Kelly

Electronic Engineering

Incorporating . . . ELECTRONICS, TELEVISION & SHORT WAVE WORLD

VOL. 20 No. 243 MAY 1948 PRICE 2/-

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements is twelve words or less 5/- and 4d. for every additional word. Box number 2/- extra, except in the case of advertisements in "Situations Wanted" when it is added free of charge. A remittance must accompany the advertisement. Replies to box numbers should be addressed to: Morgan Bros. (Publishers) Ltd., 28, Essex Street, Strand, London, W.C.2 and marked "Electronic Engineering." Advertisements must be received before the 10th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

acancies advertised are restricted to persons or employ-ents excepted from the provisions of the Control of ngagement Order, 1947.

NIVERSITY COLLEGE, SOUTHAMPTON, vites applications for the post of Lecturer in the echnical Department, University College, Southamp-n, for City and Guilds Telecommunications up to rade 3. Salary Burnham Scale. Further particulars ay be obtained from the Technical Officer with whom pplications should be lodged by 12th June.

.B.C. invites applications from men (British) for three nior instructional posts in the Engineering Training epartment at Evesham. Candidates must be gradu-es in Electrical Engineering or Physics with a sound nowledge of radio fundamentals and a good math-atical background. Teaching, research or manu-cturing experience and ability to write technical ticles or manuals are required. Candidates must addition possess either (1) fundamental knowledge nd practical experience in U.H.F. techniques (up to oo Mc/s); or (2) research or development experience audio frequency problems involving lines, and/or cording and acoustics; or (3) research or develop-ent experience in radio frequency measurements and the application of electronics to remote control echanisms. The salaries are on a grade rising by nual increments of £40 to a maximum of £840 r annum. Applications, stating age, qualifications d experience should reach the Engineering Estab-ment Officer, Broadcasting House, London, W.1, thin 7 days of the appearance of this advertisement.

B.C. invites applications from men (British) for e post of radio engineer in the Planning and Instal-ion Department in London. Applicants who should t be less than 30 years of age, should possess a iversity degree in Electrical Engineering or equivalent alifications, coupled with radio transmitter theory d practice. A knowledge of F.M. and television ould be advantageous. The successful candidate ist be able to conduct correspondence generally d in particular must have a knowledge of specifi-tion writing and the management of tenders and ntracts. The salary is on a grade rising by annual rements of £35 to a maximum of £785 per annum. plications, stating age, qualifications and experience ould reach the Engineering Establishment Officer, oadcasting House, London, W.1, within 7 days of e appearance of this advertisement.

.B.C. invites applications for the post of Engineer the Audio Frequency Section of Research Depart-ent. The successful candidate will be based initially Nightingale Square, Balham, and later at Kingswood, ar Banstead. Candidates must possess a university gree in Physics or Electrical Engineering or equivalent alifications, while some knowledge of electrical mmunication, electrical measurements and micro-one and loudspeaker technique would be an vantage. Some musical ability is desirable. The rk includes research on microphones and loud-eakers in addition to other aspects of audio frequency search and development. The salary is on a grade ing by annual increments of £25 to a maximum £580 per annum. Applications, stating age, qualifi-tions and experience, should reach the Engineering tablishment Officer, Broadcasting House, London, .1, within 7 days of the appearance of this advertise-ent.

.B.C. invites applications for two posts in the gineering Training Department: (a) Lecturer, sed at Evesham. The duties will include the teaching Physics (sound, light and heat) and also in assisting the solution of mathematical problems associated th the development work of the Department. perimental ability and teaching experience will be asset. Applicants should possess a degree in athematics with physics as a subsidiary subject. Technical Instruction Writer, based in London. ndidates should possess a degree, Higher National rtificate or similar qualifications in electrical engin-ring or physics and have a good knowledge of the dio frequency aspects of broadcast engineering. ility to write clearly and concisely and to interpret ecialist technical reports is essential. Proof of this ll be required at an interview. The salary in each se is on a grade rising by annual increments of £35 a maximum of £735 per annum. Applications, ating age, qualifications and experience, should reach e Engineering Establishment Officer, Broadcasting ouse, London, W.1, within 7 days of the apppearance this advertisement. Please quote E.T.D.1.

THE COLLEGE OF AERONAUTICS. Lecturer in Electronics. Applications are invited for the post of Lecturer in Electronics. The syllabus to be covered consists mainly of the elements of the subject, with some advanced teaching for specialist students, and the principles of airborne radio and radar equipments. Previous experience of such equipments and centimetre-wave technique is desirable but not essential. There is good opportunity for research into the application of electronic techniques to aeronautical problems. Salary, plus superannuation under the Federated Superannuation Systems for Universities, according to qualifications and experience.
Applications, giving full details of qualifications and experience should be marked " Lecturer in Electronics" and sent to the Registrar, The College of Aeronautics, Cranfield, Bletchley, Bucks., from whom further information may be obtained.

UNIVERSITY OF MANCHESTER. Two Technical Assistants are required for the construction of electronic apparatus in the Electrical Engineering Department of the University. Salary will be according to age and experience. Superannuation scheme and children's allowance. Applications should be sent to the Steward, Electrical Engineering Laboratories, The University, Manchester, 13.

SITUATIONS VACANT

SENIOR RADIO ENGINEER required for large industrial concern operating in the Middle East. Applicants should have had at least seven years' experience in technical installation, operation and maintenance of M/F., H/F. and VH/F. communication transmitters, superhet receivers and high-speed W/T systems. A knowledge of carrier current technique advantageous. Age not over 35, Secondary School education. Attractive salary plus generous allowance in local currency. Free passage out and home, medical attention, kit allowance and furnished bachelor accommodation. Write, giving age and full particulars of qualifications and experience, quoting Department F.96, to Box 1076 at 191, Gresham House, E.C.2.

FERRANTI LIMITED require for Vacuum Physics Laboratory Physicists or Engineers, graduates or with equivalent qualifications, preferably with experience of electronic vacuum work or U.H.F. valves. Application forms from Personnel Manager, Ferranti Limited, Ferry Road, Edinburgh, 5.

THE PLESSEY CO. LTD., Vicarage Lane, Ilford, have vacancies for senior radio engineers and designers capable of initiating the design of radio and television receiving equipment. Suitable applicants must possess adequate technical qualifications and experience of the industry. Apply stating age, qualifications and experience to the Personnel Manager.

CHIEF ENGINEER and Physicist required by large manufacturer in the south to take charge of important department engaged on practical microwave develop-ment. Essential qualifications are adequate technical education and practical experience in this field of radio. Applicants should state qualifications, experi-ence and age to Box 258, E.E.

EXPERIENCED DESIGNER of domestic radio receivers required by manufacturers in district south-west of London. Knowledge of television technique an advantage. Write stating details of qualifications and salary required to Box No. D 718 c/o Streets, 110 Old Broad Street, E.C.2.

REPUTABLE EXPORTERS now expanding require for their Electrical Engineering Department, expert to take over existing connexions and build up new ones. Plenty of scope and excellent prospects for right man. Good salary and share profit. Write for interview stating experience to Box 252, E.E.

VALVES AND ELECTRONIC VACUUM TUBES. Production Engineer required to take charge of small production unit. Experience on similar work essential. Good salary and prospects for experienced man. Apply Personnel Manager, Ferranti Ltd., Ferry Road, Edinburgh, 5.

ELECTRONICS ENGINEER, H.N.C. or Degree standard, age 30/40, five years experience required by Research Section of large engineering firm in the Midlands for the construction of the vibration indi-cating and recording gear, strain gauge recording apparatus and the maintenance of laboratory equipment. 5-day week. Reply stating age, experience and salary required to Box No. 440, 8 Serle Street, London, W.C.2.

REQUIRED AS TECHNICAL ASSISTANT to Chartered Patent Agent in Patent Department of the General Electric Co. Ltd., at Research Laboratories, Wembley, Middlesex, a young man with an Honours Degree or similar qualifications and preferably with some experience or knowledge of radio engineering and electronics. The assistant would receive training for qualification as a Chartered Patent Agent. Apply by letter to the Director, stating age, academic quali-fications and experience.

GLASS BLOWER required for Vacuum Research Laboratories, experienced in bench and lathe work. staff appointment for competent man, permanency. Salary including cost of living allowance up to £500 per annum. Apply Personnel Manager, Ferranti Ltd., Ferry Road, Edinburgh, 5.

RADIO ENGINEER required for development of methods of testing and measuring U.H.F. valves and T.R. switches. Applicants must be qualified in Physics or Engineering and must have experience of radio measurements, preferably but not necessarily in the U.H.F. field. Application to Personnel Manager (CHA), Ferranti Ltd., Edinburgh, 5.

R.M. ELECTRIC LTD., Team Valley, Gateshead, 11, have vacancy for Works Manager. Applicant must be conversant with time study, piece work and modern radio production methods. Apply stating age, experience and salary required.

E.M.I. ENGINEERING DEVELOPMENT LTD., Hayes, Middlesex, have a number of vacancies for intermediate and senior engineers between the ages of 25 and 35, for the development and design for pro-duction of communication receivers and transmitters, cathode ray tubes and transmitting valves. It is essential that applicants should have qualifications of degree standard, and have a practical experience in the development field: for the senior posts at least five years actual design experience is required. The inclusive starting salary of these posts is from £400 to £700 according to age and experience, with additions for exceptional qualifications or design experience. In addition there are vacancies in the junior and inter-mediate grades (£325 to £500 with degree qualification) for work on other electronic developments, both of the circuit and of the vacuum physics classes. Write stating age and full details of qualifications and experience to Personnel Department, E.M.I. Limited, Blyth Road, Hayes, Middlesex.

CHEMIST OF PHYSICIST required to establish and take charge of a research laboratory for the develop-ment of new magnetic and dielectric materials for the radio and light electrical industry. Applicants must have an Honours degree in science and experience of initiating and administering a research department. The laboratory is situated in the country and accom-modation is available in the locality. Salary offered is £800-£1,000 per annum, commensurate with qualifications and experience. Box 253, E.E.

DRAUGHTSMEN required for Radar, Telecommuni-cations and Electro-mechanical instruments. West London area. Apply in confidence, stating age, details of experience and salary required to Box 256, E.E.

JUNIOR DEVELOPMENT ENGINEER required to work on the development and engineering of Large Screen Television Equipment. Degree not necessary, but commercial experience in work of a similar nature essential. Write, stating age, qualifications and salary required to Cinema-Television Limited, Worsley Bridge Road, Lower Sydenham, S.E.26.

TELEVISION ENGINEER required by R.F. Equip-ment (Sobell Industries) for laboratories situated at Hirwaun, Nr. Aberdare, Glamorgan. Write in first instance to Personnel Manager stating qualifications, experience and salary expected.

PHYSICIST REQUIRED, specialising in high vacuum work and, in particular, having experience in the research and development of photo-electric cells and Geiger-Muller Tubes. Applicant will be preferred who has previous experience in this field and a know-ledge of production methods would be considered an advantage. Write, giving full particulars of degrees, qualifications and experience, age and salary required, to Box 260, E.E.

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CLASSIFIED ANNOUNCEMENTS (Cont'd.)

SENIOR ENGINEER required for an important position in charge of department engaged upon design and development of electronic instruments. Applicants should have been engaged on development work for some years and production experience would be considered an advantage. Write, giving full particulars of degrees, qualifications, experience, age and salary required, to Box 261, E.E.

SENIOR GLASSBLOWER required for industrial laboratory engaged mainly in development of electronic devices for television purposes. Thorough practical knowledge of glass manipulation required, bench and lathe work, hard and soft glasses, glass to metal sealing, etc. Apply giving age, experience and salary required to Pye Ltd., Meadowcroft Laboratories, Church Street, Chesterton, Cambridge.

OLD-ESTABLISHED Radio Component manufacturers desire to engage physicist-engineer with wide knowledge of centimetric wave guide technique and applications. Full details including age, education and previous employment will be treated in strict confidence. The Company's own staff are aware of this vacancy. Box 264, E.E.

YOUNG, KEEN and energetic representatives required, with some electrical and technical background, for large cinematograph equipment Company. To operate and reside in the Liverpool, Manchester and Cardiff areas. Splendid opportunities with full company support. Give career details, present occupation and minimum salary required to Box 265, E.E.

PERA requires an instrument designer with electrical and mechanical experience. Applications giving full details of experience, qualifications, age and salary required to the Secretary, Production Engineering Research Association of Great Britain, Staveley Lodge, Melton Mowbray, Leics.

A LARGE VALVE MANUFACTURERS (S.W. London) require graduates in Physics or Electrical Engineering as senior assistants for their cathode ray tube development department. Candidates MUST have had experience in design of cathode ray tubes or similar articles, should have a knowledge of electron optics and tube structures, and be capable of originating and supervising development work. Salary £700 plus, according to age, experience and qualifications. Reply to Box E.E. 583, L.P.E., 110, St. Martins Lane, W.C.2, and quote reference, C/123.

SITUATIONS WANTED

GENERAL MANAGER, 40, free now to take full control of sales, development, buying and production in small or medium sized firm in electro-mechanical, electronic or radio engineering industry. Extensive experience backed by excellent technical qualifications, A.M.I.E.E. Available interview London immediately, elsewhere 24 hours notice. Phone LABurnum 3580 or write to Box 259, E.E.

R.A.F. SERGEANT Radar Fitter, 21, C. & G. intermediate, entered mid; at present instructing signals officers in airborne radar, available July, seeks progressive position radio or electronics. Box 262, E.E.

INDIAN, 23, with 1st class Hons. and research M.Sc. qualifications in physics and 3 years radio research experience, seeks suitable employment in industry. Now doing a post-graduate course in electronics at University College, Southampton. Ready to join in September. Please reply to M. Krishnamurthi, Connaught Hall, Swaythling, Southampton.

ENGINEER, 24, Grad.I.E.E., etc., experienced in transient recording and electronic devices, requires position on development offering scope for ingenuity. Box 251, E.E.

CIVIL ENGINEER, 32, would like to act with authorities (a) engaged publicising oil and mineral exploitation, (b) geophysical survey team, (c) instrument design, (d) research on drilling and mining technology. Box 263, E.E.

BUSINESS OPPORTUNITIES

SOUND PRACTICAL RADIO ENGINEER, 37, desires partnership small progressive radio firm near sea coast. Invest up to £1,000. Principals only write Box 255, E.E.

EDUCATIONAL

COMPLETE CORRESPONDENCE COURSE covering Amateur and C. and G.I. Examinations, consisting of 12 lessons. Send for particulars. Everyman's Correspondence College, 72, St. Stephen's House, Westminster, S.W.1.

A.M.I.E.E., City and Guilds, etc., on "NO PASS—NO FEE" terms. Over 95 per cent. successes. For full details of modern courses in all branches of Electrical Technology send for our 112 page handbook—FREE and post free. B.I.E.T. (Dept. 337B), 17, Stratford Place, London, W.1.

SERVICE

LOUDSPEAKER repairs, British, American, any make, moderate prices.—Sinclair Speakers, 12, Pembroke Street, London, N.1.

FACTORY HAS TECHNICAL Staff and capacity available for manufacturing scientific or other articles in glass. Box 103, E.E.

GLASS. For special lamp-blown glassware and high vacuum work, send your enquiries to Neon Excelda Co., 11 Sheepcote Street, Birmingham, 15.

TECHNICAL ABSTRACTS BUREAU. A committee of electronic engineers and physicists with Central London library facilities is prepared to compile and supply abstracts of published researches, patent abridgements and specifications. Expansions of bibliographies, library researches and technical reports made as required. Replies to BM/FIDY, Monomark House, W.C.1.

MISCELLANEOUS

WE WILL BUY at your price used radios, amplifiers, converters, test meters, motors, pick-ups, speakers, etc., radio and electrical accessories. Write, phone or call, University Radio Ltd., 22, Lisle Street, London, W.C.2. GERrard 4447.

PHOTOGRAPHY. We specialise in advertising and catalogue-photography, and in series photographs for instruction sheets. Our pictures tell the story. Behr Photography, 44, Temple Fortune Lane, N.W.11 (SPEedwell 4298).

WEBB'S 1948 Radio Map of World, new multi-colour printing with up-to-date call signs and fresh information; on heavy art paper, 4s. 6d., post 6d. On linen on rollers, 11s. 6d., post 9d.

FOR SALE

NEW ARMOUR MAGNETIC Steel Recording Wire on standard spools, in maker's sealed tins. 60 minutes' speech or 30 minutes' music playing time. £3. Harris, Strouds, Pangbourne, Berks.

COPPER WIRES, enamelled, tinned, litz, cotton, silk covered. All gauges. B.A. screws, nuts, washers, soldering tags, eyelets. Ebonite and laminated Bakelite panels, tubes, coil formers. Tufnol rod. Flexes, permanent detectors, earphones, etc. List S.A.E. Trade supplied. Post Radio Supplies, 33, Bourne Gardens, London, E.4.

EX-R.A.F. Loran Indicators with 5 in. electrostatic c.r.t. with time base. 26 valves including 6SN7, 6H6, 6SJ7 and calibrated 100 Kc crystal, suitable for conversion to oscillograph, £10. Box 220, E.E.

IN STOCK. Rectifiers, Accumulator Chargers, Rotary Converters, P.A. Amplifiers, Mikes, Mains Transformers, Speakers of most types, Test Meters, etc. Special Transformers quoted for.—University Radio Ltd., 22, Lisle Street, London, W.C.2. GERrard 4447.

TEST METERS, Triplett, 10-5,000 volt A.C. D.C., 10-500 mA D.C., 3,000-250,000 ohms resistance. Government surplus, £5 10s. Ball-type microphones 15 ohms coil, £5 2s. 6d. Hand M.C. Microphones with 40 yards screened lead and jack plug, £4 10s. Cabinets, car radio, pierced for speaker, few only, 12s. 6d. Speakers, P.M., 2½ in., 18s. Tuning Condensers, twin 400 pf with spindle 1 in. long, ⅜ in. dia., 5s. Twin 480 pf with 2½ in. drive drum, 7s. 6d. Small Mica Condensers, 0.01-0.0005 mfd., parcel of 50 for 10s. 6d. High Voltage Condensers 0.01 mfd. 5,000 v., 1s. 6d.; 0.02 mfd., 8,000 v., 2s. 6d.; 1 mfd., 1,200 v., 3s. 6d.; 0.1 mfd., 2,500 v., 1s. 3d.; 0.25 mfd., 2,000 v., 1s. 3d.; 0.1 mfd., 1,200 v., 1s.; 2 mfd., 1,000 v., 3s. 6d.; 4 mfd., 1,000 v., 6s. EA50 valve holders, 3s. per dozen. Heavy Duty Chokes, 350 ohm, 150 mA, 12s. 6d.; 150 ohm, 200 mA, 14s. 6d.; 2,000 ohm, 300 mA, 16s. 6d.; 100 ohm, 500 mA, 22s. 6d.; 100 ohm, 700 mA, 35s. Vibrators, 6 volt 4-pin UX, 8s. 6d. Flexible insulated shaft couplings, ¼ in. spindles, 1s. 3d. Write for list of these and many other bargains. Frank Shirley, 20 Hanson Street, London, W.1.

"ELECTRONICS":—1940-1 inclusive 9s. the year; 1942-7 inclusive 12s. the year; or the lot £3 10s. carriage free. T. G. R. Dowsett, 48 Grove Road, Eastbourne.

NEW HIGH FIDELITY LOUDSPEAKERS: the Tridem 10 corner baffle £12. Incorporates high efficiency 10 in. unit, twin bass vented chambers. The Tridex Superb £37 10s. 12 in. and 5 in. with crossover network. Response even 40-12,000 c.p.s. Full details from [illegible] Sound Reproducers Ltd., [illegible] Upper Richmond Road, London, S.W.[illegible]

ENAMELLED, D.S.C. and S.C.C. Copper Wire in all gauges. Any quantities ex stock at 50 per cent. under market price. Enquiries invited stating gauges required to Box 254, E.E.

THE ENOCK PICK-UP is now available in limited quantities. Moving coil with precision ground polished diamond stylus. Weight at needle point [illegible]. No resonances within the recorded range. Price, £30 15s. 0d. [illegible] tax. Full particulars from Joseph Enock Ltd., 275a High Street, Brentford, Middx. EALing 5105.

THE MORDAUNT DUPLEX REPRODUCER, as used in the Enock Instrument, is now available separately. Folded horn bass unit and new high note reflector of original design giving exceptionally smooth response from 40-20,000 c.p.s. Even distribution over a wide angle. Reproduction has an "atmosphere" and realism hitherto unattainable. Price (ex works) 65 gns. Please send for particulars or better still, let us demonstrate. Joseph Enock Ltd., 275a High Street, Brentford, Middlesex. EALing 5105.

SIGNAL GENERATORS. Type 101 by R.G.D. 370-645 Mc/s. Type 100 by S. Bond Instruments 5-9.55 Mc/s. cont. Int. Mod. 1,000 cycles. Marconi TF 517F 150-220 Mc/s. Advance B, C and type 20. Several others. State requirements. Box 257, E.E.

