and advantage is taken of the loss of heat in evaporation. The water is self-circulating and no pumps are required.

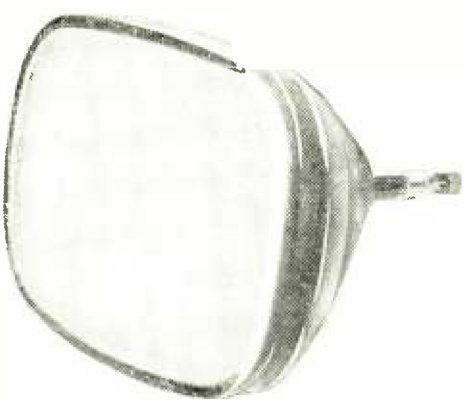
In cathode ray tubes the most interesting exhibit was a 21-inch rectangular tube, type MW33-21, made by Mullard and intended for export receivers. It has a tetrode gun with an extra electrode at cathode potential for giving uniformity of focus over the whole screen. 20th Century Electronics were showing new versions of their single-beam oscilloscope tubes with the novel feature of square screens.

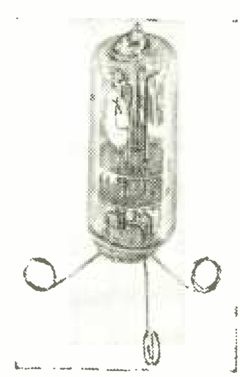
It goes without saying that the transistor field is expanding rapidly, and junction types were on view for the first time. Among these were the Mullard OC70 and OC71—high stability types with large current gains, hermetically sealed in glass and intended for use in hearing aids. They replace the OC10, OC11 and OC12 (also on show) which came out some time ago. Among point transistors, one of the latest types was the GET2, made by G.E.C. This is similar to the well-known GET1, but works at a lower voltage and has a higher current gain—3.8 as compared with 2.5. In addition the "knee" of the I_c—V_c characteristic is much sharper than in the GET1. This firm were also showing experimental p-n-p and n-p-n junction transistors in oscillator and amplifier circuits, one oscillator being powered from two dissimilar metal electrodes immersed in tap water! An experimental point type with electrode spacing of only one thousandth of an inch was capable of operating at frequencies as high as 40 Mc/s.

Turning to more prosaic semi-conductor devices, Brimar were showing a new metal rectifier, type RM5,



Square-faced oscilloscope tube by 20th Century.





(Left) Ediswan Vapotron valve in its vapour cooling system. (Centre) Mullard 21-inch rectangular c.r. tube. (Right) Two 20-Mc/s quartz crystals in evacuated glass envelope (S.T.C.).

intended for receiver h.t. supplies. With an input voltage of 250 volts r.m.s. it will give a maximum d.c. output current of 300 mA. It measures 1⅜ in square by 6 in long. For e.h.t. applications Westinghouse had some small tubular rectifiers, types 39E and 39K, with wire ends and diameters of $\frac{5}{32}$ in. Individual elements are rated at 85 V maximum peak inverse and 100 μA mean d.c. output current. This firm were also showing hermetically sealed versions of their 36EHT and 16HT rectifiers.

Among the quartz crystals on show were some interesting overtone crystals by S.T.C. for operation at frequencies up to 200 Mc/s. They have a frequency tolerance of ±0.005 per cent and an equivalent series resistance of 1 ohm per Mc/s. One example was a crystal working on a 9th overtone at 180 Mc/s.

One of the many problems associated with "potting" circuit elements is the dissipation of heat generated by encapsulated valves. The method adopted by Wayne Kerr is to enclose the valve (sub-miniature types are generally used) in a perforated metal tube with the closed end flush with, or very slightly proud of, the face of one side of the moulding. The assembly is then mounted so that this face makes contact with the metal chassis, or with a metal bracket of sufficient size, to carry away the heat from the tube.

Among the many activities of Wayne Kerr is investigating the qualities and characteristics of the various resins used in this potting, or encapsulating, process. This year they staged a demonstration showing, by means of polarized light, the strains and stresses set up in certain mouldings on solidification and it was shown also how such stresses can be avoided by using suitable mixtures.

Makers*: Brimar (V, C, G); Ediswan (V, C); English Electric (V, C); Ferranti (V, C); Mullard (V, C, G, T); Osram (V, C, G, T); Pye (Q); Salford (Q, R); S.T.C. (Q, R, G, T); Westinghouse (R, G).

*Abbreviations: V, valves; C, cathode-ray tubes; G, germanium diodes; T, transistors; R, metal rectifiers; Q, quartz crystals.

TEST AND MEASURING GEAR

Apparatus Shown at the R.E.C.M.F. and Physical Society's Exhibitions

AMONG the very few new meters to be seen at either show was the "Duo Meter" (British Physical Laboratories) which, as its name suggests, incorporates two meter movements, each with its own range switch, so that voltage and current (d.c. or a.c.) can be measured simultaneously. The same firm also showed single meters with very clear-reading 270° scales. The sensitivity of the Pye "Scalamp" galvanometers has now been doubled, as a result of suspension improvements. Another well-known range of instruments, the Evershed "Megger," has been extended by a mains-driven model with a test voltage of 10 kV. It has two scales: 0-1,000 MΩ and 60-200,000 MΩ.