MAGSLIPS, 3 in., precision made, perfect condition, [illegible] operation ideal remote control angular position indicator, phase shifter, etc., 25s. each. 1,200 ohms 20 watt ceramic potentiometers 3s. 6d. each. All post free. Hopton Radio, 1 Hopton Parade, Streatham High Road, London, S.W.16.

CONTROL UNITS type 18 comprising 5 mA and either 40V or 20V meters, also switches, plugs, etc. Price 7s. 6d. post free. Harry White, 158 Humberstone Road, Leicester.

TELEVISION CONSTRUCTORS! We can supply focus and scanning coils for High and Low impedance for 9 in.-12 in. 15 in. tubes. Rubber masks. Mazda CRM91, G.E.C. 6501, Mazda CRM121 tubes. S.T.C. rectifiers, HV capacitors, copper wires. All ranges of resistors and capacitors, etc. ELECTRONIC ENGINEERING *Home-Built Televisor Booklet* 2s. 9d. inc. postage. J. A. Perritt, 13/27 Wastdale Road, Forest Hill, S.E.23. FORest Hill 1292-2348.

CRYSTAL DIODES, Sylvania 1N22, 3s. 6d. each. 6K7G's guaranteed new, 7s. 6d. each. Postage extra. S.A.E. for complete list of stock. G.DRZ, 259 Humberstone Road, Leicester.

RECORDER, transportable, play back, fully erase, late type U.S.A. .004 in. wire, suitable speech or music. Perfect condition. [illegible] Complete £[illegible] 10s. [illegible] Grove, [illegible] Avenue, Kings Heath, Birmingham, 14.

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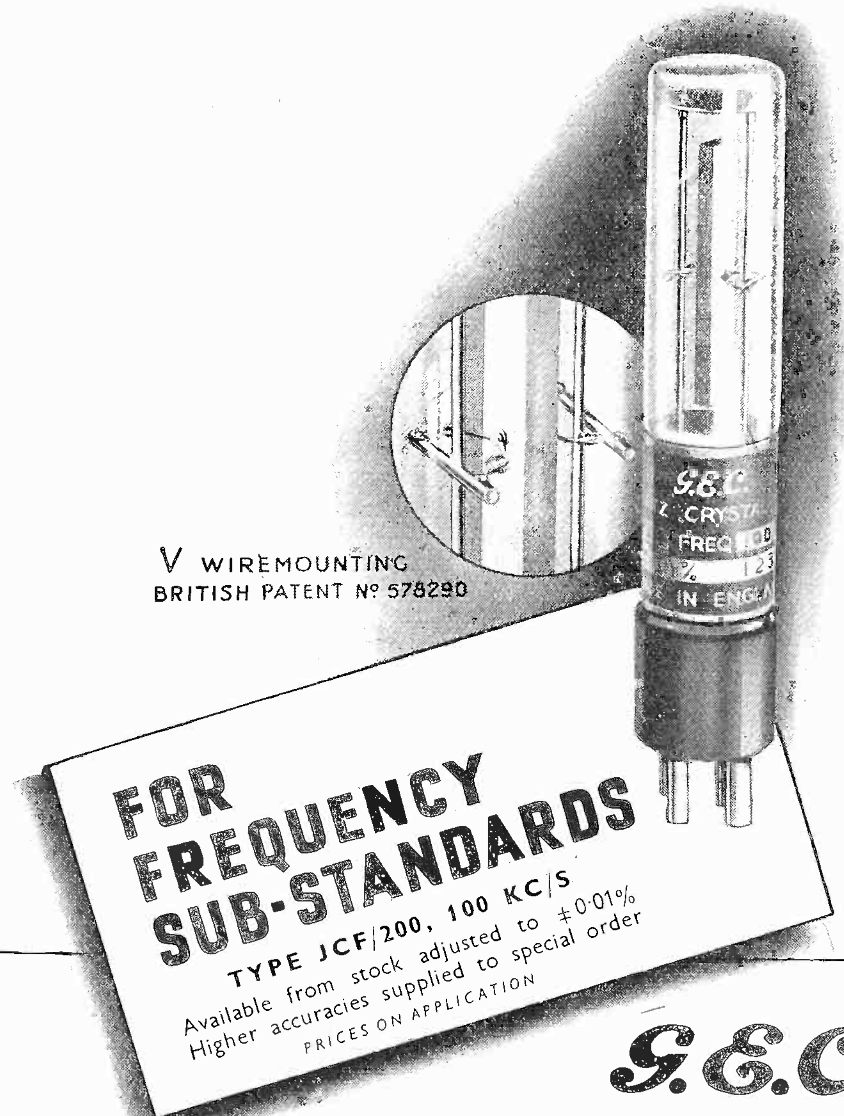
I WILL BUY a metal detector to detect at 10 feet below ground. Write to Felix Rovira S., P.O. Box 1305, Caracas, Venezuela.



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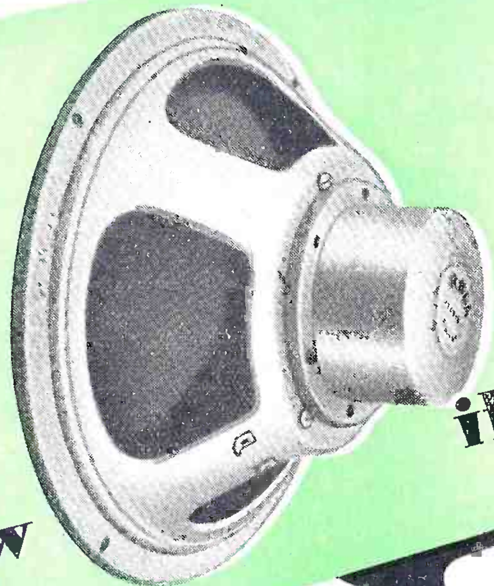

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ROLA

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8 OSCILLOSCOPE, Type 1936. X and Y amplifiers. 1 c/s-20 kc/s. D.C. shifts. 2¾ in. tube. Time base 5 c/s-10 kc/s. Expansion to 5 screen diameter. Price £50.
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10 PORTABLE FREQUENCY STANDARD, Type 1100. Outputs 1 Mc/s., 100 kc/s., 10 kc/s. Internal modulation 400 c/s. Usable up to 50 Mc/s. Accuracy ± 0.005%. Battery operated. Price £25.
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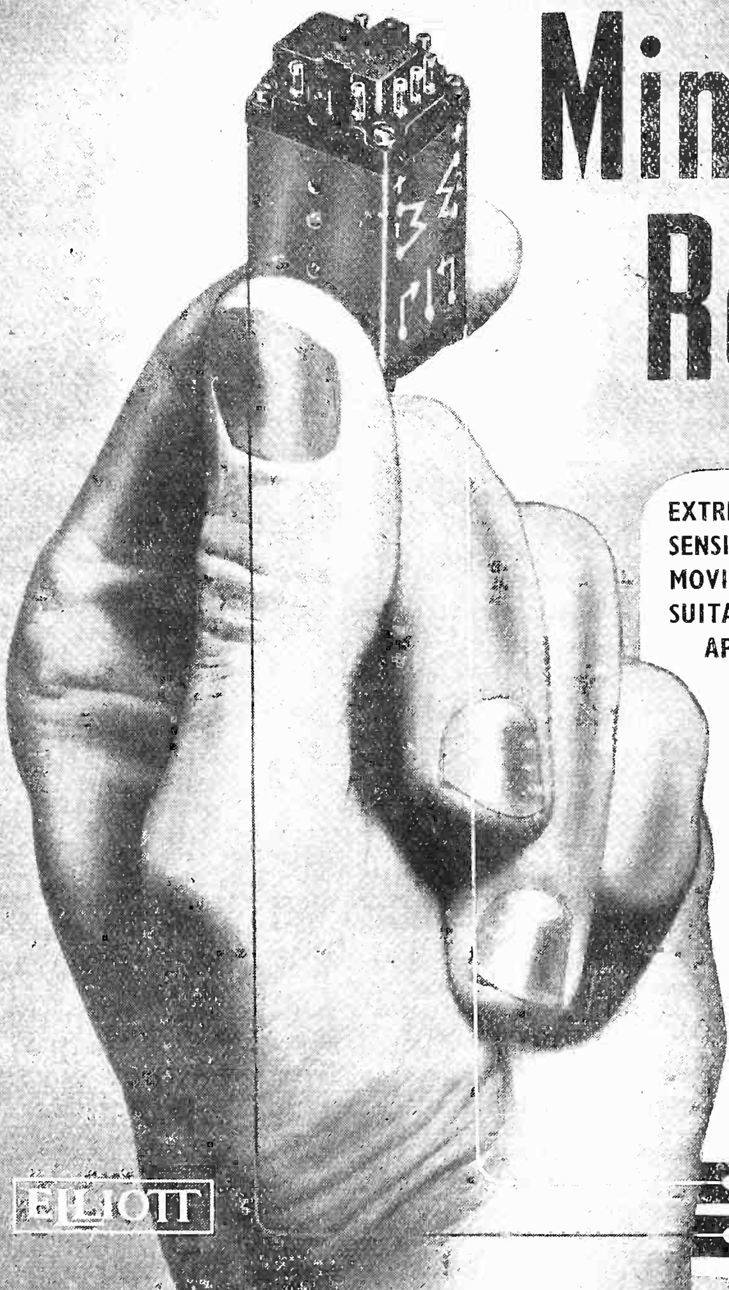
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Electronic Engineering

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 28, ESSEX STREET, STRAND, W.C.2.

TELEPHONE: CENTRAL 6565 (10 LINES) *MANAGING EDITOR:* G. PARR, M.I.E.E. *TELEGRAMS:* LECTRONING, ESTRAND, LONDON

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CONTENTS

Exhibitions

IF the Organising Committee of the Physical Society's Exhibition mingled unrecognised with the crowd, they were no doubt gratified to hear more complimentary remarks than usual about the four-day display they staged at the Imperial College.

But it is probable that they also overheard the often-expressed opinion that it was time that this Exhibition was housed in a more commodious place. The academic atmosphere of the College is certainly in keeping with the traditions of the Exhibition, now in its thirty-second year, but during these years both exhibits and exhibitors have multiplied till they are almost competing for space with the visitors.

No one would wish to see the Exhibition break completely with tradition and leave its present home, but an increasing number of visitors hold that the time has come to draw a sharper line between research and development and the ordinary display of commercial apparatus. At this suggestion one can hear the remark " What, another exhibition? " This is, of course, a fundamental objection. We have already had two exhibitions this year, and with the forthcoming B.I.F. and other exhibitions of allied interest to the electronic industry the sales departments will spend a greater part of their lives behind stands. The time spent in preparing for even a three-day show, and arranging staff for attendance, disorganises a small industrial firm for several weeks, and under present conditions is quite impracticable.

There is, however, a method by which the interests of technical visitors could be met with greater convenience and with little extra expenditure of effort on the part of industry.

Let there be a British Scientific Equipment Exhibition for the industry, which would include the present Radio Component Manufacturers' Exhibition, the Scientific Instrument Makers' Association, and allied associations, and house it in Olympia. Admission would be restricted by ticket to bona fide workers in industry and overseas buyers, and the stands would be manned by technical representatives to maintain the standard of a true scientific exhibition.

This would have the effect of concentrating the effort of producing and displaying exhibits into a week instead of distributing it over several short periods as sometimes occurs at present. In fact, there would be less duplication of work, as many industrial firms are now showing at three or more smaller exhibitions during the year.

The Physical Society's Exhibition could then be limited to research and original development work, thus preserving its original aim of encouraging British scientific instrument development. Apparatus once shown would, on completion on a commercial basis, be transferred to the larger exhibition and shown as often as desired.

There may be objections to this proposal—there usually are to most innovations, but it is put forward seriously for consideration by the responsible bodies. A second point which should not be overlooked is the claim of the larger provincial towns to have their own exhibition, and it may be that London exhibitors will have to consult the convenience of their provincial customers to a greater extent than is done at present.

PAPER SALVAGE

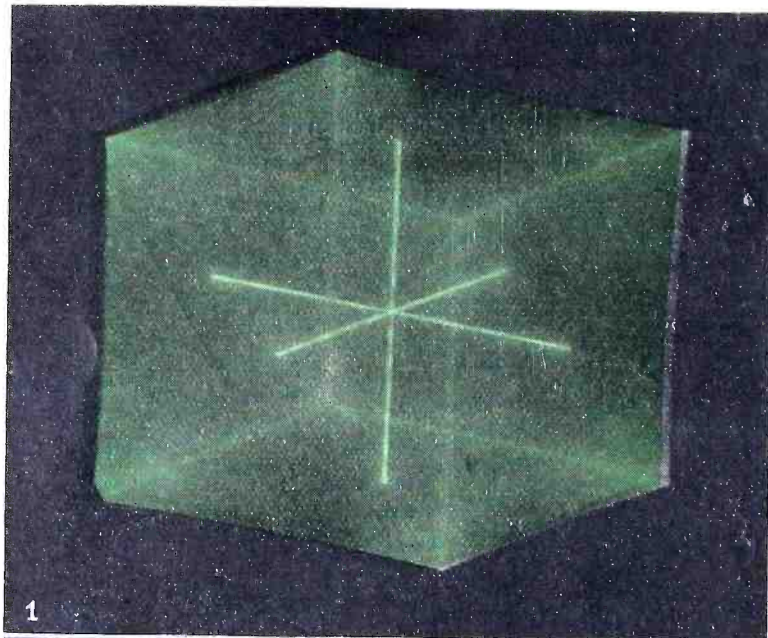
The need for salvage is once more vital and help must be given now. Every engineer can help in the drive for waste paper.

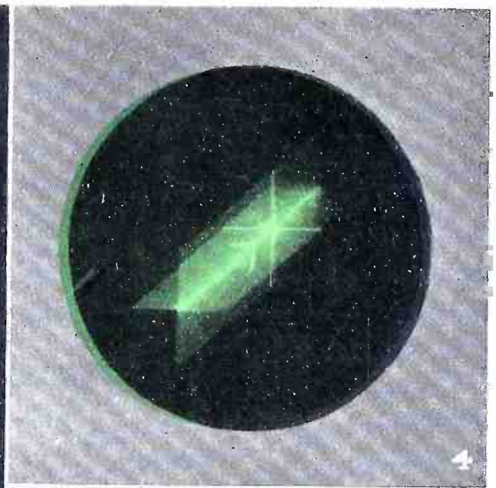
Here are some of the sources of paper salvage with which engineers are directly concerned :—

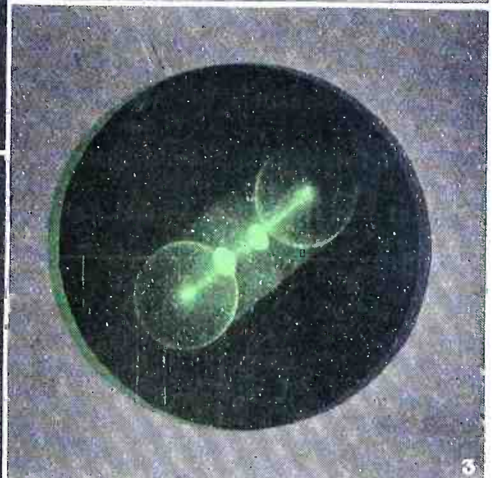
Obsolete textbooks
Periodicals
Old catalogues
Reprints of papers
Lecture note-books.

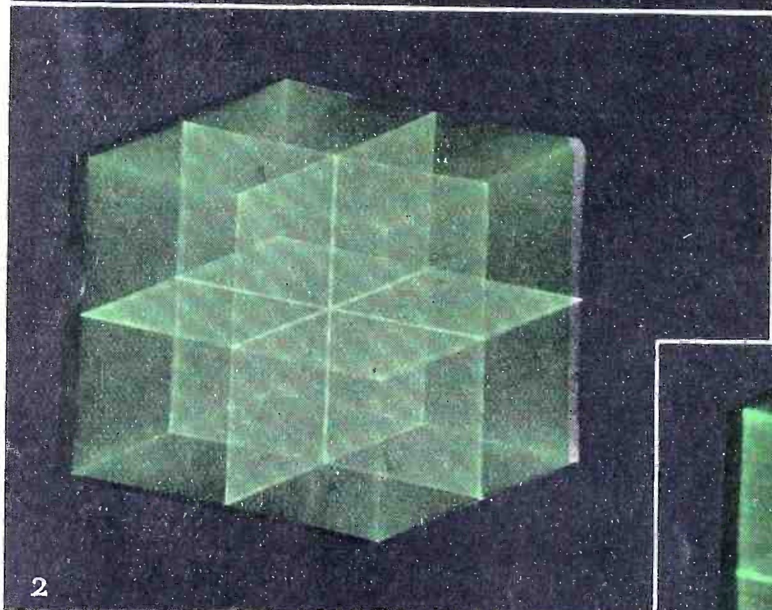
Make an effort to go through your files in the office and at home and put out waste paper for collection.

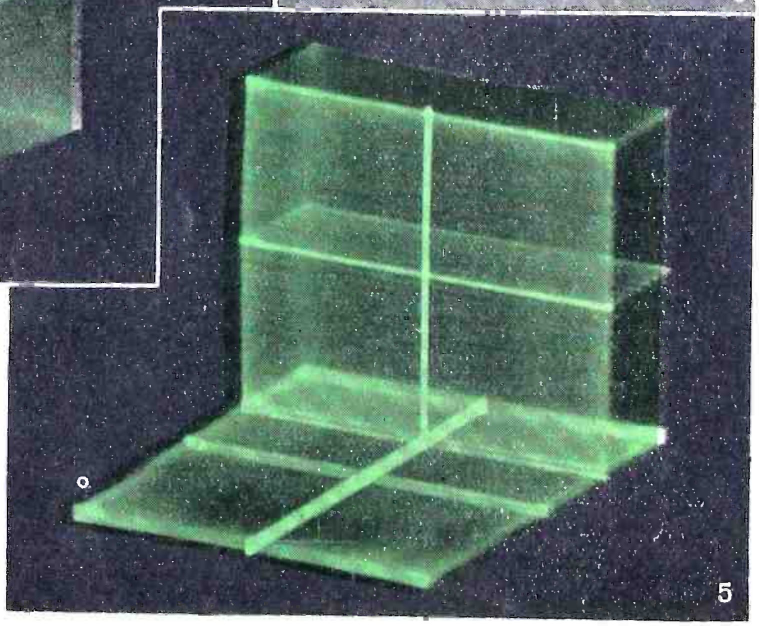
Your local salvage organisation will collect it—don't delay.











Three-dimensional Cathode-ray Tube Displays

THESE photographs show a striking and novel form of display for use in radar systems having a "pencil" beam which executes a rapid automatic scan over a limited volume of space, e.g. a square cone of 10 degrees angle. A selected 2,000 yard portion of such a cone can be considered as a cube or a cylinder, and these are the volumes represented by the displays illustrated.

A full account of the technique is given in a paper read before the Institution of Electrical Engineers by E. Parker, M.A., and P. R. Wallis, B.Sc., of the Royal Naval Scientific Service. The displays were developed at the Admiralty Signal Establishment, and the photographs of Figs. 2, 4 and 5 are reproduced by permission of the I.E.E.

Fig. 1. "Perspective cube" display of a volume of space 10 by 10 by 2,000 yards with the co-ordinate axes intensified.
Fig. 2. Another display similar to that of Fig. 1.
Fig. 3. "Perspective cylinder" display with two echoes present. In Figs. 1, 2 and 3 the position of an echo can be judged by rotating the representation.
Fig. 4. In this "crossed planes" display an echo is represented by its projections on to two orthogonal planes. An echo on the axis of the volume thus appears as a symmetrical cross, while an echo off the axis appears as two bright bars. In the photograph, a range-marker (large cross) is shown in coincidence with an axial echo.
Fig. 5. "Moving Wall" display in which all the echoes in the cube of space are shown as their projections on the horizontal plane. The vertical plane is then moved forward by the operator until its foot intersects the particular echo whose height is required. This echo then jumps up to its correct place on the wall and its position in the cube is clearly defined. In the photograph shown, both planes carry electronic cross-wires.

An Electronic Alphabet Generator

By G. T. CLACK*

A METHOD of reproducing patterns or letters on the screen of a C.R. tube has already been described by Lineback[1] and others[2,3] using photo-cells with a rotating shaped mask to generate the deflecting potentials on the X and Y plates.

Another method uses two potentiometers, the sliding contacts on the wire being linked by arms to a movable pen.[4] It occurred to the author in 1945 that a simplification of both methods would be to use an all-electronic system based on the supply mains frequency and avoiding the complication of photo-cells. The work followed no set plan originally, but during the initial stages it became necessary to make one of two choices; the first was to employ a separate circuit for each letter, and the second to arrange each circuit, where possible, in such a fashion that with switching it would produce more than one letter. Eventually a compromise was made as both methods had their disadvantages in either cost or complexity. Where it was possible, simple switching was introduced whenever a second or third character was obtainable from one circuit; this, although favouring the second choice, slightly economised in the number of valves employed and at the same time did help to reduce the possibility of any unduly complicated multipole switching.

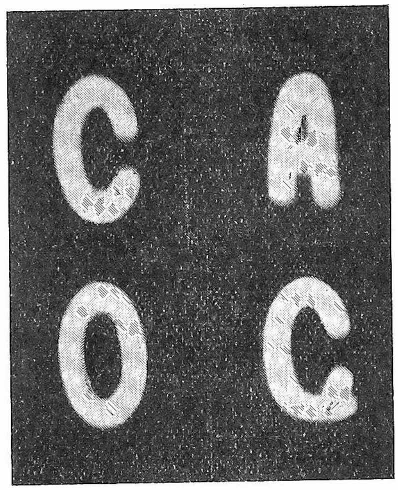
Basic Characteristics

One of the first considerations was to arrange the alphabet to show the basic strokes and other characteristics. With this in mind, examination and subsequent regrouping produced the following relationships, after the experimental work had progressed far enough for a full analysis to be made.

Characteristic	Letter
Triangulated ...	A V U M W H
R/angled ...	E F T I L J
Circular ...	O C G Q D
"8" Shaped ...	S Z N B R P K X Y

From the above it seems that as a result of the particular technique adopted during the work, the basic waveforms necessary for the formation of any letter of the alphabet are reduced to D,V,O,8.

* Bush Radio, Ltd.



Photograph of typical letters on tube screen

Script

The choice of capital letters instead of long-hand style is preferable in view of the simpler characteristics involved, and so eliminating an enormous amount of work in developing non-linear waveforms to cater for the different loops and whorls necessary in long-hand writing. Long-hand characteristics are simplified if the generation of the appropriate vertical and horizontal potentials is obtained by mechanical means such as rotating sliders controlling potentiometers. An example of this is shown in Fig. 1 which also illustrates the non-linear waveforms necessary to produce a script "e" on the screen of a C.R. tube. These waveforms could also be recorded on film or disk to operate a photo-cell or pick-up.

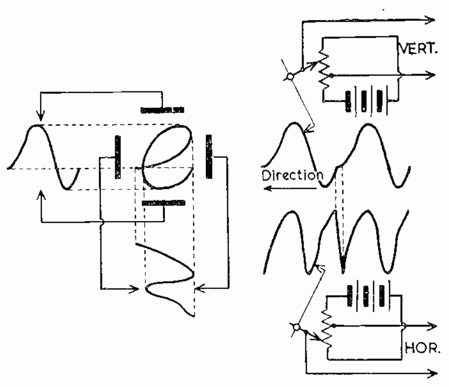


Fig. 1. Necessary waveforms to produce a script "e" on C.R.T. screen

The following details give examples of the method of generating some of the letters of the alphabet and some idea of the principle behind the make-up of others. A number of modifications and reduction in the number of circuits is possible if the system uses a double-beam C.R. tube.

Triangular Characters—"A"

"A" received attention first as it presented little difficulty in developing the necessary deflection potentials (Fig. 2). Positive going full-wave rectified 50 c/s. pulses (A) are applied to the grid of V_1 producing a "V"-shaped voltage across the anode load, R_1, *i.e.*, the inverse of the anode current pulses shown at B. Half-wave positive-going 50 c/s. pulses are applied to the grid of V_2 producing anode current pulses as shown at C. (Later the rectifier was omitted and the grid taken straight to 50 c/s. which provided the same effect.) As R_1, of V_1, is high and common to both V_1 and V_2, the increased current causes both anode voltages to limit for a major portion of the time during the period when both valves are conducting, D; the voltage (lower wave form of D) from the junction of R_1 and R_2 being negative going and similar in shape to the current pulses, provides the vertical deflection for the C.R. tube. The horizontal deflection is 50 c/s. phased through C.R. so that the + and − crests, E, occur when either or both V_1 and V_2 grids are at zero potential.

In Fig. 3(a) the vertical deflection only is shown for a period of 1/50 sec., and in 3(b) the horizontal deflection produced during one complete cycle, 1/50 sec., is illustrated as a slight ellipse in order to show the go-and-return stroke. In 3(c) the "a" and "b" traces have been superposed: as the beam sweeps across the screen from, say, left to right, it will be deflected by the first part of the vertical voltage and then by the second part on the return sweep, producing an "A"-shaped trace which has been illustrated in such a way as to clarify this explanation.

In practice, with the correct phasing of the horizontal sweep, the

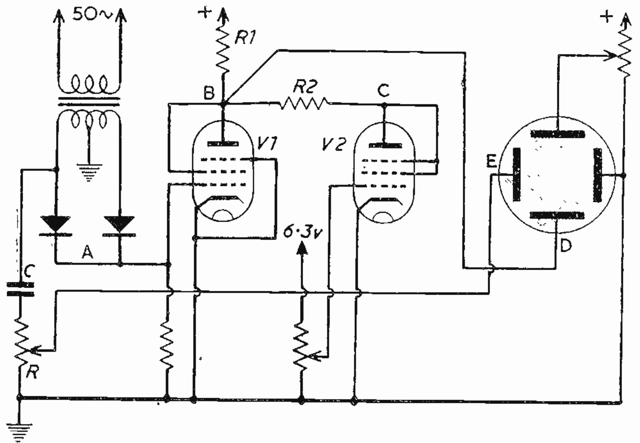


Fig. 2 (*left*). Basic "A," "U," "V," "M," and "W" generator, see also Fig. 4

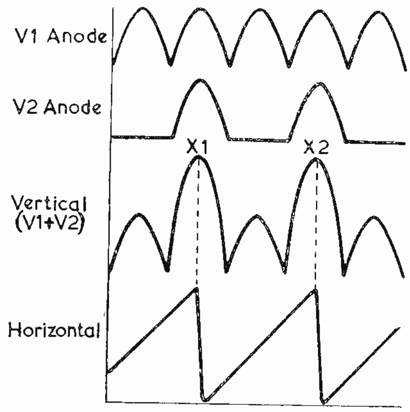


Fig. 4 (*above*). Formation of letter "W" and "M"

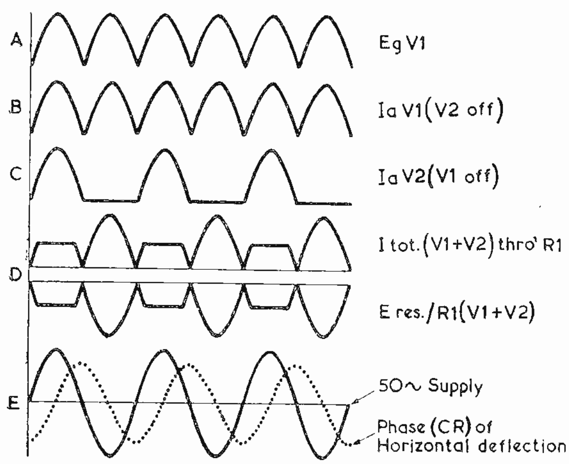
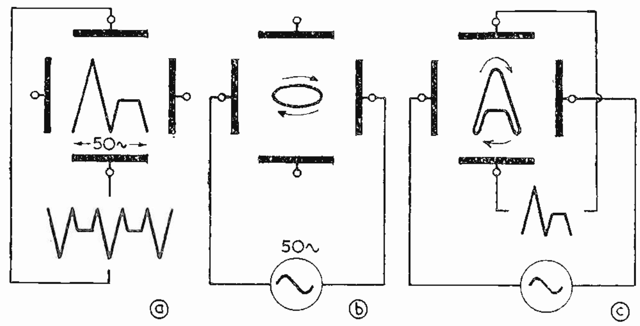


Fig. 3 (*below*). Formation of the letter "A"



character shows no irregular overlapping; the only noticeable detail is a slight increase in brilliancy of the trace where the go-and-return strokes are superposed. The slightly rounded top of the letter "A" is hardly noticeable because, when using a sinusoidal horizontal sweep, the fastest part of the stroke occurs during the formation of the top of the letter and tends to make it appear triangular in shape.

"W"

With the operation as discussed for the letter "A," but with the screen of V_1 disconnected from the anode, Fig. 2, and maintained positive through a separate resistance, V_1 then operates as a pentode and takes less plate current through R_1 so that when both V_1 and V_2 are conducting, the anode voltage never limits (Fig. 4). Both valves take approximately the same amount of plate current each time the grids go positive, with the result that on every other half-wave peak the voltage across R_1 is twice that when V_1 only is conducting. A gas-triode is used to provide a linear 50 c/s. sweep and the sync. pulse is phased to produce the commencement of the scan at the moments marked X_1, X_2, X_3, etc., in Fig. 4.

"M"

This needs no explanation other than it is the "W" waveform inverted. Both W and M can be developed from a much simpler circuit using two diodes to produce the same effect. It is naturally easier to use two sequential V's, but the foreshortened middle limb is a closer approach to the usual written shape for these letters.

Circular "O"

The orthodox method of securing a circular or elliptical trace is shown in Fig. 5 by C_1, C_2, R_1, R_2, and this serves as a basis for the letters O, C, G, Q. Both the amplitude and shape of the letter "O" is controlled by VR_1, VR_2 and VR_3, these being adjusted to produce an upright ellipse.

"Q"

An overdriven amplifier fed from the 50 c/s. supply is used with a diode clipper, D_1, to develop a small but fast, triangular extension at the bottom right-hand part of the "Q" trace. The moment at which this occurs is controlled by selecting the values of C_3, R_3 in order to produce the correct phase relationship with respect to the basic "O" trace. The amplitude and shape of the extension is controlled by the combined adjustment of R_3 and R_5. During the experimental work it was found necessary to introduce a small capacitor between the horizontal plates (C_5) to assist in phasing the tail.

"C"

This is basically the "O," but with a portion of the trace blacked out by applying a negative-going,

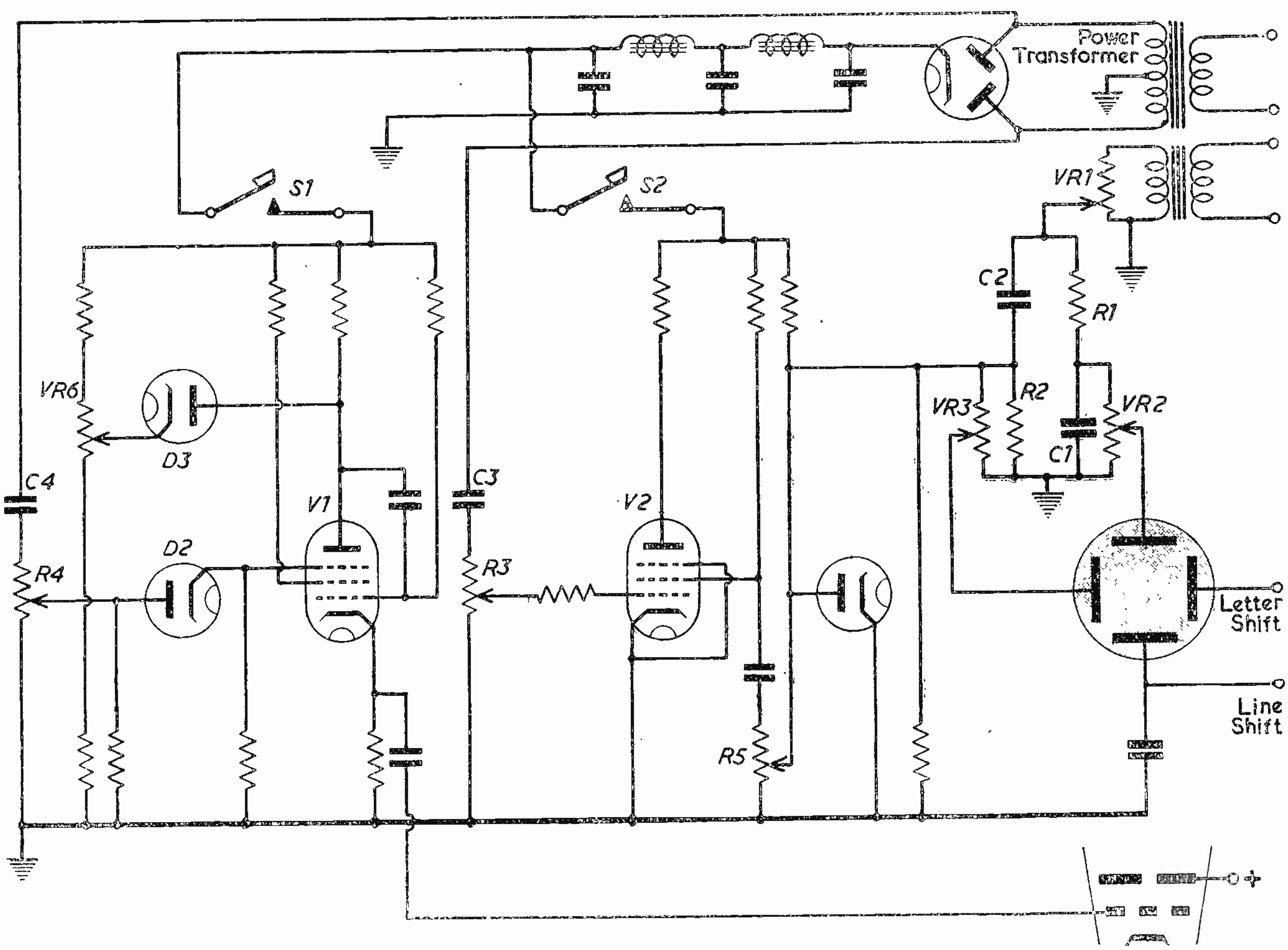


Fig. 5. Circular trace producing " O " with blackout and " pip " circuits for Q, G and C formation

square pulse to the grid of the C.R. tube. A "phantastron" oscillator is used (V_1); the time at which the C.R. tube is blacked out is determined by C_4, R_4 and the duration of the blackout controlled by VR_6.

" G "

This is easily secured by using the blackout pulse as for "C" and switching in the tail generator as used for "Q."

Right-angled—" L " and " J "

By a combination of an overdriven amplifier, Fig. 6, and a correctly phased sinusoidal sweep, a fairly good square trace can be developed, and by altering the ratio of the vertical to horizontal deflection voltages it is possible to secure any intermediate shape between an extremely elongated oblong and square trace.

Using a square trace and providing a correctly phased blackout pulse so that two adjacent sides are blacked out (dotted lines Fig. 9) the letter "L" is developed. By reversing the connexions to the horizontal plates and reducing the horizontal deflection amplitude, "J" is obtained in the form of a laterally inverted "L," but with a short base, and by slightly altering the blackout period or phase relationship a slight top to the "J" can be formed.

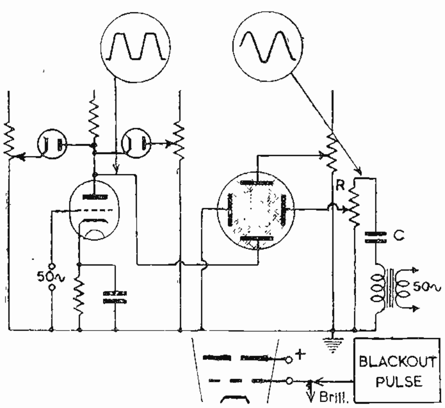


Fig. 6. Square trace with blackout on a portion of the trace to produce " L " and " J "

" E "

Positive pulses from a full-wave rectifier are applied to the grid of V_1, Fig. 7, which produces the waveform illustrated due to the high value of R_1 causing the anode voltage to limit.

The input to V_1, and other circuit values, are arranged to compromise between the most satisfactory shape, *i.e.*, minimum gap in the middle limb, and little difference in brilliancy between the fast and slow parts of the trace. Both the phasing of the sync. and the flyback of the linear horizontal sweep require careful adjustment, otherwise an irregular trace will be developed. Should the flyback be too slow, the letter will possess an unduly long middle limb.

" F "

As for "E," but with (a) blackout pulse to extinguish the bottom limb, or (b) carefully synchronised timebase with fast flyback so that bottom limb does not appear on trace.

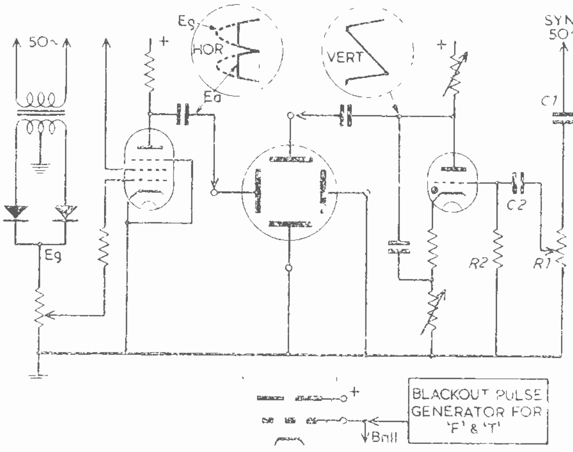


Fig. 7 (*left*). Basic "E," "F" and "T" generator

Fig. 8 (*below*). Method of producing horizontal deflection for "Y"

Fig. 9. Small letters *V, H, G* on left-hand side of traces refer to vertical, horizontal plates and grid of C.R. tube. The large letters on the right give the basic trace from which is derived additional letters, shown in smaller type. The supplementary waveforms shown are either added to or replace other waveforms

"T"

As for "E," but with the vertical deflection applied to the horizontal plates and vice-versa, together with correct proportioning of the trace amplitudes, a blackout pulse is applied to the grid of the C.R. tube on each alternate limb.

"8" Characteristic

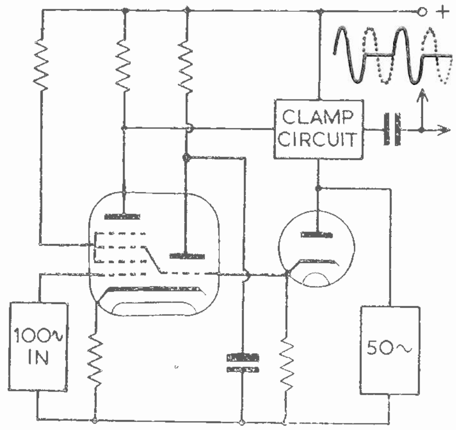
A 2:1 Lissajous pattern is the basis for S, Z, N, X, etc. (see Characteristic Table). In the case of S a portion of the right-hand down stroke of a Figure 8 is blacked out by a suitably phased pulse applied to the grid of the C.R. tube. By employing two diodes to operate as positive and negative peak limiters, the 50 c/s. vertical sweep is flattened at top and bottom, then by retaining the "S" blackout pulse and reversing the connexions to the plates a Z trace is produced. "N" is simply the "Z" trace rotated through 90° by changing the connexion to the X and Y plates.

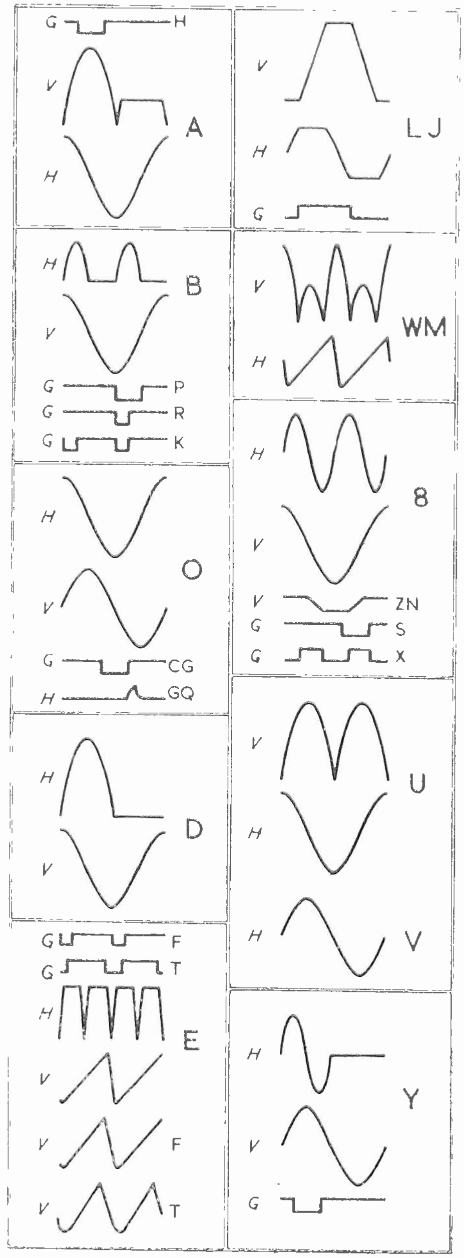
X is obtained by rearranging the blackout on the Z trace or by using blackout pulses coinciding with the top and bottom of a 2:1 Lissajous pattern. The numerals 2, 3, 4, 7 and 8 are reproduced by similar methods of blackout and phasing of the 2:1 trace. A method of producing Y is to apply a 100 c/s. sinusoidal voltage to the signal grid of a mixer valve and use the oscillator section to switch the mixer portion on and off at 50 c/s. (Fig. 8). When the 100 c/s. input is correctly synchronised, only the alternate cycles coinciding with the negative half-cycle of the 50 c/s. supply will be amplified. In the case of a single valve the same result is obtained by using the suppressor grid as the switching electrode, and in both cases a clamping circuit must be employed to hold the anode potential down during the period that the mixer anode current is cut off.