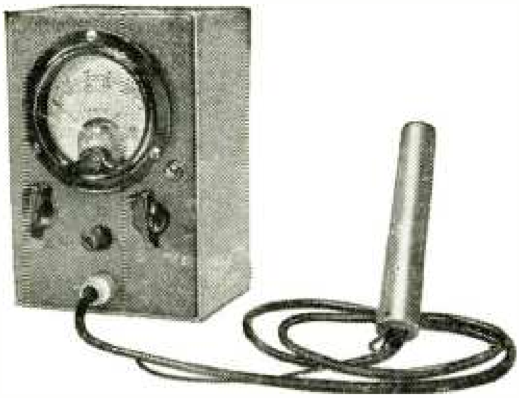
New valve voltmeters continue to be produced. The Solartron 20 c/s-20 kc/s phase-sensitive voltmeter brought out last year has been supplemented by a model for 0.5 c/s-1 kc/s, which is easier to use, because the four-phase output from the OS103 oscillator obviates the necessity for frequency-sensitive phasing adjustments on the voltmeter. Elaborate use of negative feedback in the Solartron VF252 voltmeter enables ±1% accuracy to be claimed over a range of 10 c/s to 100 kc/s, while exceptional sensitivity readings can be made down to 20 μV. Instruments in this class are necessarily large and mains-driven; in complete contrast is the Furzehill V210 crystal diode valve voltmeter, which, although provided with six d.c. ranges (1-300 full-scale) and all these except the 300-V range for a.c., are completely self-contained, including batteries, in the very small case shown here. A flashing neon tube indicates when the unit is on, and also by its frequency gives a guide to the condition of the batteries. The Cintel signal-level meter comprises an amplifier, meter, and calibrated attenuator; its frequency range is 20 c/s-100 kc/s, and lowest range 0-1 mV. An instrument shown by Joyce, Loebl comprises a sub-standard a.c. voltmeter preceded by a highly-stabilized amplifier, enabling nearly the full accuracy of the meter to be retained, with the addition of very high input impedance. Although not a precision instrument, the Langham Thompson cathode-follower unit also operates as a high-to-low impedance matcher, and is notable for its extremely small size, in spite of containing its own battery power.

The principle of the well-known heterodyne type of wave analyser for a.f. has been adopted by Airmec in an instrument covering the wide r.f. range of 30 kc/s-30 Mc/s. To avoid second-channel difficulties the i.f. is 0±3 kc/s. This instrument, type 853, is suitable for measurements of field-strength, interference, insertion gain and loss, frequency, etc.

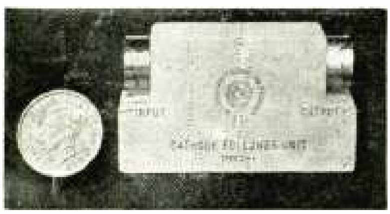
There are few new oscilloscopes, though a number of improved models. Mark II of the Mullard wide-band oscilloscope is an engineered version of the model previously shown, having a flexible and comprehensive triggered time base of constant sweep length, and calibrated delay circuits. It is particularly suitable for the analysis of high-speed complex waveforms. The Furzehill oscilloscopes, notable for some years for their direct-coupled amplifiers, are now obtainable with single-stroke time base, and one of them (type 0.100) has calibrated time and voltage. There is also an entirely new and relatively small general-purpose model (0.120) at a moderate price.

The construction of decade resistance boxes has changed little for a good many years, but now a notable departure by Tinsley is the substitution of printed units in place of the groups of conventional wire-wound resistors. Compactness, stability and low reactance are combined with higher power dissipation. Another new decade resistance technique has been developed by Pye: a box giving very precise and stable small increments of resistance. If steps of 0.0001Ω were provided in the conventional manner they would be subject to large uncertainty owing to switch contacts. In the Pye box low-resistance steps are brought in by shunting a fixed resistance with relatively large values of resistance, sufficient to swamp the switch resistance very effectively. Total range in the specimen shown is 50-61.111Ω; the 50Ω residual resistance can be tolerated in bridge and other measurements for accurate low resistance, because they would in any case be made on a difference basis. To avoid risk to more precise standards through overloading, Furzehill have introduced a workmanlike high-dissipation five-decade ±1-% resistance box (R600) totalling over 1 MΩ in steps of 10 Ω.

A precise decade of capacitance is costly, but where ±1% is good enough the box now produced by Servomex gives 0.001-0.999 μF inexpensively, using three 3-pole wafer switches and groups of capacitors in 1:2:2:5 ratio. The principle of the Sullivan capacitor introduced some years ago, in which the range of a 100-pF variable air capacitor is multiplied tenfold by a decade unit also with air dielectric, has now been extended in a model having the same total capacitance made up of a 10-pF variable (giving more precise readings) and two decade units. This capacitor is incorporated in a new Schering bridge covering 0.1 pF-100 μF with ±0.01% precision. British Physical Laboratories also showed a Schering bridge, using a tuned visual null indicator. The trend towards transformer ratio arms continues. Langham

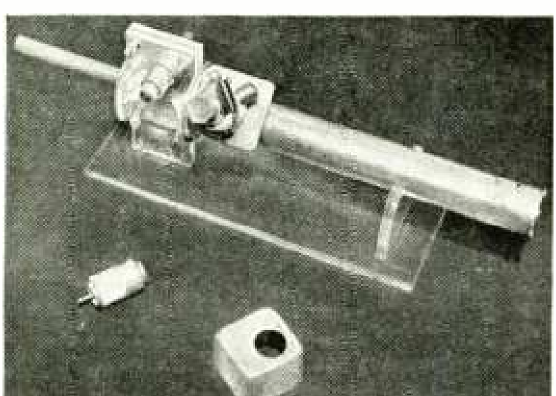


Furzehill V210 portable valve voltmeter.



Miniaturized cathode follower unit made by Langham Thompson.

Standing-wave indicator for 3-cm band made by Elliott.



Piston attenuator made by Advance Components.

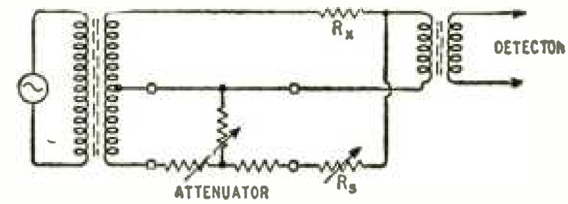


Fig. 1. In transformer-ratio bridges for v.h.f., the range of values of the standard resistance R_s, and of the ratio, is limited. In an exhibit by Wayne-Kerr this limitation was shown to be overcome by an attenuator inserted as shown.

Thompson have a capacitance bridge on this principle, reading up to 250 pF in three ranges; and Wayne-Kerr (who use it exclusively in their bridges) have two new self-contained mains-driven models with "magic-eye" balance indicator; the B321 for inductance and resistance, with a discrimination of 0.00001 μH at 10 kc/s (max. 10 mH), and the B221 for capacitance and conductance, with a discrimination of 0.0001 pF at $10/2\pi$ k/cs (max. 100 μF). An interesting feature of both these bridges is that the readings come up in figures at a window, as in a cyclometer, and the unit symbol and the position of the decimal point is controlled by the range switch! Errors in reading are thereby excluded. An experimental v.h.f. bridge technique demonstrated by Wayne-Kerr is shown schematically in Fig. 1. Where values of standard resistance or transformer ratio would in the ordinary way be impractically high, an attenuator is used instead. A modification of the Marconi Instruments universal bridge is now available under the type number TF868/1, having the alternative frequency of 10 kc/s to give greater discrimination when measuring low values of reactance. Finally in this section, two Hay bridges for measuring incremental inductance of iron-cored components: the Furzehill B800 covering 50 mH-500 H in four ranges at frequencies of 25-2,000 c/s; the other by Cintel, 10 mH-1,000 H in seven ranges, at 50 c/s. Both provide for Q measurement from 3 upwards, and convenient application of desired amounts of a.c. and d.c.

Adjustable stabilized power supplies are indispensable laboratory equipment, and there is now a much wider choice of units, especially for a.c. and for relatively heavy currents. The Solartron range of valve-stabilized d.c. power units has been extended by compact and inexpensive chassis models for incorporating in experimental equipment; they also provide unstabilized l.t. a.c. Although h.t. accumulators have been virtually banished, it has been difficult to find a substitute for the large l.t. accumulators, but a unit is now offered by Servomex providing up to 7 A at 1-30 V, stabilized within 25 mV. It is a servo-controlled motor-regulated equipment. Two l.t. power outputs, each up to 20 A 14 V, a.c. or d.c. or both, but unstabilized, are provided from a Joyce, Loebl unit. Of the new a.c. mains stabilizers, the Cintel employs a motor-operated Variac, and full load at 230 V is 15 A. The Sorensen type of stabilizer is supplied by Langham Thompson with maximum outputs from 0.25-15 kVA, and uses the saturable-reactor principle. The difficulty of making saturated transformer regulation satisfactory against variations in frequency and load power factor without reducing the high-speed correction of voltage variations is solved in a novel manner by Philips: the quick-acting transformer is used straightforwardly for voltage stabilization, and is compensated for frequency and power-factor variations by a separate electronic chain which (since these variations are much slower) is not restricted in design by the need for fast response.