The rest of the waveforms necessary to produce the alphabet are shown in Fig. 9.

Word Formation

The presentation of several letters simultaneously is necessary in order that complete word formation becomes possible. To achieve this, the D.C. potentials on the vertical and horizontal shift circuits must be under control in such a way that each time a letter is presented the trace is deflected laterally a predetermined distance; it will also be necessary to control both shift potentials independently and as





required, so that a blank space can be inserted between each letter group and each complete line of letter groups. By doing this the C.R.T. screen will be scanned in much the same way as a television screen, except that the "line" build-up takes place as a series of small uniform lateral deflections and not at a constant speed.

An aid to the sequential presentation of each letter is to use a long persistence screen which will produce fairly good results when the repetition rate of each letter or group is rapid enough to maintain the fluorescence at an average level of brightness such that it can be viewed without the use of a viewing mask. A writing speed at about 60 words per minute (average typing speed) will maintain a five-letter group at a brilliancy level sufficient to be viewed in comfort.

One method is for use with a long persistence screen and supplies a small uniform shift each time a letter is applied to the C.R. tube (Fig. 10).

V_1 is biased to well beyond cut-off to ensure that C_2 does not accumulate a charge during the inactive periods. When any key is depressed, a positive pulse occurs at the grid V_1, cancelling the standing bias and opening up the valve for a period determined by the transformer primary inductance and the negative bias on V_1. During this "open" period, C_1, which is held at full H.T. potential, discharges through V_1 into C_2, and with correct proportioning of the circuit constants the potential across C_2 will rise in equal increments each time a key closes the primary circuit.

As V_2 is part of the horizontal shift circuit, the potential across C_2 will determine the plate current through this valve and hence the position of the trace. The shift potentiometer, VR_1, is used to start the trace from any convenient part of the screen.

A similar circuit can be used on the vertical shift, in which case the "Space bar" switch of Fig. 10 becomes the "Line shift" switch and the "Line bar" becomes the "Line return." It will be realised that there must be no leakage path across the cathode capacitor, otherwise the trace will tend to drift back until C_2 is discharged. The valve, V_2, must naturally have an extremely high grid-cathode leakage to avoid discharging C_2, and from observations made on average glass-seal base valves, the leakage is not serious unless there occurs a lapse of 10 seconds or more between each horizontal deflection of the trace. The only mechanical point to consider is that the D.C. shift switches must close shortly before the letter voltages are switched to the plates of the C.R. tube if blackout pulses between each letter are not applied, otherwise the trace is likely to show slight blurring at the moment of changing each letter.

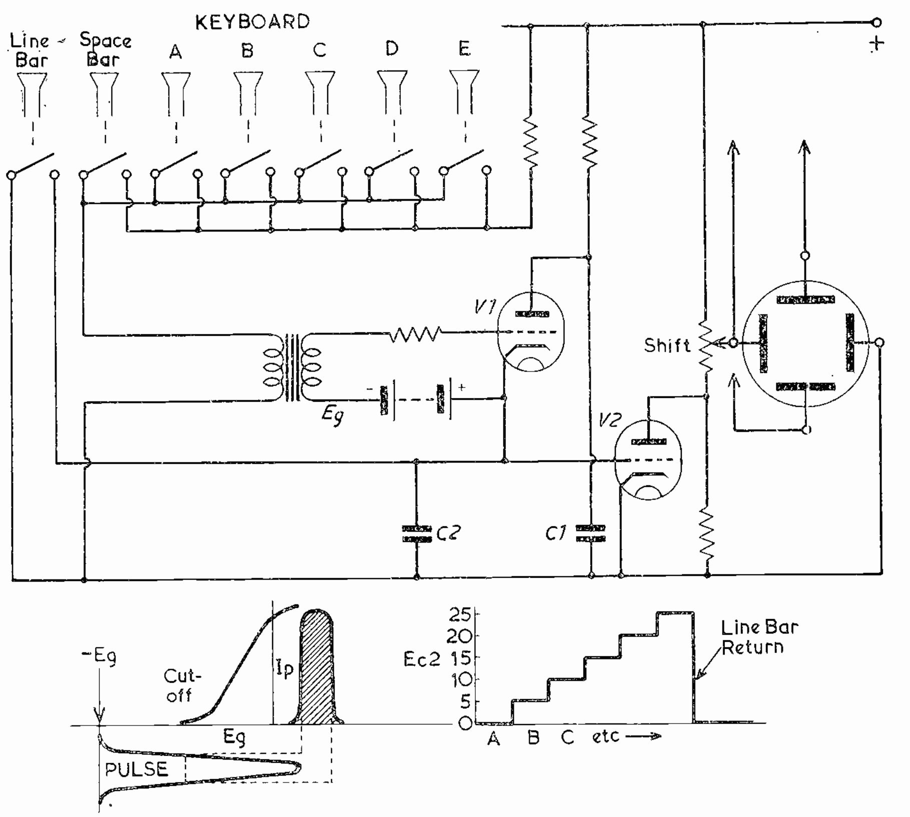


Fig. 10. A method of providing a lateral shift to permit word formation

The foregoing description will illustrate one particular technique employed to produce a writing trace on the C.R. tube screen. Apart from the blackout pulses, all the waveforms used are full sinusoid, half-sinusoid, linear and symmetrical trapezoid rates of change of voltage which are very simply derived from the power supply frequency and the resultant traces closely approach the orthodox shapes.

This method of developing the waveforms requires only two frequencies, 50 c/s. and 100 c/s., both of which are related so that perfect synchronisation is readily achieved. There is not necessarily any limit to the frequency or combination of frequencies of the applied deflection potentials other than that to produce a readable trace on the C.R.T. screen. There is, however, the need for flexibility of controls used for phasing and amplitude of both deflection and synchronising voltages in order that the optimum trace configuration can be realised.

Most of the circuits described to produce the basic waveforms can be replaced by much simpler circuitry, but the advantage gained by using valves is that it is easier to introduce compensation in order to improve the shaping of some of the traces, especially so when developing non-linear waveforms for "script" traces.

The presentation of word traces may be considered as yet another application of the versatile C.R. tube, despite the fact that apart from the use of these waveforms for screen writing all the circuitry described herewith is fairly conventional and well known. This method of combining waveforms to produce screen writing is the subject of patent applications.

References

[1] Lineback, H., *Radio News*, Feb., 1946, p. 30.
[2] Baker, G. T. "Number Display using the C.R. Tube," *Journal I.E.E.* Vol. 94, Pt. III, No. 32, p. 421, Nov. 1947.
[3] "The Numeroscope", *Electronics*, p. 98, Feb. 1948
[4] *Radio Engineering*, Vol. 13, No. 3, p. 15, 1947.

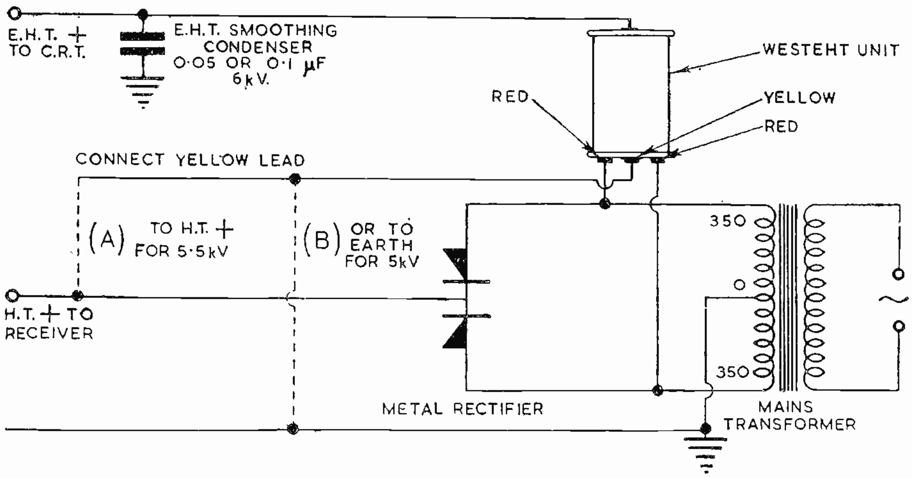


Diagram showing connexion of " Westeht " Unit to H.T. transformer of receiver

A New Rectifier E.H.T. Unit

The " Westeht "

THE " Westeht " E.H.T. supply unit has been designed to provide the anode high tension supply for the cathode ray tube in all forms of electronic equipment using tubes operating at anode potentials of the order of 5 KV. In such equipment a conventional centre-tapped H.T. winding and rectifier at 300-0-300 or 350-0-350 volts is usually available. The E.H.T. unit has been designed to be connected directly to this supply, and, by means of a special patented voltage multiplying circuit, consisting solely of condensers and rectifiers using "double-voltage" elements, it produces a voltage of the order of 5 KV at the top terminal. The only other component required is the usual reservoir condenser, which is needed with any E.H.T. supply system to provide smoothing.

It is generally accepted that the greatest single source of trouble in equipment using cathode ray tubes is the high voltage transformer with a highly insulated heater winding, the reason being that the insulation between the heater winding and the E.H.T. winding has to withstand approximately double the output voltage.

The " Westeht " eliminates the E.H.T. transformer or E.H.T. windings, and the associated valve rectifier; it is much lighter and occupies less chassis area than a transformer-valve system of comparable reliability.

Mounting and Connexions

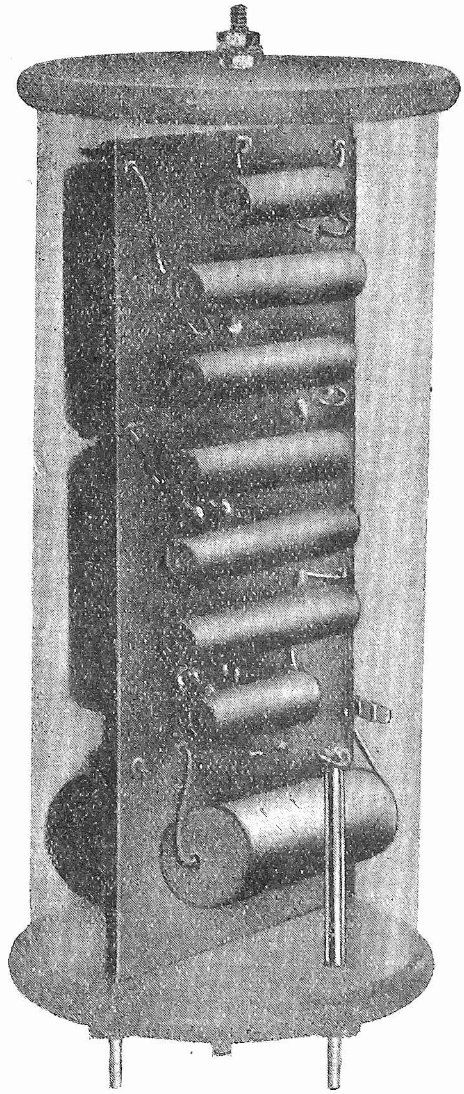
The " Westeht " E.H.T. unit is designed for mounting directly to the chassis with one central fixing bolt. Three clearance holes must also be provided to accept the bushings which carry the low voltage connecting pins through the chassis.

The circuit diagram shows how the "Westeht" is connected directly to the existing H.T. rectifier circuit, no change in the latter being necessary.

The only connexion above chassis is that between the top terminal and the smoothing condenser, which should preferably be mounted close to the unit, enabling a short connexion to be made.

The under-chassis wiring consists of three connexions. The two red tags should be joined to the outer ends of the normal centre tapped H.T. transformer winding (assuming that this voltage does not exceed 350-0-350 volts R.M.S.). If a lower E.H.T. voltage is required, or if the full winding voltage exceeds 350-0-350 volts, tappings should be provided symmetrically on this winding at any desired voltage under 350.

The yellow tag may be connected either to the centre tap of the transformer winding (earth), or to the positive terminal of the normal H.T. rectifier in accordance with the E.H.T. voltage required.



View of interior of " Westeht " Unit. The overall dimensions are 7¾" high by 3¼" diameter

Although the " Westeht " E.H.T. unit is nominally rated for an output of 150 microamperes mean D.C., as this meets the requirements of normal cathode ray tubes, the mean load current may, if desired, be increased to 250 microamperes if the output voltage delivered is sufficient.

The input current of the unit depends upon the load, but is only of the order of one milliampere so that its effect on the transformer is negligible.

The " Westeht " is manufactured by the Westinghouse Brake & Signal Co., Ltd., of 82 York Way, Kings Cross, N.1, and is sold at £7 10s. net.

Circuit and Current Noise

By E. J. HARRIS, Ph.D., D.I.C.*

THE useful sensitivity of any electronic amplifier is limited by the sum of the electrical noise inherent in the signal source and the noise generated by the input stage. Let us consider the case of an amplifying stage of voltage gain N times connected to an input circuit having a resistive component R ohms. The usual resistance noise formula (the Nyquist or Johnson noise, equation) gives for the mean square noise voltage across the resistance[1,2]:

$$\overline{\Delta V_R^2} = 4kTRb$$

where k = Boltzmann's constant, T = absolute temperature, b = bandwidth of amplifier in cycles). This noise E.M.F. will be amplified by the stage and have a mean value $N^2\overline{\Delta V_R^2}$ volts squared at the output. In addition, there is the noise produced by the valve, made up of shot noise, and, in the case of multi-electrode valves, partition noise. Under amplifying conditions the shot noise is given by the equation[2]:

$$\overline{\Delta V_s^2} = 2eI_a f^2 b \mid Z \mid^2$$

(I_a = anode current, e = electronic charge, f^2 = screening factor due to space charge, $|Z|$ = the modulus of the anode impedance); and the partition noise is given by:

$$\overline{\Delta V_P^2} = 2eI_a \frac{(I_s + f^2 I_a) \mid Z \mid^2}{I_s + I_a}$$

(I_s = screen current). The total noise at the output of the stage has a mean intensity $\overline{\Delta V^2}$ (the mean square amplitude will be called the intensity):

$$\overline{\Delta V_o^2} = N^2\overline{\Delta V_R^2} + \overline{\Delta V_s^2} + \overline{\Delta V_P^2}$$

The signal necessary to make signal equal to noise, which is generally taken as the limit of detection, can now be calculated:

(1) Minimum signal amplitude detectable

$$= \left(\overline{\Delta V_R^2} + \frac{\overline{\Delta V_s^2} + \overline{\Delta V_P^2}}{N^2}\right)^{\frac{1}{2}}$$

Clearly it is desirable to make N high, as this reduces the relative effect of the valve noise. This is frequently achieved in practice by including transformer coupling into the stage. In a multi-stage amplifier (except a super-heterodyne), it is only the noise generated by the first valve which is significant compared with the noise at the input, provided the gain of the first stage is greater than, say, 5 times. It is often convenient to express the valve noise in terms of the equivalent resistance at the input terminals which would give rise to noise E.M.F. equal to that from the valve.

Thus $\dfrac{\overline{\Delta V_s^2} + \overline{\Delta V_P^2}}{N^2}$

is set equal to $4kTR_vb$ and R_v is called the equivalent noise resistance of the valve. Modern low noise valves have values of R_v of some 2,000 ohms at higher frequencies, *i.e.*, above 1 Kc/s. It will be remarked that the amplitude of the noise from both resistances and valves is independent of frequency, so that theoretically the limiting sensitivity is independent of frequency. However, experiment[3,4] has shown that the performance of valves deteriorates as the frequency is reduced; and further that a number of semi-conducting resistive materials, such as are used as detectors of electrical or thermal radiation, give rise to noise which is both frequency and current independent. This latter phenomenon will be called current noise; it is additional to the current and frequency independent thermal noise. This fact becomes important at the lowest audio-frequencies, because both the valve noise and the current noise increase as the frequency at which the observation is being made is diminished. Some examples will help to show the magnitude of the effect.

A. Valve Noise

An amplifier with bandwidth of one cycle using a SP41 type of valve will give signal equal to noise with an input of 0.005 microvolt when the band is centred on 1 Kc/s., *i.e.*, the equivalent resistance of the valve is 1,500 ohms. With the band centred on 100 c/s. the limiting signal increases to 0.0135 microvolt (equivalent resistance of valve 11,000 ohms); and centred on 10 c/s. the limiting signal becomes 0.05 microvolt (equivalent resistance of valve 150,000 ohms). (*See* Fig. 1). At the lower frequencies variations of the grid current make the performance even worse than these figures, which were obtained with the grid strapped to the cathode. For this condition the equivalent noise has been found to be little affected by changes of the operating conditions, *i.e.*, the ratio (noise at anode)/gain is not very dependent on the anode current within normal limits. When the grid is used with a high resistance between it and cathode it becomes important to keep the grid current low. Evidently, low frequency amplifiers, such as are used in electro-biology, are more likely to have their performance limited by valve noise than are ordinary audio-frequency amplifiers, which generally cut off at 50 to 100 c/s. The "noise" becomes indistinguishable from "drift" at low frequencies.

B. Current Noise

Use of semi-conductors as detectors of thermal radiation employing either photoconductive or thermo-conductive effects involves passing a current through the semi-conductor and measuring the E.M.F. appearing across it. In order to avoid D.C. amplification and drift due to instability of the material, the incident radiation is usually interrupted and the alternating component of the E.M.F. developed across the sensitive material is amplified. Since the sensitive materials have an inherent time lag, it is necessary to work at fairly low interruption frequencies, *e.g.*, at 800 c/s. for a photo sensitive element and 20 c/s. for a bolometer. The noise originating in the detecting element sets the limit to the overall sensitivity. There may be 10 to 1,000 times as much current noise as thermal noise (which would be 0.25 μV in the example plotted), the ratio depending upon the current and the frequency (*see* Fig. 2).

The crystal mixers used at microwave frequencies, carry direct current arising from the rectified part of the local oscillator power. This direct current gives rise to noise which modulates the intermediate frequency output on account of the non-linear characteristic. A particular specimen of a silicon-tungsten

* Biophysics Research Unit, University College.

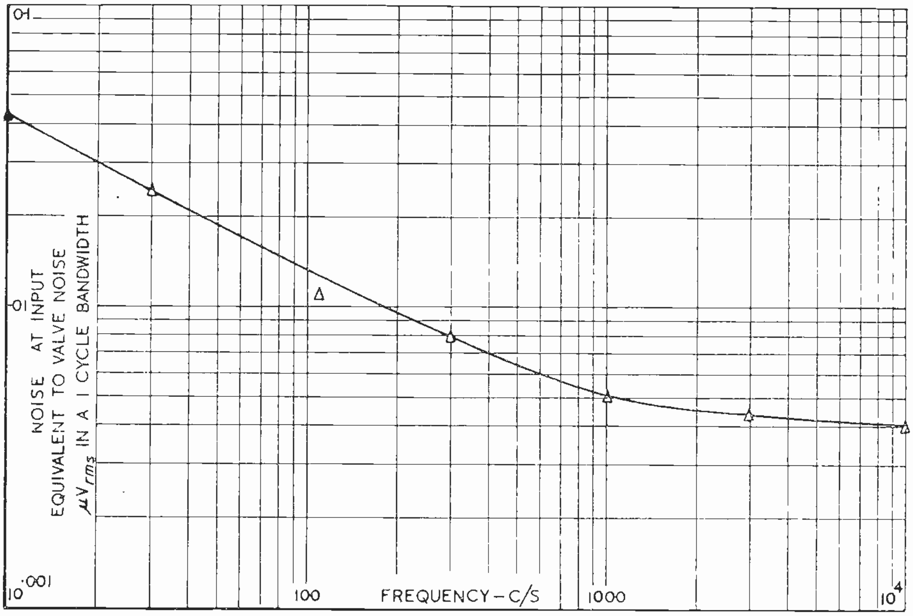


Fig. 1. Noise at input equivalent to SP.41 (V_g – 1.5 ; I_a = 1.58 mA ; V_s = 100 V.)

crystal furnished the following data: the root mean square amplitude of the noise in a one cycle bandwidth increased from 0.26 microvolt at 1 Kc/s. to 0.75 microvolt at 100 c/s. and 2.2 microvolt at a 10 c/s., for a current of 0.5 milliamp., which is a usual figure. (Fig. 3). Fig. 4 shows the noise per cycle bandwidth generated by a carbon resistor, 1 megohm, 1 watt type, when carrying a current of 50 microamp. For comparison the thermal noise level would be 0.128 microvolt. The serious effect of grid current in the first stage of a low frequency amplifier employing carbon resistors is very obvious.

Let us consider very briefly the sources of the various kinds of noise which have been mentioned. The thermal noise can be thought of as originating in the changing distribution of the free electrons within the material. Shot noise, which is only observed in valves and rectifiers, is related to the fluctuations in the number of electrons crossing between the electrodes at any instant. Partition noise arises because of the fluctuations in the sharing of the current between the various electrodes of the valve. The frequency dependent component of valve noise, which has been called "flicker noise," is additional to shot noise. It has been explained in terms of variations of emissivity of

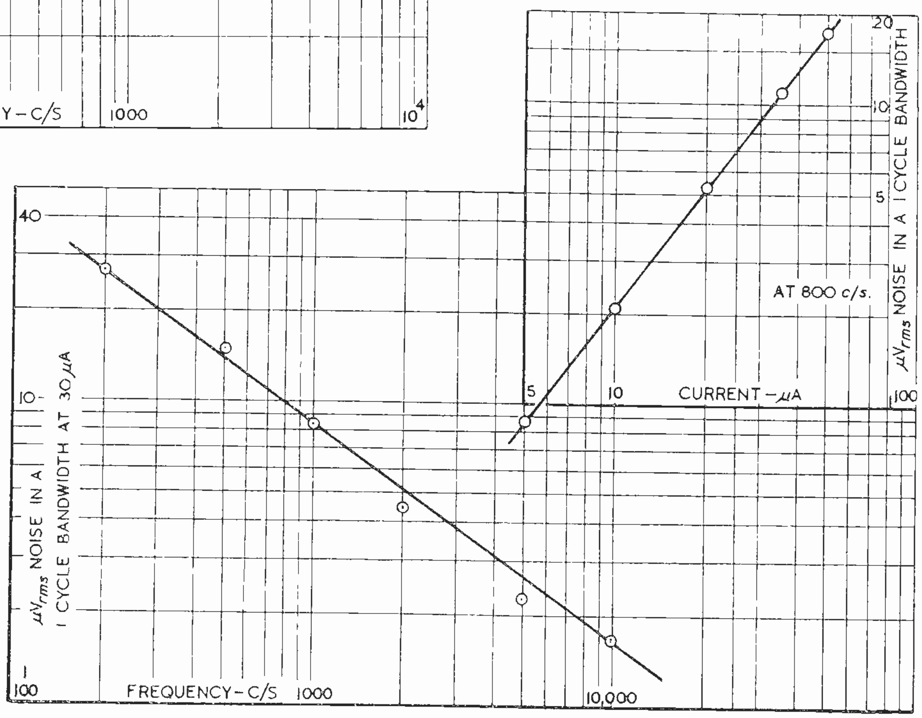


Fig. 2. Current noise of lead sulphide resistance

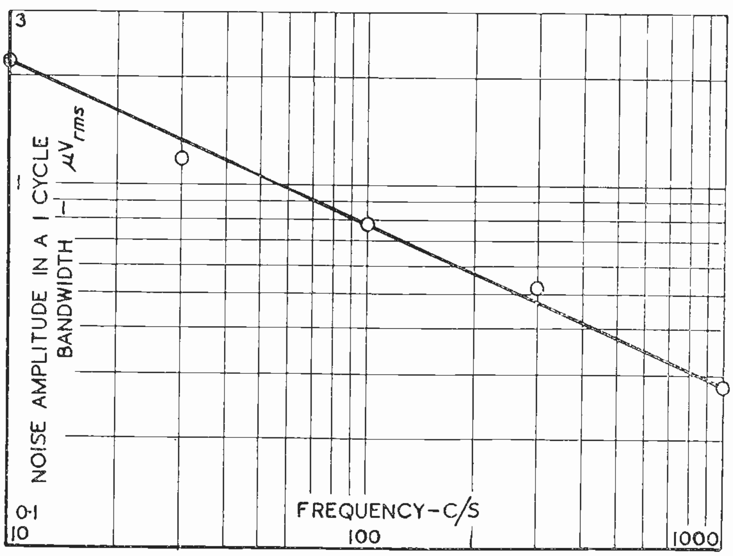


Fig. 3. Current noise of silicon - tungsten crystal carrying 0.5 mA in the "easy" direction

the cathode surface by Schottky,[5] but the equation he derived does not agree with all the experimental results. The empirical law relating the noise intensity to frequency has been found to be:

$$\overline{\Delta V_f^2} = \frac{K}{f^y}$$

(f = frequency, y = a constant between 1 and 2, K = a constant). A similar explanation may apply to the current noise observed in the case of carbon microphones and resistors,[6] and colloidal metallic films,[7] the noise intensity from which depends upon the current (I) and frequency (f) according to the law:

$$(2) \quad \overline{\Delta V_f^2} = \frac{KI^x}{f^y}$$

Macfarlane[9] suggests that the process of giving an electron sufficient energy to escape from a heated cathode surface, is similar to that of giving an electron sufficient energy to cross the potential barrier which exists when a thin film of non-conducting material is situated between two conducting surfaces. Such potential barriers are familiar to those who have worked with rectifying contacts, but they have only recently been envisaged as existing in non-metallic resistors. They do not possess rectifying properties, for the material on each side of the barrier is exactly the same. One confirmation of the relation between current noise and the presence of barrier layers is the fact that semi-conductor films of the same resistance can be prepared either chemically, in which case the layers are built up uniformly and show little current noise, or by vacuum sublimation, in which case layers are of polycrystalline structure and are some 10 times as noisy. At high frequencies the barriers are shunted so the resistive component appears much less than at lower frequencies.[10] Any mechanism which gives rise to alteration in the mean energy required by the electron in order to cross the barrier, will result in a fluctuation of the barrier resistance, just as changes of the emissivity of the valve cathode gives rise to fluctuations of the inter-electrode current. In the new theory the mechanism is ascribed to the migration of atoms up to the barrier layer, where they become polarised. The polarisation alters the properties of the barrier. The modified theory predicts that the index y in Equation 2 may vary from case to case, and further, that for linear resistors the constants x, y in Equation 3 will be related by x = 1 + y. This has been experimentally verified[1] for the noise-current and the noise-frequency relations of carbon resistors and lead sulphide films. The noise in the case of valves and non-linear resistors remains inversely proportional to some power of the frequency, but the current dependence is altered by the fact of the changing slope resistance. The theoretical equation:

$$\overline{\Delta V_f^2} = \frac{K I^{2m+2}}{(\omega^2\tau^2 + 1)^{m+\frac{1}{2}}}$$

involves a time constant (τ) which represents the mean life of the atoms near the surface. The value of this constant must be greater than the order of seconds, in order to account for the experimental results, as no flattening of the noise intensity versus frequency curve is found down to frequencies of less than 1 c/s.

An important property of valve flicker noise is that the change of emission from the cathode gives rise to a fluctuation E.M.F. between cathode and grid and also a fluctuation of grid current, which in turn becomes an E.M.F. at the grid depending on the grid-cathode impedance. The working amplification is applied to both fluctuation E.M.F.'s. Equation 1 can be rewritten to include the valve flicker noise as:

(Minimum detectable signal voltage) =

$$\left[\overline{\Delta V_R^2} + \frac{\overline{\Delta V_S^2} + \overline{\Delta V_P^2}}{N^2} + \int_{f_1}^{f_2} \frac{K}{f}\, df\right]^{\frac{1}{2}}$$

(*Continued at foot of next page*)

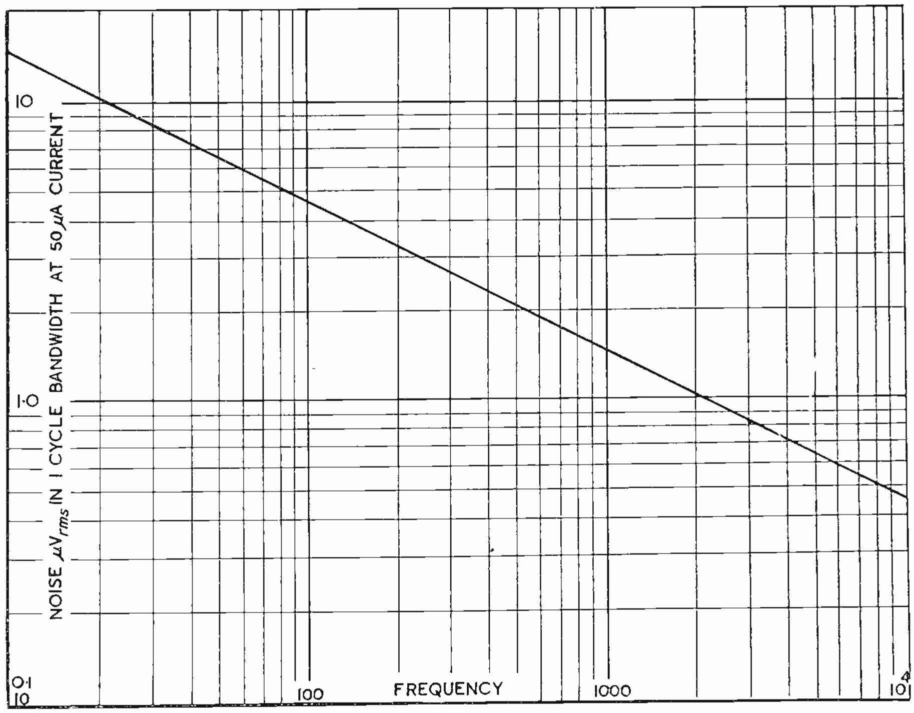
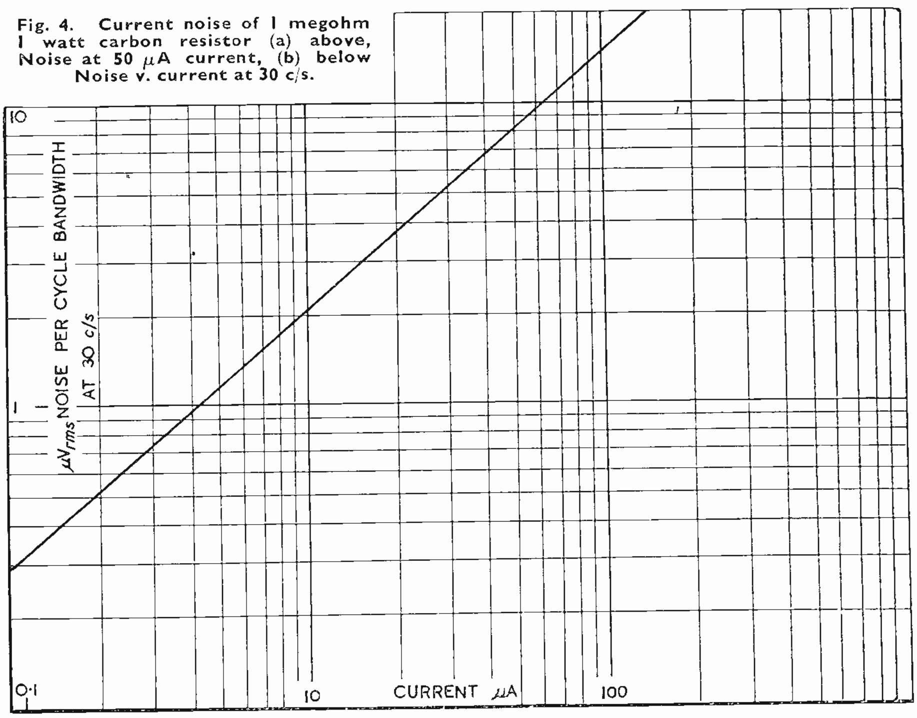


Fig. 4. Current noise of 1 megohm 1 watt carbon resistor (a) above, Noise at 50 μA current, (b) below Noise v. current at 30 c/s.



The Role of Electronics in Atomic Energy Programmes

An Address given by Professor Sir John Cockcroft, F.R.S., at the Radio Industries Club on March 23

ELECTRONICS has four main applications in Atomic Energy Programmes—to the control of nuclear reactors; to experimental work in nuclear physics and radio-chemistry; to the protection of the health of workers, and to the production of high energy particles and radiations.

An atomic pile, or nuclear reactor, consists usually of an assembly of uranium metal in a pile of graphite. When the pile reaches a critical size, a nuclear chain reaction starts in the uranium. A uranium nucleus splits up spontaneously into two heavy atoms, giving out in the process several elementary nuclear particles—the neutron. These neutrons have the facility of splitting up more uranium nuclei, releasing energy in the process. Thus, a chain reaction develops characterised by a reproduction constant, K, of the reaction which measures the number of children for each parent neutron. If K is greater than unity the population of neutrons, and with it the development of heat, increases. The magnitude of the reproduction constant is controlled by moving into or out of the pile a metal rod containing boron, which is a strong absorber for neutrons. To increase the power level of a pile, the control rods are partially withdrawn, thus increasing K above unity. The power level then increases exponentially with time, the time constant varying inversely as the excess K made available. When the desired power level is reached, the control rods are wound in, reducing K to unity again.

The operating power level is usually determined by measuring the number of neutrons entering an ionisation chamber. These neutrons produce ionisation—a very small current is collected and amplified by high stability D.C. amplifiers, and this operates recorders and activates automatic mechanism controls to keep the power level constant. In practice, power levels are maintained constant to about one part in 10,000.

The control rods are activated by an amplidyne or other suitable servo mechanism and their position is fed back to the control desk and recorded on continuous recorders to provide a record of past operation. Other ionisation chambers are connected through amplifiers and release mechanisms to so-called safety rods which are driven into the pile if the power level reaches a fixed limit.

"Safe level"

The production of heat in a pile is accompanied by the release of powerful radiations, neutrons, gamma rays and high-speed electrons. For the most part, they are confined within the pile by a concrete shell 5-7 ft. in thickness, which reduces the number escaping to a safe level. The safe level which a human being can tolerate without experiencing any measurable physical or biological effect is well known from experience in X-ray and radium therapy. The safe level for neutrons is not known with quite the same certainty, though much experience was accumulated during the war. We can measure the intensity of the neutron and gamma rays outside the pile by suitable ionisation chambers—we usually have three—one containing high pressure argon to measure gamma rays, one containing hydrogen to measure fast neutrons, and one containing boron trifluoride gas to measure slow neutrons. The ionisation currents are amplified and recorded in continuous recording meters to provide a record.

The intensity of these radiations may vary from place to place in an experimental pile laboratory. Portable instruments of lower accuracy are therefore provided which can be carried about and put down where an experimenter is working so that he has by his side a record of radiation intensities. In addition, all workers carry simple devices, a photographic film which is blackened by radiation, and a small thimble ionisation chamber which is discharged by radiation, which enable the health department to maintain a continuous watch over exposures of personnel. We find, in fact, that the exposure of personnel is well below the officially accepted "safe level."

We have also to keep a watch on the mild radioactivity produced in air used for cooling a pile to check that the air reaching ground level is

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Circuit and Current Noise (*continued from previous page*)

(f_1 and f_2 being the limits of the amplifier pass-band).

We see that the low frequency noise term is independent of stage gain. This has been confirmed over a range of values of N between 10 and 300 times. The value of K depends upon both the grid resistance and the grid current flowing. The figures given in Fig. 1 are only applicable when the fluctuations in the grid circuit can be ignored. If the flicker noise is related to cathode temperature fluctuations it might be possible to reduce it. For example, a compensation for the effect of gross changes in cathode temperature can be applied to valves used as D.C. amplifiers[11] in which a twin triode is used. It is problematical, however, whether this type of compensating circuit will improve the performance when the limitation is set by fluctuations arising locally in the cathode coating.

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perfectly safe to breathe. Here again, ionisation chambers are placed in the grounds surrounding a pile and the radiation levels monitored.

Particle counting

Physicists working with the pile have to measure accurately the number of electrons, neutrons and gamma rays entering their apparatus. In the early days of radioactivity, particularly in Rutherford's early work, much of the experimental work was carried out by the simple device of the scintillation screen. High speed atomic particles —helium nuclei in particular—produce a minute visible flash or scintillation when they strike a screen of zinc sulphide. So one sat in a darkened room looking at the screen with a microscope, counting the scintillations—one could never count more than 60 per minute without getting confused. To-day we look at the scintillation screens with electron multipliers. In this way, we can see the much fainter scintillations produced by electrons and count at an enormously high rate, thereby greatly facilitating our experiments. Instead of using screens covered with zinc sulphide, we use naphthalene—or anthracene —the material used in moth balls.

Slow neutrons are recorded by minute glass counters containing boron trifluoride. The neutrons split up the boron, throwing out a helium nucleus which produces ionisation which is measured and carried to activate a counter.

Counting is done by the well-known scaler counting in scales of 2, 4, 6, 8 or 10, 100, 1000. The scaler was, I think, invented by Dr. Wynn Williams in the Cavendish Laboratory electronic development period of 1928-32. Impulses from the counter actuate flip-flop circuits causing the anode currents to pass alternatively in two triodes. One of these triodes passes impulses to the next pair and so on, so that the tenth triode passes current at every tenth impulse from the counter. In the Cavendish days we had one scaler built from thyratrons borrowed from our good friends at the B.T.H. To-day the Cavendish will have 50 scalers and Harwell at least 200.

Not only do the physicists require scalers. They are becoming a common tool of chemists and biologists, and will come into use in many industries.

Radio-chemistry

The chemists at Harwell are concerned very largely with the new branch of chemistry—radio chemistry. They have to work out methods for separating plutonium from uranium and the radioactive fission products after the uranium metal rods are removed from the pile. The chemical separation processes are followed by measurement of the radioactivity of solutions or evaporated solutions. The sample is taken, placed on a shallow tray and exposed below an alpha particle counter if plutonium is being analysed. The counter consists of a shallow chamber filled with methane so that the alpha particles produce electrons by ionisation and these are collected as a pulse of current. So to work with these chambers we require fast amplifiers having a band-width of perhaps a megacycle. The amplifier in turn operates the scaler. So our chemistry labs. contain a number of counting rooms fitted with instruments for automatically recording the time taken to obtain, say, 10,000 counts from the sample. A large number of samples may be arranged round the rim of a large wheel with automatic devices to bring one sample after another into position and record the time for 10,000 counts.

The chemist has to be carefully protected from undue exposure to radiations or radioactive dusts. He works in specially designed " hot " laboratories with a high air flow sweeping out any radioactive products from the fume hoods into large exhaust ducts. In front of the fume hood hangs an ionisation chamber recording the intensity of radiation to which the chemist is exposed. Monitors are provided to measure the concentration of radioactive dust. As he leaves his lab., the chemist washes his hands carefully and then inserts them into an apparatus which measures how much radioactive material is left on them. If it is too high it rings a bell, and he must wash them again. After leaving his lab., he goes to a changing room, and after changing his overall and removing shoe covers, he is looked at by a shoe monitor to see whether he is carrying any radioactive material to contaminate other laboratories.

The other electronic devices are required to monitor the effluent from his laboratory for radioactivity. A panel of the Medical Research Council determines the safe level of radioactivity in drinking water—incidentally it has fixed this at a level 10,000 times below that of the Bath Spa waters, so it is pretty safe. We have then to assure ourselves and the Ministry of Health that when our effluent gets to the Thames it will not lead to an activity greater than this safe tolerance level. So effluents have to be monitored for both alpha and beta activity.

All these health activities require a large health organisation, and at Harwell we have a staff of about 30 engaged in such activities.

Particle accelerators

Of the last application of electrons —to the development of high-speed particle accelerators—I have little time left to speak.

There is a whole family of new machines. You know already about cyclotrons. There is its successor the synchro-cyclotron, the electron synchrotron, the proton synchrotron, the betatron, the bevatron (from B.E.V. —billion electron volts), the linear accelerator and several others. These machines are designed to produce electrons or protons, having energies of up to, or even over, 1,000 million volts in the attempt to open up new regions of physics—the physics of the elementary particles. Of this large new family I will speak of only one, the linear accelerator, on which the A.E.R.E. group at T.R.E. have been working. In this machine the 2-megawatt magnetron is connected to the end of a corrugated wave-guide in such a way that a travelling wave runs along the guide, speeding up as it goes along. Electrons are injected and " surf ride " along the electron wave and at the end of the guide emerge with energies of 4 million electron volts. To obtain still higher energies further lengths of wave-guide can be connected, and there is no reason in principle against producing energies of the order of 500 million volts in this way. We have, however, already got a very nice 4 MeV X-ray generator which will compare favourably in size and complexity with other types.