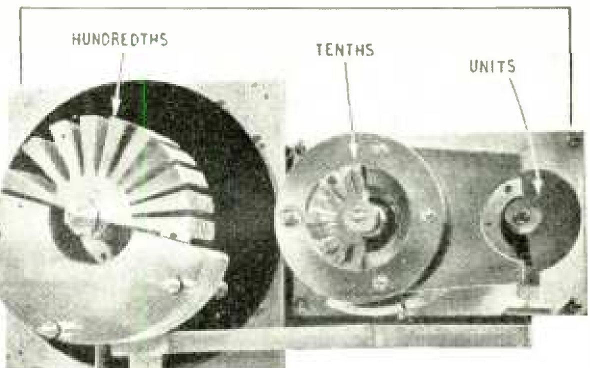
The Elliott power frequency generator, a production form of a prototype shown a year or two ago, is a link between stabilized a.c. power units and signal generators.

(*Continued on page* 301)

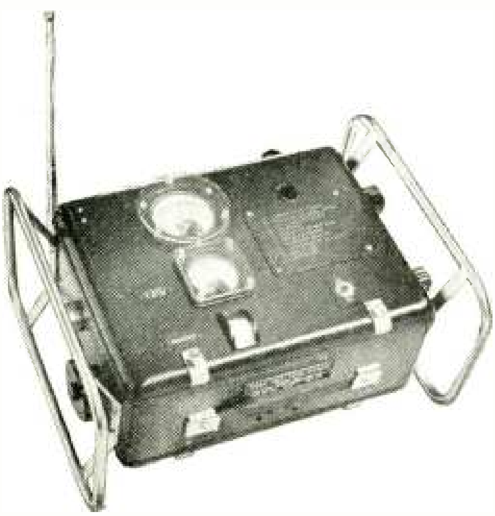
It provides two outputs of 70 VA at 0-750 V, 0-5 A, and 40-2,500 c/s. Output stability is better than ±0.02%, and frequency better than ±0.005%; and the relative phase can be adjusted from 0° to 360°. The basis is an RC oscillator, amplified, and stabilized by negative feedback.

Arranged in ascending order of frequency, new signal sources begin with the Solartron OS103 decade oscillator, at 0.1 c/s, or even (to order) 0.01 c/s. The top frequency in both models is 11.1 kc/s. A special feature is the four-phase output, intended primarily for use with the phase-discriminating voltmeter already mentioned. Associated Electronic Engineers have two RC a.f. oscillators: one to provide 4 watts output over the usual 20 c/s-20 kc/s in three ranges; and the other with slightly less output but exceptionally pure waveform—a total harmonic content of 0.06% is claimed. Airmec showed two r.f. signal generators to Government specification for use under arduous field conditions in any climate, and provided with both a.m. and f.m.: type 871 covering 85 kc/s-32 Mc/s and type 872 20-80 Mc/s. Also, mainly for use with a r.f. wave analyser to be mentioned later, a calibrating oscillator, type 858, 30 kc/s-30 Mc/s, for providing accurately known fixed outputs at 10 mV, 100 mV and 500 mV, with less precise interpolation. The Wayne-Kerr v.f. oscillator, 10 kc/s-10 Mc/s, is now provided (as type S341) with a 50-c/s square-wave output. Increasing interest in the v.h.f. and u.h.f. bands has brought forth a number of new oscillators. Particularly suitable for television servicing in bands I and III is the Advance Q1, covering 7.5-250 Mc/s, with such facilities as sine and square-wave modulation, and output variable 1 mV-100 mV, at a very reasonable price. The well-known D1 10-300 Mc/s signal generator is now modified as D1/D with direct-reading voltage and frequency scales. Its inductive continuously variable 20-db attenuator, as well as the familiar resistive step attenuator, is now separately available. The 300-1,000 Mc/s L1 signal generator shown last year is now in production, and its piston attenuator is separately available. It works in the H_{11} mode, is provided with a screen to exclude E modes, and a crystal diode for monitoring the output, and its attenuation range is 126 db. The Standard Telephones QD2, a high-performance signal generator covering the range 96-160 Mc/s, also employs a piston attenuator, calibrated in decibels and millivolts or microvolts from 0.5 V-100 mV to an accuracy of ±1 db. Particular attention has been paid to linear modulation up to 90 per cent depth at frequencies 30 c/s-10 kc/s. The extensive "Windsor" range of Taylor testgear will shortly include a synchronized TV pattern generator having a carrier range of 40-240 Mc/s and output approximately 50 μV-10 mV, available for either 405-line or 525-line standards.