A Two-Phase Telecommunication System

Part I. General Principles and Requirements

By D. G. TUCKER, Ph.D., A.M.I.E.E.*

1. Introduction

THE principle of two-phase transmission for communication systems was first set out some years ago.[1] It depends on the fact that a twin-sideband, suppressed-carrier,† modulated signal requires for demodulation a carrier supplied in a suitable phase relationship. If the demodulating carrier differs from the correct value by $\pi/2$ radians then no demodulated output is obtained. Thus, if two signals are modulated by separate carriers of the same frequency but different phase, and then both sidebands are transmitted, with suppressed carrier, in the same communication channel, the two original signals can be obtained separately on demodulation in two paths (branching from the common channel) by carriers of phase exactly $\pi/2$ radians different from the phase required to demodulate correctly the unwanted signal. The applications of this principle are varied. It is suitable for the transmission of multi-channel v.f. telegraph signals, or other v.f. pulse signals, because as these are normally transmitted as twin-sideband signals in any case, a saving of two-to-one in frequency band required is effected by two-phase transmission. It does not effect any saving of bandwidth for speech transmission, because this is normally single-sideband, and the two-phase principle requires twin-sideband working. It has applications as a secrecy system, however. The particular application with which the author's work was connected was the transmission of speech code-signals derived from the Vocoder[2]; here the requirement was to transmit 10 code signals, each requiring a frequency band of 0-25 c/s.; this was to be done in 5 two-phase pairs, each requiring a v.f. bandwidth of 50 c/s. Groups and super-groups of channels were planned for. Unfortunately the work was never completed, as the immediate need for it disappeared with the changing military situation in 1942. Enough was done, however, to demonstrate the practicability of the system and the difficulties of design, and two channels of a workable system were set up and tested out in the laboratory in June, 1942. The present account of the system based on Post Office Advance Research Report No. 11578, issued August, 1942, is intended to place on record some of the basic principles and practical requirements elucidated during this work.

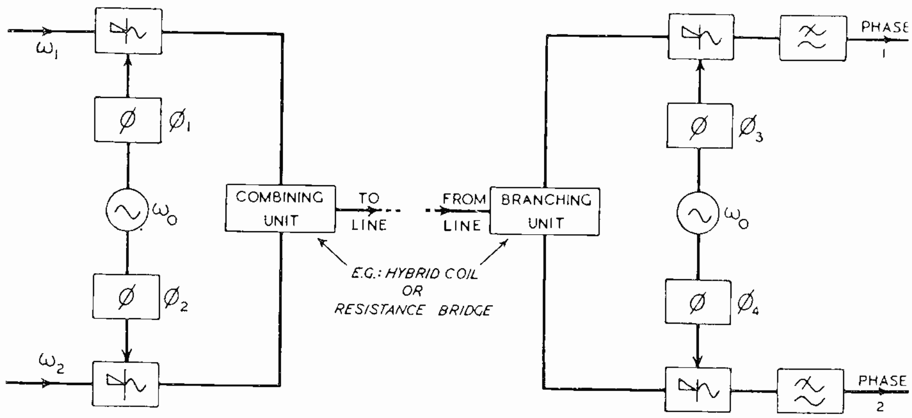

Fig. 1.

2. General Principles of a Two-Phase Channel

Fig. 1 shows a two-phase channel. Consider input signals $A_1 \cos \omega_1 t$ and $A_2 \cos \omega_2 t$. Let the carriers modulating these signals be $\cos(\omega_0 t + \phi_1)$ and $\cos(\omega_0 t + \phi_2)$. Then the primary products of modulation, *i.e.*, the required twin-sideband, suppressed-carrier, signals derived from the fundamental frequency of the carrier, are proportional to:

$$A_1 \cos \omega_1 t . \cos(\omega_0 t + \phi_1)$$

and $A_2 \cos \omega_2 t . \cos(\omega_0 t + \phi_2)$

At the receiving end, both signals are received in both branches. Consider the case shown as Phase 1 in Fig. 1. Then if the carrier is $\cos(\omega_0 t + \phi_3)$, the output signal is proportional to:

$$A_1 \cos \omega_1 t . \cos(\omega_0 t + \phi_1) . \cos(\omega_0 t + \phi_3) + A_2 \cos \omega_2 t . \cos(\omega_0 t + \phi_2) \cos(\omega_0 t + \phi_3) \quad \ldots\ldots (1)$$

The first term may be resolved into:

$$\frac{A_1}{4}\left\{ \cos[(2\omega_0 + \omega_1)t + \phi_1 + \phi_3] + \cos[(2\omega_0 - \omega_1)t + \phi_1 + \phi_3] + \cos(\phi_1 - \phi_3 + \omega_1 t) + \cos(\phi_1 - \phi_3 - \omega_1 t) \right\} \quad \ldots\ldots (2)$$

The first two terms of this are the high-frequency terms which are readily filtered out, leaving only the last two terms which can be expressed:

$$\frac{A_1}{2} \cos(\phi_1 - \phi_3) . \cos \omega_1 t \quad \ldots\ldots (3)$$

Similarly the second term of (1) leads to:

$$\frac{A_2}{2} \cos(\phi_2 - \phi_3) . \cos \omega_2 t \quad \ldots\ldots (4)$$

So that the total output signal in Phase 1 is the sum of (3) and (4).

Now our requirement is that ω_1 be accepted in Phase 1, and ω_2 rejected. This means that:

$$\cos(\phi_2 - \phi_3) = 0$$

in order to make the output of ω_2 zero, which is the main requirement, and:

$$\cos(\phi_1 - \phi_3) = 1$$

in order to make the output of ω_1 a maximum.

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* Post Office Research Station.

† The carrier need not be suppressed from the point of view of two-phase working, but its transmission would be undesirable in any practical system because of amplifier loading.

$$\begin{aligned} &\text{Thus } \phi_2 - \phi_3 = \pi/2 \\ &\text{and } \phi_1 - \phi_3 = 0 \end{aligned}$$

$$\left.\begin{aligned} &\text{So } \phi_1 = \phi_3 \\ &\text{and } \phi_2 = \phi_1 + \pi/2 \end{aligned}\right\} \qquad (5)$$

giving the necessary and sufficient conditions for Phase 1.

In Phase 2 we require to accept ω_2 and reject ω_1. Working as before, we find the conditions are:

$$\left.\begin{aligned} &\phi_2 = \phi_4 \\ &\text{and } \phi_3 = \phi_1 - \pi/2 \end{aligned}\right\} \qquad (6)$$

Summarising, we can state the requirements of the system, deduced or implied above, thus:

(a) The carrier supplies at the two ends to be both in the same phase relative to any signals on the system.

(b) The carriers fed to the two modulators from the main supply at the sending end to be different in phase by $\pi/2$ radians.

(c) The carriers fed to the two demodulators from the main supply at the receiving end to have the same phase-shift relative to the supply as those at the sending end.

(d) Only the two sidebands of the *fundamental* carrier frequency to be received by the demodulator. (Sidebands of harmonics of the carrier will, in general, have unsuitable phase relationships).

A typical circuit schematic for the receiving end will be shown in the succeeding part of this article.

3. The Practical Significance of the Requirements of a Two-Phase System

It will be evident that the effect of any departure from the requirements set out in the preceding section will be crosstalk from the unwanted signal in each phase.

Considering Phase 1, the ratio of unwanted signal to wanted signal is, from (3) and (4),

$$\frac{A_2 \cos(\phi_2 - \phi_3)}{A_1 \cos(\phi_1 - \phi_3)} \qquad (7)$$

For small discrepancies from the stated requirements, $\cos(\phi_1 - \phi_3)$ is not greatly different from unity. The reference levels on the two phases will in general be equal. If the difference $\phi_2 - \phi_3$ departs from its nominal $\pi/2$ by an amount θ, we may say, then, that the crosstalk/signal ratio is:

$$\sin\theta \qquad (8)$$

or since θ is small, the ratio is approximately θ.

It is thus evident that very accurate control of the phase angles is required, not so much for demodulating the wanted signal, but for eliminating the unwanted signal. A departure from the ideal quadrature condition of only 3°15′ gives rise to a signal/crosstalk ratio of 25 db., which is about the worst value likely to be specified for practical systems. The initial setting-up of the phase shifters to give the correct relations among ϕ_1, ϕ_2, ϕ_3, and ϕ_4 is not a matter of great difficulty, and these values should remain adequately constant; but the maintenance of the main carrier supplies in identical phases at the two ends of the system is a very real difficulty. There are several ways in which this can be effected:

(a) Direct transmission of a tone of the carrier frequency on another, similar, line. This would give very satisfactory results, the tone being used directly as the carrier supply at the receiving end; but the use of an additional line would nullify the saving of line plant expected from the transmission of two signals in the same frequency band unless several systems were involved.

(b) The use of a low basic frequency from which the carrier supplies can be generated by multiplication at each end; the low frequency is transmitted on the same line as the two-phase system. The main objection to this arises when a multi-channel system is being operated with a small channel spacing. In such a case, the basic frequency will normally be equal to the channel spacing (or perhaps to one-half of it), and this may be too low to be effectively transmitted on the line; moreover, it would be subject to greater phase variations in transformers, equalisers, etc., than the channels themselves.

(c) The use of a control tone above the highest channel frequencies. This would be generated by multiplication from the basic frequency at the sending end, and divided to the basic frequency at the receiving end by a frequency-divider of the "regenerative modulator" type,[3,4] which is relatively free from stray phase variations. Probably no divider using a synchronised oscillator or multivibrator is suitable, owing to the large phase variations which can occur within the synchronised frequency range.

(d) The transmision of two tones above the highest or below the lowest channel frequencies, separated from one another by a frequency difference equal to the basic frequency of the system. Simple rectification and filtration will then produce the wanted basic frequency at the receiving end.

Of these four methods, the last two were the ones favoured for the author's application, and undoubtedly the simplicity of the method (d) is very attractive, and makes it the preferable method where the extra frequency range it requires is readily obtainable.

Another factor influencing the phase accuracy is the linearity of the phase-frequency response of the line or other parts of the transmission system. Since the actual carrier of the twin-sideband signal is suppressed, the virtual carrier can be regarded as having a relative phase exactly halfway between the relative phases of the two sidebands. If the phase characteristic is not linear, so that the phase shifts between carrier and one or other sideband are not equal, then the phase of the virtual carrier will be different from that of the original carrier, and, moreover, will vary with the actual frequency of the sideband. Unwanted signals in a channel cannot therefore be eliminated even by a readjustment of the phase shifters. Linearity of the phase-frequency response of the system is not actually required if the phase shifts can be made symmetrical about the carrier; but as this is not generally practicable with lines, it is best to specify linearity.

The last requirement of Section 2, that the sidebands of harmonics of the carrier should not be demodulated, is easily met by the use of filters.

References

[1] H. Nyquist, "Certain Topics in Telegraph Transmission Theory," *Trans. Am.I.E.E.*, 1928, 47, p. 617 (*see* particularly p. 624).

[2] H. Dudley, "The Carrier Nature of Speech," *Bell Syst. Tech. J.*, 1940, 19, p. 495.

[3] R. L. Miller, "Fractional-Frequency Generators Utilising Regenerative Modulation," *Proc. I.R.E.*, 1939. 27, p. 446.

[4] D. G. Tucker and H. J. Marchant, "Frequency Division without Free Oscillation," *Post Office Elect. Eng. J.*, 1942, 35, p. 62.

(To be continued)

The Physical Society's 32nd Annual Exhibition

Electronic apparatus shown at the Imperial College, April 6-9, 1948

Atomic Physics

Geiger-Müller Tubes and Counters

Tubes with stabilised characteristics over a wide flat plateau and suitable for alpha, beta, gamma, cosmic and X-ray work. Operating at moderate H.T. voltages, all are of the external extinction type.

Dawe Insts. Ltd., Harlequin Avenue, Gt. West Road, Brentford.

"Baldwin-Farmer" Electrometer

This instrument incorporates facilities for charging small condenser chambers to a known potential and for measuring the residual charge after exposure to ionising radiation. It is applicable to the measurement of dose-rate distribution in radiotherapy and has a wide application for the protection of personnel against stray radiations.

Baldwin Instrument Co., Ltd., Brooklands Works, Princes Road, Dartford, Kent.

The "Microid" Millikan Oil-Drop Apparatus

This equipment is a simplified form of Millikan's apparatus, arranged for use at low voltages in the determination of the value of the electronic charge, *e*. The principle of the experiment is the determination of the separate charges on a number of oil drops, carrying multiples of the electronic charge, by observing their rate of fall under gravity and their rate of ascent under a known electric field.

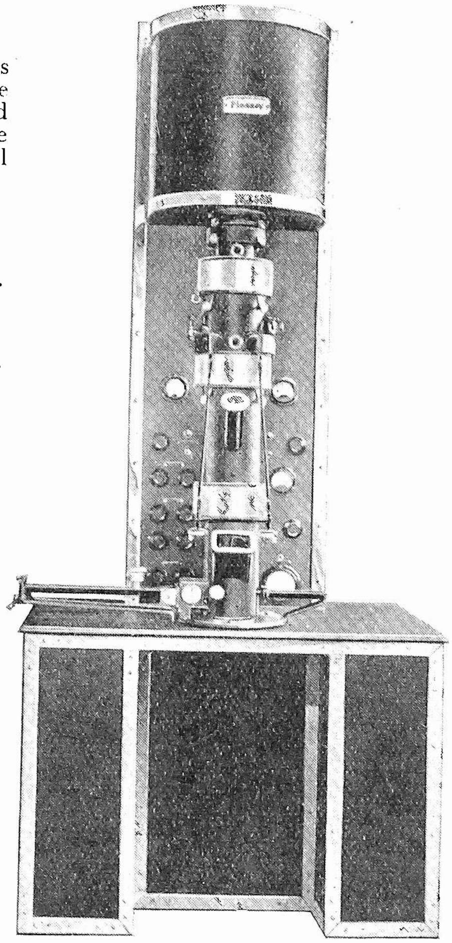
Griffin and Tatlock, Ltd., Kemble Street, London, W.C.2.

Bridges

666 Resistance and Capacity Bridge

This instrument employs a moving-coil meter as a null balance indicator instead of the usual magic eye, and gives a definite and easily recognised indication of balance. There are six ranges of capacitance from 10 pF to 100μF, six ranges of D.C. volts from 1 volt to 500 volts, and five ranges of A.C. (peak) volts from 10 volts to 500 volts. The instrument has been designed to meet the demands of radio and television service engineers, for use where voltage measurements have often to be made across high impedance circuits.

Measuring Instruments (Pullin) Ltd., Electrin Works, Winchester House, Acton, London, W.3.



Experimental Electron Microscope incorporating an R.F. 50 K.V. E.H.T. supply unit with electronic stabilisation. Magnification up to 20,000 diameters. The vacuum system uses rotary backing pumps and a silicone oil-diffusion pump.

The Plessey Co., Ltd., Ilford

Editorial Note:

The catalogue of the Exhibition contains nearly 1,000 items of interest to electronic engineers and physicists.

The continued restrictions on space have compelled us to limit this brief report to a representative collection of new exhibits, and apologies are offered to the many manufacturers whose products have had to be omitted.

It is hoped to cover the remaining items of interest at this and other exhibitions in a new feature "Electronic Equipment," which will appear regularly in subsequent issues of *Electronic Engineering*.

Manufacturers are invited to send brief particulars of new products for inclusion under this heading.

Photographs should be supplied on glossy paper and show as much detail as possible.

Impedance Measuring Equipment

This equipment enables impedances of values 1-100,000 ohms to be determined in the frequency band from 30-500 Mc/s. By use of exponential capacitances in the bridge circuit, the whole impedance range is displayed on a single scale (and in a single range) and has a percentage accuracy which is constant over this scale.

The General Electric Co., Ltd., Kingsway, London, W.C.2.

Direct-Reading Inductance Bridge

A simple and inexpensive inductance bridge of exceptionally wide range, 10 μH. to 10 H.; accuracy 2 per cent. A novel feature is the direct reading of both inductance and resistance.

High-Accuracy Schering Bridge for Very Low Capacitances

Range 0.001 to 4 pF., accuracy better than 0.001 pF. This is an equal-arm substitution Schering bridge operated at A.F., the capacitance standard being of the silica-insulated co-axial type, double-screened with micrometer adjustment.

H. W. Sullivan, Ltd., Leo Street, S.E.15.

Pye Radio-Frequency Bridge Type 940162

This R.F. bridge has generator,, bridge, detector and A.C. mains power supply built in. Its ranges are:—Frequency range 100 Kc/s.-5 Mc/s. Inductance range 10-20,000 μH. Capacitance range 10-950 pF. Resistance range 10-10,000 ohms.

W. G. Pye and Co., Ltd., "Granta" Works, Newmarket Road, Cambridge.

Components

"Micadisc" Lead-Through Capacitor

The circular mica lead-through capacitor for heavy current ratings has been improved, the capacitance and voltage rating extended, and external flanges or lugs have been eliminated. Maximum ratings are:—Current 200 amps: voltage 2,000 D.C., 250 A.C., capacitance 0.1 μF.

Energy Storage Capacitors

Various types for photo-flash equipment are manufactured in a range of capacitances for voltages of 2.5 kV upwards. Special features are small size and light weight: plug-in connexions.

The Telegraph Condenser Co., Ltd., North Acton, London, W.3.

Resistance Pressure Gauges (Type G207)

Primarily intended for dynamic measurements with D.C. polarisation and and R.C. amplifier, the gauges are an adaptation of the resistance-wire strain-gauge technique.

Low-Range Condenser Pressure Gauge (Gauge G212)

This pressure gauge is of the variable capacity type for use with the Southern F.M. system. Ranges covered are 0-1 lb/in² up to 0-10 lb/in². A water-cooled type is available for use at abnormal temperatures.

Vibration Pick-up (Type G209)

A small R.F. dust core mounted on spiders and electromagnetically damped moves within a fixed coil forming part of an oscillator circuit. Movement under vibration modulates the oscillator frequency, the demodulated signal being recorded on an oscillograph.

Southern Instruments, Ltd.,
Fernhill, Hawley,
Camberley, Surrey.

Electroformed Waveguide Components

The internal accuracy and finish in most waveguide components is of primary importance. The production, and especially the quantity reproduction to close limits of such components is difficult and costly by normal methods of machining or casting. Electroforming, however, provides a means of manufacture of awkwardly shaped fittings, accurately and at relatively low cost, with a satisfactory standard of finish.

The process may be briefly described as follows. First, a demountable steel mould is made, whose internal dimensions are the same as those of the component. Castings are then made in a special low melting alloy, which does not expand or contract on solidifying. These are electroplated to the required wall thickness, *e.g.*, 1/16 in., the alloy being subsequently melted out. The resulting finish, after slight cleaning, is then similar to that of the original mould.

Marconi's Wireless Telegraph Co., Ltd.,
Marconi House,
Chelmsford, Essex.

Electromagnetic Limit Switch

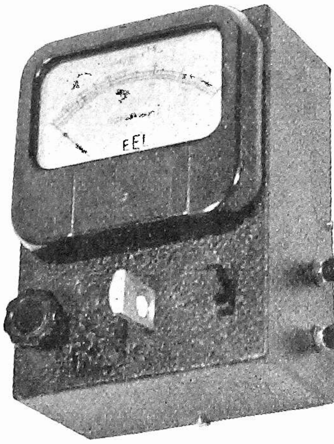
This basically consists of two coils, one energised by A.C. and the other connected through a backing-out circuit to a relay. If a rod of magnetic material is inserted into the coils, the relay operates. This switch has various applications, not only as a limit switch but as an intrinsically safe sparkless switch. Of use in the mining industry.

Londex, Ltd.,
207 Anerley Road, S.E.20.

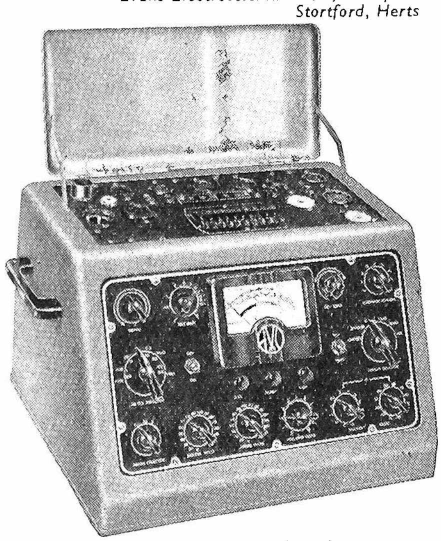
Optical Colour Filters

The range of Chance optical colour filters has been extended to include OY15 [Daylight to Photoflood (3450° K)]. OY18 (Yellow). OB8 (Daylight Blue). OB10 (Blue) OGr3 (Green). OX5 (Infra Red).

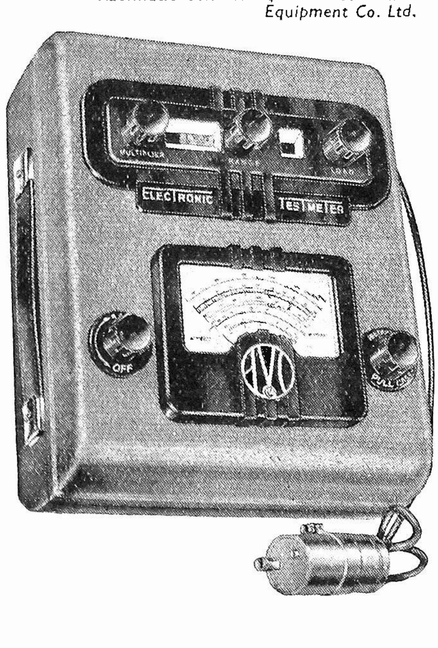
Chance Brothers, Ltd.,
Smethwick,
Birmingham, 40.