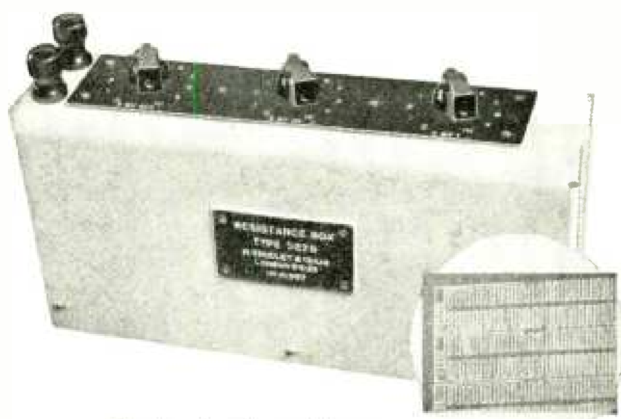
A considerable amount of new microwave apparatus was shown this year, including X-band (3 cm) waveguide test benches by Decca, Elliott, Ferranti, Marconi Instruments, and Metrovick. The Ferranti outfit is a break-away from the usual assembly of pipes, the guides being milled out of the two halves of a light-alloy block. Another of its notable features is a three-klystron input, to facilitate measurements at several spot frequencies without re-adjustment. The attenuator elements in most microwave equipment are thin nichrome films deposited on rhomboidal glass slips, giving a wide frequency range and little reflection. For use with the Elliott X-band torque-vane wattmeter shown last year there is now an artificial load with ceramic element and a quarter-wavelength slider for the elimination of standing-wave errors. A different approach to the standing-wave problem is shown in the Wayne-Kerr instrument, which contains two vanes on the same suspension, separated by quarter of a wavelength, as shown in Fig. 2. The same firm also demonstrated an X and S band Q meter, incorporating a new klystron oscillator unit obtainable separately. The Q meter oscilloscopically compares the decay of oscillations in a resonant cavity with the known rate of a capacitor discharge, and an accuracy better than ±1% is claimed.



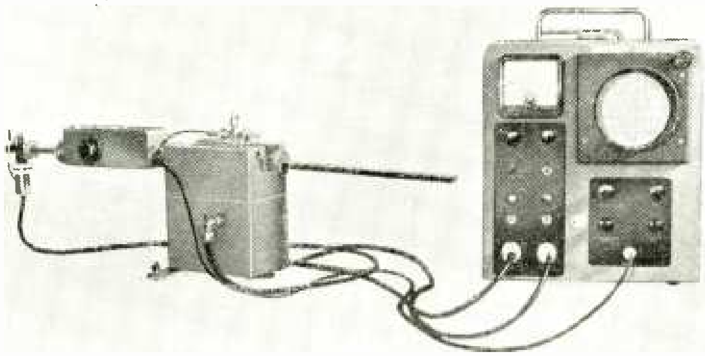
Sullivan decade air-dielectric capacitor; the capacitor marked "units" is 10 pF and continuously variable.



Transmitter and receiver performance tester made by Wayne-Kerr.



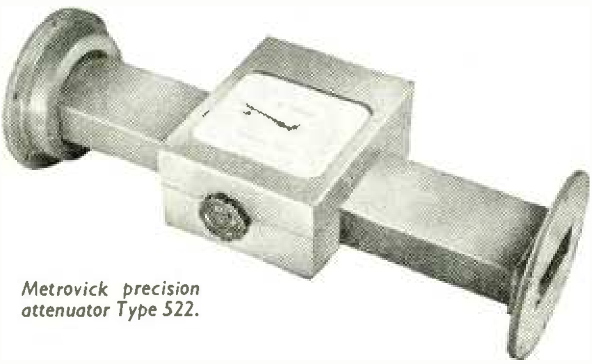
Tinsley decade resistance box with (inset) part of one of the printed circuit units.



Marconi Instruments automatic standing-wave indicator.

The remaining instruments fall outside the foregoing categories. The Marconi Instruments TF982 mobile v.h.f. test set, for example, includes almost everything: r.f. oscillator, a.m. modulator, a.f. oscillator, i.f. check with four crystals, r.f. power meter, a.f. power meter, multi-range test set, attenuator and terminating unit. Another new exhibit by the same firm was the TF1054 radio-noise and field-strength measuring equipment for the range 0.15-2.4 Mc/s. The TF1055 is the same except for frequency range 2.4-30 Mc/s. They will be used to test compliance with the new legal requirements for the suppression of interference, and consist of two receivers with loop and rod aerials; gain is standardized by a noise diode. Similar models are being produced to extend the frequency range up to 600 Mc/s. The Wayne-Kerr Test Set X740A is a Service instrument for the comprehensive testing of v.h.f. transmitter-receivers by non-technical personnel. Although weighing only 16 lb, it includes a.f. and r.f. signal generators, v.h.f. wattmeter and a.f. output meter, and the results of measurements are indicated as "Pass" or "Reject." Tests include transmitter power output, noise, and modulation depth, and receiver sensitivity and noise. Development of the accurate Solartron feedback voltmeter already mentioned necessitated precise calibration, and the instrument for doing this was shown, as model AT203, since it is of general utility for use with amplifiers, valve voltmeters, etc. It takes a 10-V signal at 0-300 kc/s, provides a meter check of correct level, and subdivides it down to 10 μV. A new Cintel frequency monitor has been produced, similar in technique to other models by this firm, but with a frequency range extended to 20 Mc/s. Frequencies over 10 Mc/s are divided by 10 for measurement. The oscilloscopic spectrometer by Salford Instruments contains 38 filters which analyse an incoming signal and present the relative outputs as vertical lines on the c.r.t. screen. The range is 10 c/s-100 kc/s. C.r.t. presentation of families of valve curves has been adapted by Mullard for transistors, and is obviously a great labour saver. A frequency-standardizing equipment by British Physical Laboratories uses the B.B.C. broadcast transmission on 200 kc/s to control a chain of multivibrators and a clock; accuracy about 1 in 10^6. The same firm showed a frequency discriminator for giving direct reading of the difference between two frequencies. A possible application is the reading of weather conditions from radio sondes. Servomex demonstrated a great improvement on the usual rather crude method of testing stickiness of meter movements. The equipment consists in effect of a 3-speed slow time base. An important feature is protection against external surges, etc., that would otherwise cause misleading irregularities in the movement of the pointers.

Reverting to Elliott X-band equipment, other well-engineered items are a precision wavemeter of the piston type with a resetting accuracy of 0.0003 in, with clock-gauge method of position indication within 0.01 mm. Equipment for the 0.9 cm band was also shown. The trend towards cleaner exteriors and the use of clock gauges for position indication was also exemplified on the Metrovick stand. Standing-wave-ratio measuring gear by Marconi Instruments incorporated a mechanically reciprocated receiver probe and a c.r. display. Barr & Stroud, besides a nichrome/glass attenuator, showed an automatic X-band aerial diagram plotter, recording in cartesion form on Teledeltos paper. The previously shown Ekco plotter is now "tidied up," and an interesting feature of the demonstration was the "free-space" cabinet for the aerial, lined with aquadag-coated slats—analogous to the acoustic rooms used for testing loudspeakers.



Metrovick precision attenuator Type 522.

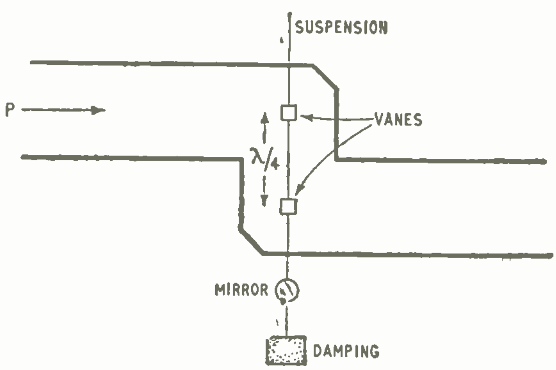


Fig. 2. Suspended-vane Wayne-Kerr waveguide wattmeter; two vanes are used to minimize standing-wave errors.

Interference Suppression

BRIEF reference is made to the work on the design of inexpensive radio-interference suppression chokes with ferromagnetic cores, undertaken by the British Electrical and Allied Industries Research Association during the past year, in the 33rd annual report of the E.R.A. A comprehensive survey, however, of this work has been prepared under the title "The Properties and Design of Iron-Cored Suppression Chokes," by J. Miedzinski, B.Sc., and will eventually be available from the E.R.A., Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Further reports on the properties of the core materials are being prepared.

Reference is also made in the annual report to the work undertaken on the measurement of radio interference from high-voltage transmission lines and a survey covering this investigation is in course of preparation.

Plotting Aircraft Positions

AN aircraft plotting system in which the radio bearings from a number of direction-finding stations are passed automatically to a traffic control centre and there displayed on a map of the service area has been developed by Standard Telephones and Cables. It is intended to operate primarily in conjunction with a network of S.T.C. cathode-ray v.h.f. direction finders Type PV1B, but it is possible to adapt it for use with certain other types of v.h.f. direction-finding equipments. It enables the position of an aircraft to be determined by radio bearings taken on v.h.f. telephone messages and the time taken to fix its position is less than that normally required for the aircraft to establish its identity. The actual position can be passed back on completion of the identifying or other message.

The principal equipment required at the position-finding centre is a display cabinet fitted with a ground-glass screen on which is engraved a map of the service area showing the usual topographical features and any other special data required. The screen can be either 40 in or 60 in square.

Mounted at the back of the cabinet is an assembly of projection cathode-ray tubes, each corresponding as closely as possible to the position of the d.f. stations comprising the network. These projector units are similar to those used in projection television receivers, but have deflector coils designed to give very high angular accuracy. They project a rotatable trace on to the map as shown in the illustration. The point of intersection of three such traces, as in normal radio d.f. practice, gives the position of the aircraft.

Signals for operating the display are sent automatically by the d.f. stations as soon as a bearing is determined, and there is no delay beyond that needed for the bearing and with the PV1B equipment it is almost instantaneous. The signals can be sent over any ordinary communication channel, line or radio, so that the position-finding centre can be located at any convenient site inside or outside the service area of any of the d.f. stations.

The d.f. stations need not necessarily be devoted exclusively to this aircraft position-finding system and in the case of the PV1B equipment the addition of a telemeter sending attachment enables it simultaneously to perform local services at aerodromes.

Display screen of the S.T.C. aircraft position-finding system showing bearings automatically relayed from three d.f. stations.

RANDOM RADIATIONS

By "DIALLIST"

Any Old Tubes?