Densitometer, for determining amount of coal dust in mines by drawing a given quantity of air through filter paper. The filter holder operates a spring shutter, ensuring that the light is cut off from the meter when the holder is not in place
—Evans Electroselenium Ltd., Bishops Stortford, Herts



(Above) **Improved universal valve tester and characteristic meter**
(Below) **Multi-range electronic testmeter**
—Automatic Coil Winder and Electrical Equipment Co. Ltd.



Copying Lens for Picture Telegraphy

A special lens has been designed for projecting the illuminated slit on a picture telegraph apparatus on to the sensitive film. The ratio of object to image in this case is 4:1, and the maximum light transmission is necessary in order that fast speeds may be maintained in transmitting.

Wray (Optical Works), Ltd.,
Ashgrove Road,
Bromley, Kent.

Ipot (Inductive Potentiometer)

This has been developed for general application to computing instruments. It is an accurate potentiometer and in addition can be used as an auto-transformer arranged for both for step-up and step-down of voltage.

Muirhead and Co.,
Elmers End, Kent.

Miniature Moving Coil Relays

Model S115 has overall dimensions of approximately $1\frac{3}{4}$ by $\frac{5}{8}$ by $\frac{7}{8}$ in. Adjustable change-over contacts of platinum-iridium are fitted. Relays with sensitivities from 100 μA to 50 mA., are available, the contacts being rated at 0.5 W for voltages up to 110 V.

Sangamo Weston, Ltd.,
Gt. Cambridge Road,
Enfield, Middx.

Counting and Timing Equipment

Chronotron Millisecond Meter

The Chronotron Millisecond Meter enables measurements to be taken of times between 0.1 milliseconds and 10 seconds in six ranges. It can be used for timing camera shutters by means of a photo-cell.

Electronic Instruments, Ltd.,
17 Paradise Road,
Richmond, Surrey.

High Stability Process Timer

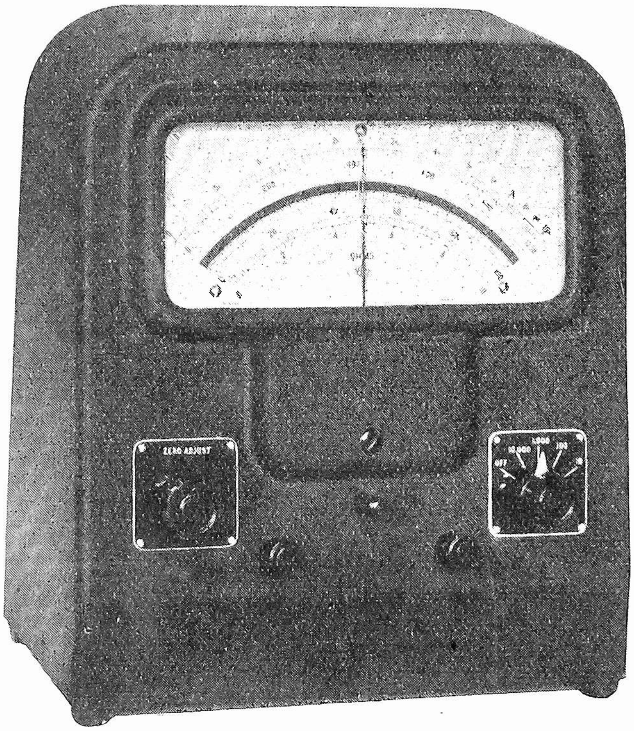
Designed to have a degree of accuracy better than ± 2 per cent., this instrument incorporates a voltage-stabilised power supply and selects periods of 0.2 second to 11 seconds in increments of 0.2 second, then in steps of 1 second each to 1 minute. The range can be extended to 2 minutes, but modified models can give extensions up to 15 minutes.

W. H. Sanders (Electronics) Ltd.,
Stevenage, Herts.

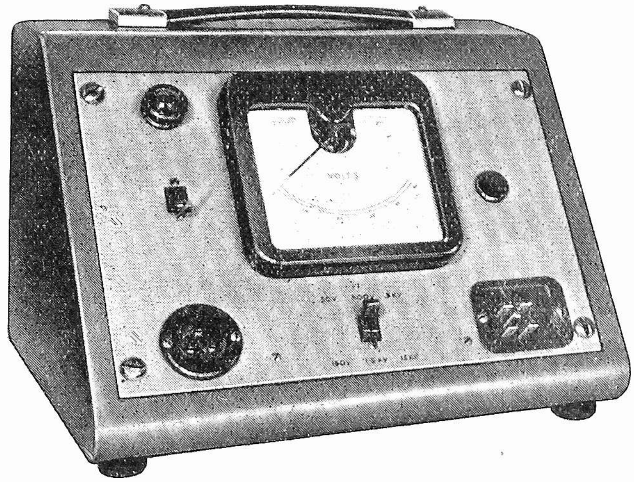
High-Speed Counter

Reaching up to 300 impulses per second. (Electrostatic unit-counting coupled to mechanical counter.) One of the many varied uses of this equipment is the counting of small articles by means of a photoelectric cell.

Londex, Ltd.,
Anerley Works,
207 Anerley Road,
London, S.E.20.



Four-range mains operated ohmmeter with knife-edge pointer and mirror scale
—*Measuring Instruments (Pullin) Ltd., Winchester St., Acton, W.3.*



(Above) **High voltage R.F. valve peak voltmeter, fitted with 3 connector units (not shown). 15 KV. max at frequencies between 100 Kc/s. and 30 Mc/s.**
—*Rediffusion Ltd., Broomhill Rd., S.W.18*

Electro-Medical Apparatus

Ritchie-Sneath Stimulator

With a voltage output constantly variable up to a maximum of 150 volts, this portable apparatus is designed to produce the various types of current and voltage wave-form essential for the electro-diagnosis of nerve and muscle injury. The circuit consists of a modified form of multivibrator circuit capable of giving a ratio of 100,000 :1 between interval and pulse.

Multitone Electric Co., Ltd.,
223/7 St. John Street,
London, E.C.1.

X-ray Dose-Rate Meter

This is a sub-standard instrument for the use of X-ray physicists. A small ionisation chamber is connected to the instrument by means of a screened flexible cable. The indicating meter has two ranges, 0 to 20 and 0 to 100 roentgens per minute. Calibration cable adjusted to within 1 per cent. of the reading, correction for barometric pressure and ambient temperature being provided.

Baldwin Inst. Co., Ltd.,
Brooklands Works,
Princes Road, Dartford.

Portable Electroencephalograph

A double-channel equipment for transportable requirements. It is mains operated with the exception of the first two stages and is assembled in two units measuring $16\frac{1}{2}$ by 13 by 7 in. The record is taken on 1 in. waxed paper and a C.R. tube is provided for direct viewing with electronic switching of the trace.

Marconi Instruments, Ltd.,
St. Albans, Herts.

Oscillators

Variable Frequency R.C. Oscillator (40 c/s 125 Kc/s)

A highly stable and powerful oscillator in which the frequency is varied in five continuous sweeps. The frequency stability is 0.1 per cent. and the calibration accuracy 1 per cent. Output power up to 3.5 W is available with harmonic content 60 db. down to 500 mW. at 1,000 c/s and level to ± 0.2 db. throughout the entire frequency range.

Fixed Frequency R.C. Oscillator (40 c/s to 100 Kc/s)

Frequency is determined by an R.C. network, any number of which may be plugged into the oscillator to give any number of frequencies in the range.

H. W. Sullivan, Ltd.,
Leo Street,
London, S.E.15.

Wide Range Low-Frequency Oscillator (No. 940173).

Frequency range 25 c/s to 100 Kc/s in four ranges. This instrument embodies an R.C. oscillator circuit which contains a compensating resistance to maintain the output substantially constant for all frequencies.

Pye Radio, Ltd.,
Cambridge.

pH Meters

The Model 3A pH Meter is a portable direct reading instrument, mains driven. It has an original arrangement of scales and in addition to the conventional pH and millivolt scales, there is a third scale, the pH scale calibrated 3.5 pH units each side of zero.

A small battery-operated direct-reading pH meter is also shown, designed primarily for field use.

Electronic Instruments. Ltd.,
17 Paradise Road,
Richmond, Surrey.

Battery pH Meters

There are two forms of this direct-reading pH meter, both with two ranges of 0-8 pH and 7-15 pH. The simpler uses external batteries; the other is completely portable.

Muirhead and Co., Ltd.,
Elmers End,
Beckenham, Kent.

Power Supplies and Stabilisers

High Stability Power Frequency Valve Generator

This instrument provides a highly stabilised A.C. supply for instrument testing circuits. The supply is in two parts, one for energising voltage elements and the other current elements. The frequency range is 40 to 2,500 c/s in four bands, and the frequency stability is one part in 20,000 for a period of five minutes.

Elliott Bros., Ltd.,
Century Works,
Lewisham, S.E.13.

New A.C. Stabiliser

This instrument will give outputs up to 1KVA with a stability of one part in 10,000 and a harmonic content not exceeding 1 per cent. The effective stabilisation ratio is 1,000:1 and internal impedance is less than 0.01 ohm. The temperature drift and sensitivity to vibration have been eliminated.

Precision D.C. Stabiliser

This will give any D.C. voltage from 20 to 600 V at load currents up to 120 mA with a stability of one part in 100,000 from the A.C. mains. The reference potential is derived from a standard cell operating under practically open circuit conditions.

H. Tinsley and Co., Ltd.,
Werndee Hall,
South Norwood,
London, S.E.25.

Stabilised Power Supply

The Type 1931 will deliver 250 mA at 350 V $\pm$ 70 V, the output change from no-load to full-load being less than 0.1 V.

The ripple voltage in these units is less than 1.0 mV, and they are provided with metering facilities on the various output tappings.

Furzehill Laboratories, Ltd.,
Boreham Wood, Herts.

A Motor-Operated Precision Regulator

With remote control, enabling precise adjustment to be attained from a distance. Magnetic clutch and limit switches are incorporated to prevent over-running.

The Zenith Electric Co., Ltd.,
Villiers Road,
London, N.W.2.

Resistance Meters

Megohmmeter

An electronic instrument for bench or portable use covering the entire megohm range from 0.3 to 20,000,000 megohms in seven decades using either 500 or 1,000 V for test. The edgewise indicator has a 6 in. scale. When testing condensers, a neon lamp on the panel indicates visually when an adequate preliminary charging time has elapsed.

Electronic Instruments, Ltd.,
17 Paradise Road,
Richmond, Surrey.

Four-range, Mains-Operated Ohmmeter

This is a self-contained instrument with built-in indicator having an 8 in. rectangular dial with knife edge pointer and mirror scale. An important feature of this instrument is the wide range and almost linear scale. Single and double range instruments are also available.

Measuring Instruments (Pullin) Ltd.,
Winchester House,
Acton, W.3.

Insulation Tester, Type 402B

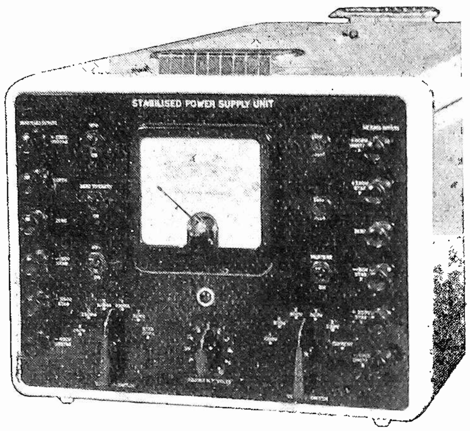
This instrument has been designed particularly for application in measuring the moisture content of such things as tobacco. It has a direct reading scale, the percentage water content being read on a curve. Capable of measurement of leakage resistance over the range 0.1 to 10,000 Megohms.

Dawe Instruments, Ltd.,
Harlequin Avenue,
Great West Road,
Brentford Middx.

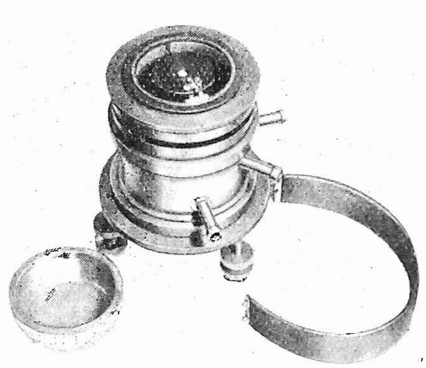
Electronic Insulation Indicator (S.118)

This consists of a moving coil instrument operating in the cathode circuit of a triode valve. The scale is logarithmic and gives a range of values from 0.01 Megohm to 100,000 Megohms. Designed for use on 240 V 50 c/s mains, the instrument incorporates a self-contained voltage regulator.

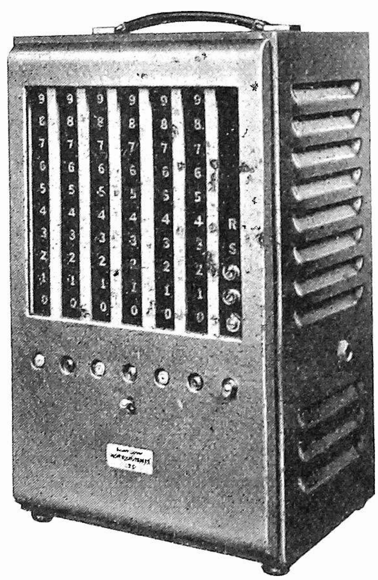
Sangamo Weston, Ltd.,
Gt. Cambridge Road,
Enfield.



Type 1931 Stabilised Power Supply Unit
—Furzehill Laboratories Ltd.



High-temperature X-ray diffraction powder camera enabling specimens to be heated to 1000° C *in vacuo* or any required atmosphere
—The Plessey Co. Ltd., Ilford.



Electronic Counter Type TF.922. Will count periodic or random impulses at speeds up to 1 Mc/s, or time intervals up to 1 sec. in steps of 1 μsec. The indication is given to the nearest μsec. by the illuminated figures on the panel
—Marconi Instruments Ltd., St. Albans, Herts.

Special Apparatus

Echo-Sounding Equipment, Type "A" (MS.21)

This has been developed for hydrographic survey and comprises four main units:—(1) recorder-amplifier, (2) A.C. converter and transmission unit, (3) transmitting oscillator, (4) receiving oscillator. The main power supply is taken from three large-capacity accumulator batteries (36 V), the A.C. converter supplying power for the amplifier, internal illumination and marking devices and high-voltage transmission unit.

Henry Hughes and Sons, Ltd.,
Husun Works,
Great North Road,
Barkingside,
Ilford, Essex.

Enamelled Wire Tester

This apparatus is used for testing the enamel covering for pin holes for pliability and hardness. By means of the tester, reels of wire can be graded for use on the class of work for which the quality of the enamel covering is most suitable.

Evershed and Vignoles, Ltd.,
Acton Lane Works,
Chiswick, London, W.4.

Visual Null Indicator

Mains-operated single-valve amplifier and moving-coil galvanometer to take the place of ear-phones or vibration galvanometer in A.C. bridge work. Frequency range 40 to 15,000 c/s.

Baldwin Inst. Co.,
Princes Road,
Dartford, Kent.

The Comverter

The need for an efficient conversion of the normal 24 V D.C. to 115 V 3-phase, 400 c/s A.C. for driving aircraft gyroscopic instruments has resulted in the design of the Comverter. To eliminate the disadvantages of conventional motor converters Sperry have designed a rotary interrupter comprising a standard commutator assembly driven by a small motor. By the use of a multi-segment commutator a high rotational speed is rendered unnecessary.

The Sperry Gyroscope Co., Ltd.,
Gt. West Road, Brentford.

Wire Tensioner

The purpose of this device is to ensure that when coils are being wound with fine wire the tension of the wire is maintained at a constant and predetermined value so that coils with the same number of turns may have the same resistance. Wire is drawn from the bobbin against the torque of a small motor and this torque can be varied to suit the gauge of wire. Further, the small motor will rewind any excess wire drawn from the bobbin and a device is incorporated so that should the wire break, the small motor is automatically brought to rest. The apparatus operates on 230 V A.C. supply.

Evershed and Vignoles, Ltd.,
Acton Lane Works,
Chiswick, W.4.

Magnetic Amplifier

This is a very sensitive D.C. valve amplifier in which the input modulates a 1,500 c.p.s. carrier wave by means of a magnetic modulator. The zero error depends principally on the symmetry of the magnetisation characteristic of the transductors and the noise in the modulating stage; these are below the input level of 10^{-17} watts. The unit is specially applicable for detecting with a high degree of stability very low D.C. inputs of reasonable output impedance and low-frequency alternating currents.

Ferranti, Ltd., Hollinwood, Lancs.

High-Temperature X-ray Diffraction Powder Camera

This new design enables specimens to be heated to a temperature of 1,000° C. with a base-metal-wound furnace, or to considerably higher temperatures with special windings. It can be rotated and moved in a vertical direction. A high degree of vacuum or any desired atmosphere can surround the specimen.

The film ring is entirely separate from the vacuum chamber and can be removed without any interruption of electrical vacuum or water connexions.

The Plessey Co., Ltd., Ilford, Essex.

Vacuum Equipment

Oil Diffusion Pumps

Improved oil-diffusion pumps from 7-600 litres/sec. capacity.

Metropolitan-Vickers Electrical Co., Trafford Park, Manchester.

Vacuum Coating

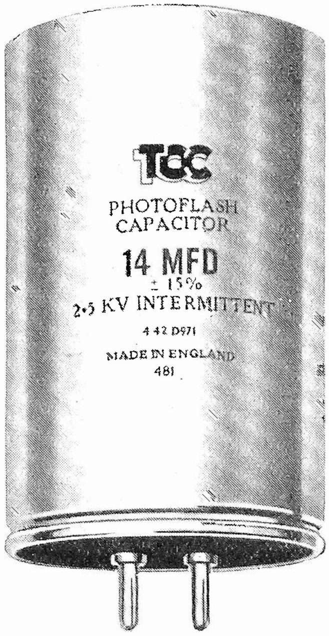
Provided with a single-stage rotary vacuum pump this equipment (model S.5) gives adequate vacuum conditions for sputtering certain metals, gold for example. Satisfactory deposition of silver and platinum requires a very low oxygen concentration, and for such cases provision is made for the addition of an oil-diffusion pump, so that satisfactory sputtering pressures can be maintained against the admission of an inert gas, such as argon or hydrogen.

W. Edwards and Co. (London) Ltd., Kangley Bridge Road, Sydenham, London, S.E.26.

Ionisation Gauge

The Mazda 29D2 is a directly heated ionisation gauge intended for high vacuum measurement work. It is rated as follows:—Filament volts: 6.0 volts (approx.). Filament current: 1.3 amps (approx.). Collector voltage: 25 volts. Internal wire electrode voltage: + 185 volts. Internal wire electrode current: 1.0 mA. Collector current: 20 μA/micron pressure.

Edison Swan Electric Co., Ltd., 155 Charing Cross Road, W.C.2.



New photoflash capacitor for 2 KV upwards
—Telegraph Condenser Co., Ltd., Acton.

Valve Voltmeters

Micovac Electronic Test Meter

The Micovac electronic test meter is a battery operated valve voltmeter with 22 ranges for D.C., A.F., and R.F. voltages and resistance. It has a very high input resistance on D.C. and the ability to measure R.F. up to 200 Mc/s a second.

Electronic Instruments, Ltd., 17 Paradise Road, Richmond, Surrey.

Valve Millivoltmeter (Type TF899)

This high-impedance instrument is designed for use between 50 c/s and 100 Mc/s, and measures 0-2,000 mV in three ranges. The input capacitance is approximately 7 pF. and the resistance is greater than 1 Megohm at 1 Mc/s.

Marconi Instruments, Ltd., St. Albans, Herts.

Valve Voltmeter, Type 613B

This is an improved model of the sensitive amplifier type using a straightforward circuit, which gives reliable operation and mechanical simplicity.

Dawe Instruments, Ltd., Harlequin Avenue, Gt. West Road, Brentford.

Sensitive Valve Voltmeter

Incorporating a D.C. amplifier the full-scale sensitivity of this meter is 1 mV on both D.C. and 3.4. ranges. It may also be used to measure high resistances, a million megohms indicating 1/10 full scale, and similarly resistances as low as 1/10 milliohm.

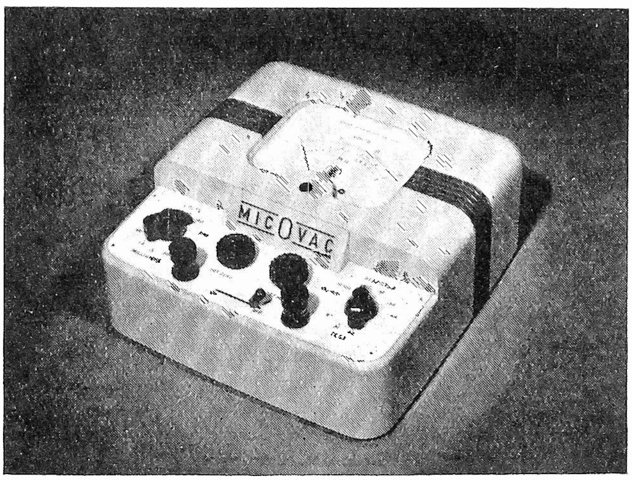
Elliott Brothers (London) Ltd., Century Works, Lewisham, London, S.E.13.