SOME TIME AGO a wireless dealer told me of an episode which had been puzzling him quite a bit. A small van arrived at his shop one day. From it descended a couple of "spiv" types, who asked if he'd any discarded television c.r. tubes, offering to pay good money for any that passed a "little test." Not liking the look of the men and realizing that they were up to no good, he chased them out. But what could their particular ramp be? What on earth could they do with cast-off c.r. tubes? The answer, as he had just discovered when I saw him a day or two before writing this, was tied up with the fact that none that he might have offered would have passed that "little test." He is a skilled man, who looks after his customers well, reactivating (where possible) tubes whose emission is down and giving a new lease of life to any suffering from cathode-to-heater short-circuit by fitting an isolating transformer. Any tube that he discards is a genuine dud. The aforesaid test would have led to the purchase of any tube if it suffered from nothing beyond the defects mentioned. Not all dealers are as scrupulous or as skilled as he is and anyway the isolating transformer can't be used where the mains supply is d.c. These things had made it well worth the while of his unsavoury visitors to equip themselves with a small motor van and to make dealing in discarded cathode-ray tubes a whole-time job.

Service!

How do they make their profit? My dealer had found the answer to that question when spending the Easter holiday with an entirely non-technical relative of his in another town. The relative, who owns a 15-inch television receiver, had been roped in to subscribe to a ridiculously low-priced all-in maintenance scheme operated by newcomers to the neighbourhood. He was delighted with it: "Other firms wouldn't insure my set because it is nearly two years old. But *they* did; and when the tube passed out last week they fitted a new one without a murmur." My dealer asked whether the present tube carried a guarantee: "They say that they keep that, as they're maintaining the set." He asked whether the dark patch in the middle of the screen was there when the set was returned with its replacement tube: "Oh, yes; they tell me that these tubes always have it when new, but that it soon wears off." Whipping off the back of the set the dealer found, as he'd come by now to expect, that the "new" c.r. tube had been provided with an isolating transformer for its heater. I'm not saying that this is what is done with all the c.r.t. throw-outs that are bought; there may be perfectly legitimate uses that I am not aware of for some of them. But this incident certainly provides food for thought.

Those D—d Dots

FOR SOME TIME now I've been suffering from an annoying form of television interference: innumerable white dots peppered in random fashion all over the screen. At first sight one might think that an unsuppressed motor-car engine had been left running rather fast some little way from the house. But that isn't the answer, for it's always there: Saturdays, Sundays, every day; and at all hours, even the small ones. Having found that all my neighbours were experiencing the same thing, I made a report to the Post Office and two of their engineers arrived to investigate. Well, I hardly need say that the interference was *far* less intense than I'd ever known it in many weeks, and as we watched the screen it became feebler and feebler. When they made a tour round the neighbourhood they couldn't get so much as a smell of it, even with their most sensitive apparatus. Shortly after they'd gone it was back again as bad as ever. One can't help wondering whether the person responsible for the interference spotted the Post Office van and took action accordingly.

A Grim Business

RECEIVING a present from a friend on the Continent can be no light matter in the queer times in which we live. Early in April I heard that a pair of valves of a new type were on their way to me. Time passed. Then came a letter from the Customs folk, asking me to complete section so-and-so of the enclosed form. This was almost as big as one's daily newspaper, but my section consisted of only about half a dozen questions. There was a footnote to the effect that the questionee should reply "Not Known" to any to which he didn't know the answers. As I did not know the weight, the value and so on, this didn't take long. Having signed and dated the document, I returned it with a letter assuring Her Majesty's Officers that I had no intention of selling these articles and that they were purely for my own use for experimental purposes. When the package eventually turned up I found that it bore a label, attached by the sender, on which were the answers to all the questions to which I'd had to reply "Not Known!"

Here's Hoping

BY THE TIME that you read this the international exchange of television programmes will probably have had some trial runs. I hope sincerely that the whole thing will be a real success for it's an excellent idea. I trust that the fears expressed to me when the whole thing was very much in the embryo stage by one of those concerned in trying to organize it will prove completely baseless. "How's the eight-nation hook-up coming along?" I asked. "The gods send it isn't an eight-nation muck-up," was his gloomy reply!

Try It : It Works!

ISN'T IT about time that the powers that be stopped kidding themselves (and trying to kid others) that the policy of persuading people to fit suppressors to motor vehicles is ever going to be successful? From checks that I've made on vehicles passing my own house I'd say that somewhere about 80 per cent of the cars, vans and lorries over a year old continue to radiate interference as freely as ever. If the authorities won't bring pressure to bear, there's one way in which owners of television receivers can. Comparatively few tradesmen seem to have "suppressed" their lorries and delivery vans. When the arrival of your groceries, fish or coal results in a snowstorm on the television screen, or in unpleasant noises from the loudspeaker of the short-wave receiver, a 'phone call to the owner of the offending vehicle to the effect that, if he doesn't mend his ways and spend the necessary couple of shillings on having a suppressor fitted, you'll find another supplier, usually produces rapid and satisfactory results.

UNBIASED | By FREE GRID

$R=V^2+3W$

THE cryptic title to this item, "lifted" direct from the pages of *Amateur Photographer*, lends support to the doubts I cast last month on the somewhat dogmatic statement of an A.M.I.E.E. that repeatedly switching on and off an electric lamp —and by legitimate inference a thermionic valve—does nothing to shorten the life of the filament.

Forcibly impressed

If the writer in *A.P.* and the official publication of a well-known lamp and valve manufacturer, which he quotes, be correct (and who should know better than a manufacturer of these devices?) the switching process *does* shorten filament life owing to the heavy initial surge of current through the cold filament. The writer does not say *why* this heavy initial surge of current shortens its life but surely it can be for no other reason than that it causes a very large and sudden expansion of this delicate thread of wire.

The lamp and valve manufacturer's publication suggests the use of a series resistor—which can be shorted out after a few seconds—to combat this. It also gives the formula at the head of this note for calculating the value of the resistor; R being the required resistance in ohms, V the voltage applied to the lamp and W the lamp wattage. It is useless for those opposed to my views to say that this initial surge is serious only in the case of over-run photographic floodlights, for projector lamps are also mentioned and these are *not* over-run devices. The *A.P.* expert further states that the argument applies to "all filament lamps."

I admit, however, that it does apply in lesser degree to ordinary domestic lamps owing to their lower running temperature and in even less degree to valves with their comparatively low-temperature dull-emitter filaments, but it does apply *a bit*. Could anything meet the case more aptly than the schoolboy's translation of the well-known Latin tag "*Magna est veritas et prevalebit*," namely, "Great is truth and it shall prevail a bit?" I myself recollect so translating this tag in my youth and the enormity of my error was so forcibly impressed on me that its recollection still prevails more than a bit. In this case the truth I spoke about filament life prevailed—at any rate a little bit.

Clinical Radiometry

IT IS astonishing what little use we make of the vast resources of electronics to lessen the labour of man by relieving him of irksome repetitive tasks that could be better done by a machine.

A glaring instance of this came to my notice recently when I happened to be in a hospital ward where several patients were recovering from the immediate effects of an operation which, as after all operations, meant that a nurse was kept trotting round every half-hour to take each patient's pulse and recording it on a chart.

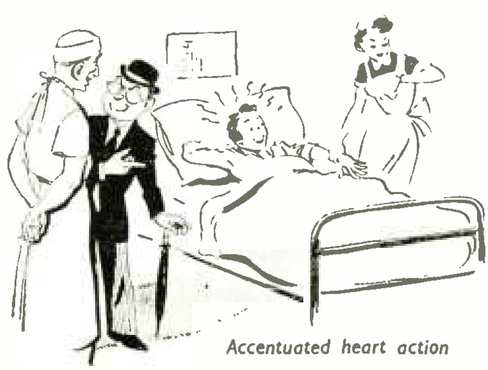
Apart from the fact that it disturbed the patient to be seized by the wrist and manhandled—or should it be womanhandled?—just when he had fallen into a doze it was obvious that, in this particular men's ward at any rate, entirely false readings were being obtained. As the nurse was an exceptionally attractive-looking girl her approach every half-hour accentuated the patient's heart action and in some cases caused it to miss a beat.

This sort of thing causes cardiac strain at a time when it can least be tolerated and the pulse readings are not, of course, a true reflection of the patient's post-operative condition. I pointed this out to the house physician, who at once grasped my point, and the pretty nurse, and replaced her by a more homely looking specimen of her profession with medically satisfactory results.

All these undesirable effects could be avoided and the nurse released for other duties if use were made of the radio-sonde principle whereby changes in the many meteorological "variables" are continually transmitted.

In these days of miniaturization it should not be difficult to construct a micro-wave transmitter not much bigger than a wrist watch. Each transmitter in a ward would work on a slightly different frequency and would radiate a few yards to the ward-sister's office where heartbeats could be read at once and at any or every moment from a battery of small c.r. tubes, one for each patient; any glaring irregularities could be made to cause a red light to flash in order to attract attention. If necessary, film recordings could be made.

By various modifications temperatures and other variables could be similarly transmitted. Maybe the sub-miniature wrist transmitters could be made simpler if they merely had to feed induction signals to a copper band around the ward; a technique about which I wrote last month.



Accentuated heart action

Does It Matter ?

HALF-TRUTHS are notoriously dangerous, far more so, in fact, than honest straightforward lies and it is for this reason that I am sorry to see the radio correspondents of certain newspapers telling their readers that television stations have not the coverage of ordinary sound broadcasting stations because TV waves, unlike ordinary radio waves, can only travel in straight lines.

This is such a glib and simple explanation that it is swallowed without question by the lay mind and if you try to challenge it the layman who has accepted it is apt to be rather resentful at any attempt to rob him of it; he usually asks somewhat truculently what is your explanation of the undeniable facts of the case that the reliable range of TV stations is not much more than an optical one. You usually find yourself launched on a full-scale lecture on wave propagation which is far beyond your hearer's understanding and so he soon loses patience and dismisses you as a charlatan.

Perhaps after all it is better to let the public stew in the technical heresies which it loves. Does it matter, for instance, that most people believe that George Stephenson invented the steam locomotive or that Watt invented electric lamps and fires?