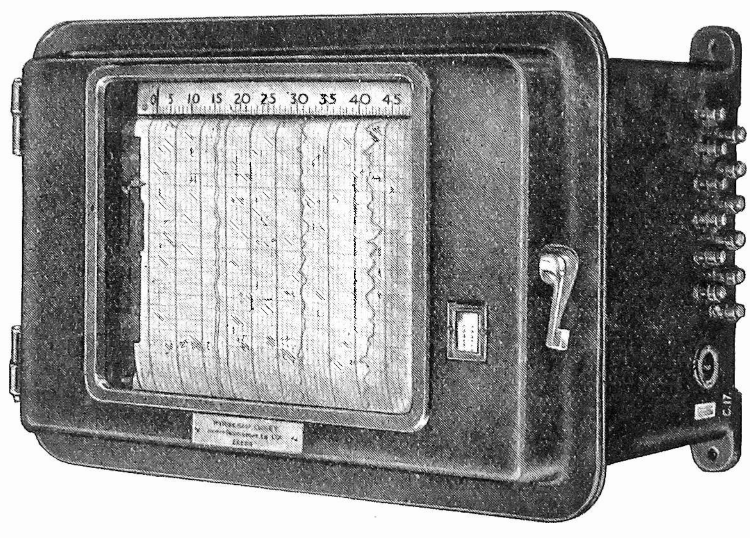
Diode Voltmeter

High impedance meter with a frequency range from 50 c/s to 250 Mc/s. The instrument is unusually stable and the zero setting remains constant on all ranges.

Furzehill Laboratories, Ltd., Boreham Wood.

(Left) **"Micovac" electronic testmeter, mains or battery driven**—*Electronic Instruments Ltd., Richmond.* (Right) **Pyrotron Chart Recorder, giving records on a 10 in. chart, with electronic amplification. Input 1 mV**—*Bowen Instrument Co.*





Two Transmitters on One Aerial

By H. B. MORTON, B.A., and J. W. WHITEHEAD, B.Sc., M.I.E.E.*

Introduction

IN 1943 the authors investigated the problem of several transmitters installed on a small site with restricted space for aerials. After discussion it was proposed to employ certain pairs of transmitters on single aerials using simple acceptor and rejector circuits at appropriate points in the feeder systems, and the following theoretical investigation was carried out to determine whether such a scheme was practicable.

The scheme was restricted to transmitters operating in the 3-15 Mc/s. band, with a minimum frequency separation of 500 Kc/s. between any given pair.

Although complete finality was not attained, the theoretical considerations, coupled with laboratory measurements, have indicated that insuperable difficulties should not arise.

Under conditions of 500 Kc/s. separation, the loss introduced in either circuit by the addition of a parallel transmitter circuit is shown to vary from 0.27 to 2.6 db. over the frequency band considered. For greater separations the loss is lower, and with a separation of 1 Mc/s., it does not exceed 0.62 db. The highest peak voltage expected to appear across any component when using transmitters generating 2 KW in a 700 ohm aerial load is less than 13 KV.

The Theoretical Investigation

The circuit of Fig. 1 was considered a feasible means of feeding two transmitters, of respective operating frequencies $f_1 = \frac{\omega_1}{2\pi}$ and $f_2 = \frac{\omega_2}{2\pi}$, into a common aerial load of effective impedance 700 ohms.

The resonant circuits L_1C_1, L_2C_2, are tuned to f_2 and f_1 respectively, and thus present a high series impedance at these frequencies between the transmitters (T_1, T_2) and the load.

At frequencies other than f_2 and f_1, these circuits present a relatively low impedance, the precise value of

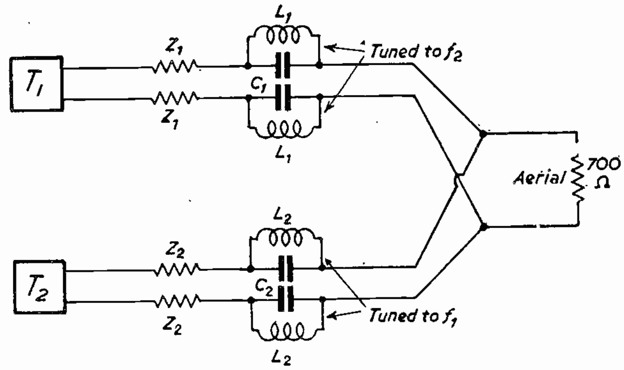


Fig. 1. The application of two transmitters to a single aerial

which depends on the choice of L_1, L_2, C_1 and C_2. Cancellation of the reactive component of this impedance at the frequency of the signal which is to be passed down the line is achieved by further series impedances, Z_1 and Z_2, possessing reactances which are numerically equal to the respective " residual " reactances of the L_1C_1 and L_2C_2 circuits at f_2 and f_1, but opposite in sign.

The effectiveness of the energy transfer between each transmitter and the aerial will be governed largely by the losses in the filter circuits.

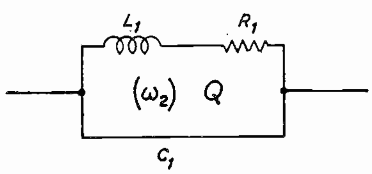


Fig. 2. To illustrate circuit losses

The losses in the circuit L_1C_1 are represented in Fig. 2 by a resistance R_1 in series with L_1. The circuit magnification factor is Q_1 and R_{d1} is its dynamic resistance. Then at resonance:

$$\omega_2^2 L_1 C_1 = 1 \qquad \text{(1)}$$

$$R_1 = \frac{\omega_2 L_1}{Q_1} \qquad \text{(2)}$$

$$R_{d1} = \frac{L_1}{C_1 R_1}$$

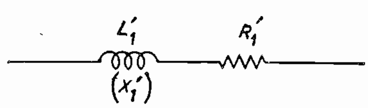


Fig. 3. Equivalent circuit of Fig. 2 at frequency f_1

At any frequency ω_1, the circuit of Fig. 3 may be regarded as equivalent to that of Fig. 2, where:

$$X_1' = -\left[\frac{\omega_1 C_1 R_1^2 + \omega_1 L_1(\omega_1^2 L_1 C_1 - 1)}{R_1^2\omega_1^2 C_1^2 + (\omega_1^2 L_1 C_1 - 1)^2}\right] \qquad . \text{(3)}$$

and

$$R_1' = \frac{R_1}{R_1^2\omega_1^2 C_1^2 + (\omega_1^2 L_1 C_1 - 1)^2} \qquad \text{..... (4)}$$

Negative values of X_1' correspond to capacitive reactance.

At frequencies well removed from resonance, terms in Equations (3) and (4) which involve R_1^2 are small in comparison with those involving $(\omega_1^2 L_1 C_1 - 1)$ and may be neglected.

$$X_1' = -\frac{\omega_1 L_1}{\omega_1^2 L_1 C_1 - 1} = -\omega_1 L_1 \frac{\frac{1}{L_1 C_1}}{\omega_1^2 - \frac{1}{L_1 C_1}}$$

$$= -\frac{\omega_1 \omega_2^2 L_1}{\omega_1^2 - \omega_2^2}$$

$$R_1' = \frac{R_1}{(\omega_1^2 L_1 C_1 - 1)^2} = \frac{R_1}{\left(\frac{\omega_1^2}{\omega_2^2} - 1\right)^2}$$

from Equation (1).

The sign of the value thus calculated from X_1' shows whether the impedance represented in Fig. 3 by L'_1 is inductive (positive) or capacitive (negative). The value of the reactance required to neutralise it at angular frequency ω_2 is therefore given by:

* Central High School, Leeds.

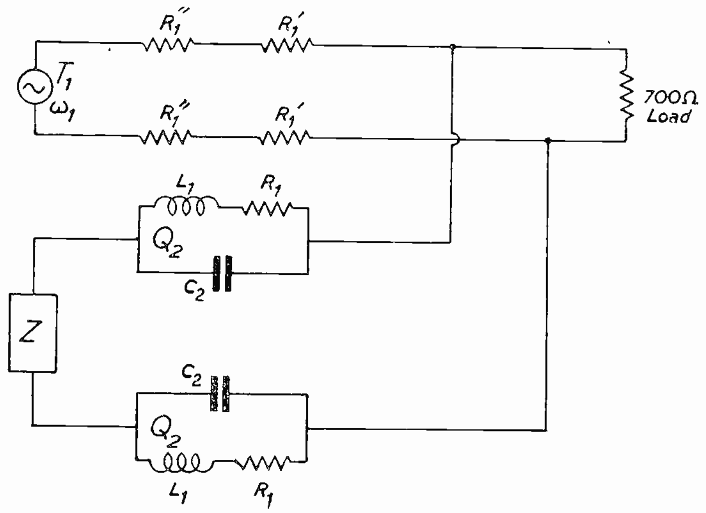


Fig. 4. Complete circuit as viewed from transmitter T_1

$$\omega_1 L_1'' = \frac{\omega_1\omega_2^2 L_1}{\omega_1^2 - \omega_2^2} \quad \text{.................... (5)}$$

$$L_1'' = \frac{\omega_2^2}{\omega_1^2 - \omega_2^2}\,.\,L_1 \quad \text{.............. (6)}$$

$$R_1' = \frac{R_1}{\left(\frac{\omega_1^2}{\omega_2^2} - 1\right)^2} = \frac{\omega_2 L_1}{Q\left(\frac{\omega_1^2}{\omega_2^2} - 1\right)}$$

.... (7)

For the series circuit tuned to f_1, of which Z_1 forms one component, assume a total resistance R_1'' and magnification Q_1''.

$$R_1'' = \frac{\omega_1 L_1''}{Q_1''} = \frac{\omega_1\omega_2^2}{\omega_1^2 - \omega_2^2}\,\frac{L_1}{Q_1''} \quad (8)$$

For convenience it has been now assumed that $L_1 = L_2$, and that the R.F. resistance of L_1 remains sensibly constant over the frequency band.

The circuit, as viewed from the transmitter T_1 working at angular frequency ω_1, now appears as shown in Fig. 4.

The L_1C_2 circuits are tuned to f_1.

$$\therefore\ C_2 = \frac{1}{\omega_1^2 L_1}$$

$$R_{d2} = Q_2^2 R_1 = Q_2^2\,.\,\frac{\omega_1 L_1}{Q_1}$$

...... (from 2) ...... (9)

The impedance Z (Fig. 4) may be assumed small in comparison with R_{d2}, and in general will have a predominantly resistive component of the order of 700 ohms. The circuit may therefore be represented by Fig. 5.

Assume now that the transmitter T_1, when correctly matched into its new load as represented in Fig. 5, gives the same output W as would be the case when working directly into a 700 ohm load.

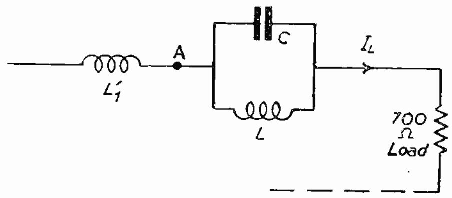


Fig. 5. Simplified circuit of Fig. 4

Let I_a be the current supplied by the transmitter when working into the 700 ohm load alone, and I_b the current when working into the new load of Fig. 5. Let this new load be S ohms.

Then,

$$700\,I_a^2 = S.I_b^2 = W \quad \text{........... (10)}$$

$$S = 2(R_1' + R_1'') + \frac{700(2R_{d2} + 700)}{2R_{d2} + 1{,}400}$$

...... (from Fig. 5) ......

Also,

$$I_b'\ (\text{Fig. 5}) = I_b\,\frac{2R_{d2} + 700}{2R_{d2} + 1{,}400}$$

and the power W' developed in the 700 ohm load of Fig. 5 is given by:

$$W' = (I_b')^2\,.\,700$$

$$= 700\,I_b^2\left[\frac{2R_{d2} + 700}{2R_{d2} + 1{,}400}\right]^2$$

$$= \frac{700}{S}\,.\,I_a^2\,.\,700\left[\frac{2R_{d2} + 700}{2R_{d2} + 1{,}400}\right]^2 \quad (11)$$

We can now obtain an expression for $\frac{W'}{W}$, the efficiency of the system.

$$\frac{W'}{W} = \frac{700}{S}\left[\frac{2R_{d2} + 700}{2R_{d2} + 1{,}400}\right]^2$$

$$= 700\left[\frac{2R_{d2} + 700}{2R_{d2} + 1{,}400}\right]^2 \frac{2R_{d2} + 1{,}400}{700(2R_{d2} + 700) + (2R_{d2} + 1{,}400)\,.\,2\,.\,(R_1' + R_1'')} \quad \text{..... (12)}$$

$$R_1' + R_1'' = \frac{\omega_2 L_1}{Q\left(\frac{\omega_1^2}{\omega_2^2} - 1\right)} + \frac{L_1\omega_1\omega_2^2}{Q_1''(\omega_1^2 - \omega_2^2)}$$

... (from 7 and 8) ......

Assume now that the magnification of all the tuned circuits is identical $= Q_1$.

$$R_1' + R_1'' = \frac{\omega_2 L_1}{Q_1}\,.\,\frac{\omega_2^4 + \omega_1^3\omega_2 - \omega_2^3\omega_1}{(\omega_1^2 - \omega_2^2)^2}$$

.... (13)

In estimating the lower limit of the efficiency of the system, it will suffice to consider only relatively large values of $(R_1' + R_1'')$ (*see* Equation 12). These occur when ω_1 and ω_2 are nearly equal (Equation 13). When this is so, we may write:

$$R_1' + R_1'' = \frac{\omega_2 L_1}{Q_1}\,\frac{\omega_2^4}{(\omega_1^2 - \omega_2^2)^2}$$

$$= R_1\left(\frac{\omega_2^2}{\omega_1^2 - \omega_2^2}\right)^2 \quad \text{........... (14)}$$

and $R_{d2} = Q_1\omega_1 L_1$ (from Equation 9)

.... (15)

W'/W may now be evaluated by substituting (14) and (15) in Equation (12), and hence the loss at any frequency f_1 due to parallel feeding may be deduced.

This has been done for the following values:

$L_1 = L_2 = 2\mu$H

$Q = 150$

$\omega_1 = 3$, 9, and $15 \times 2\pi \times 10^6$ radians/sec. for values of ω_2 between 3 and $15 \times 2\pi \times 10^6$ radians/sec. Results are shown graphically in Fig. 6.

A further curve designated "D" has been drawn through points corresponding to 500 Kc/s. separation between the two transmitter frequencies, giving an approximation to the loss to be expected for this minimum separation over the band considered. It is seen to vary between 0.27 db. at 3 Mc/s. to 2.6 db. at 15 Mc/s.

For two dissimilar frequencies f_1 and f_2 Mc/s., the loss may readily be deduced as it tends to the value given by Equation (12) when $(R_1' + R_1'')$ is neglected.

$$i.e.,\ \frac{W'}{W} = \frac{2R_{d2} + 700}{2R_{d2} + 1{,}400}$$

$$= R_{d2} - 350/R_{d2} \text{ approximately.}$$

$= 1 - 350/R_{d2} = 1 - 350/Q_1\omega_1 L_1$
$= 1 - 0.1856/f_1$,
where $Q_1 = 150$, $L_1 = 2\mu$H, whence
$\log_e (1-0.1856/f_1) = 0.1856/f_1$ approx.

$\therefore$ Loss $= 0.1856/f_1 \times 0.4343 \times 10$
$= 0.860/f_1$ db.

This expression gives an approximation to the loss at frequencies due to the f_1 feed circuit at any frequency f_2 well removed from f_1—say, outside the band 0.7 f_1 to 1.3 f_1.

Circuit Conditions and Component Ratings

Consider one of the feeder lines involved, as drawn in Fig. 7. Circuit LC is tuned to angular frequency ω_2, and its residual reactance at ω_1 (the frequency of the signal in the other feeder line) is balanced by series reactance L_1' (or C_1').

For 2 KW developed in the load, $700\ I_L^2 = 2{,}000$, $\therefore I_L = 1.69$ amps.

At frequency f_1 point A (Fig. 7) may be considered as being at earth potential, and the potential developed across C may be taken as half that developed across the load.

Potential across $C = 0.5\sqrt{700 \times 2{,}000}$
$= 594\ V_{r.m.s.} = 840\ V_{peak}$.

Allowing for the possibility of modulation depths of 100 per cent., a peak voltage of double this value may be encountered: and unless tuning operations are carried out at reduced power, it is likely that the whole voltage developed across the system will appear across C. It will, however, be assumed either that tuning will be carried out at low power, or that the signal during tuning adjustments will be unmodulated. A p.d. greater than 1,680 volts will not then appear across C.

$$L_1' = \frac{\omega_2^2}{\omega_1^2 - \omega_2^2} \cdot L \quad \text{from Eq. (5)}$$

$$X_{L1}' = \frac{\omega_1\omega_2^2}{\omega_1^2 - \omega_2^2} \cdot L \text{ at } \omega_1$$

$\therefore$ voltage developed across L_1' due to feed current I_L

$$= \frac{I_L\omega_1\omega_2^2 L}{\omega_1^2 - \omega_2^2} \quad \text{(r.m.s.)}$$

$$= 9.57 \times 10^{-6} \times \frac{\omega_1\omega_2^2}{\omega_1^2 - \omega_2^2} \text{ volts peak}$$

for 100 per cent. modulation.

The highest voltage will thus correspond to the smallest difference between ω_1 and ω_2. For our minimum separation of 500 Kc/s. the extreme values will therefore work out to 583 volts peak and 12,840 volts peak.

The corresponding minimum voltag will occur when the two frequencies are very dissimilar and the value of L_1' is very small. The minimum value of L_1' is given by:

$$L_1' = \frac{(3)^2}{(15)^2 - (3)^2} \cdot 2\mu\text{H} = 0.083\ \mu\text{H}$$

and the maximum value by:

$$L_1' = \frac{(14.5)^2}{(15)^2 - (14.5)^2} \cdot 2\ \mu\text{H} = 28.5\ \mu\text{H}$$

The range of inductance required for neutralising therefore lies between 0.08 μH and 30 μH.

The range of capacitance is found similarly to vary between 3.9 pF and 1,331 pF, and the voltages at these extremes do not exceed 1,720 volts peak.

Component values and ratings will thus vary between these limits:

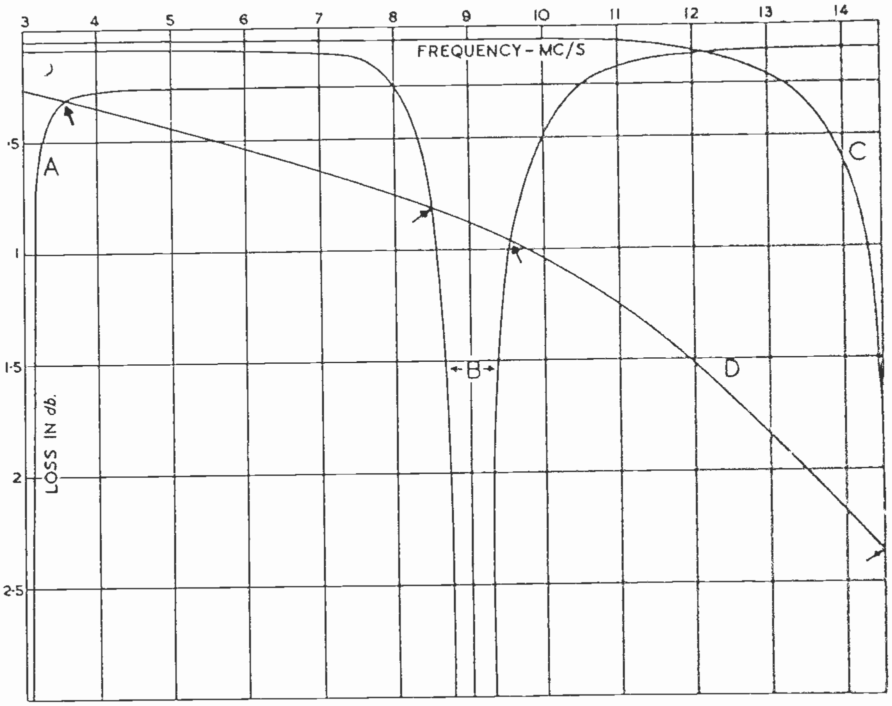


Fig. 8. Loss at 3-15 Mc/s. due to effect of parallel feed circuits, (A) at 3 Mc/s., (B) at 9 Mc/s., and (C) at 15 Mc/s. Cirve (D) shows suggested loss for 500 Kc/s. separation at all parts of the band (approx.)

(a) In the parallel resonant circuits:

$L = 2\ \mu$H

$C = 56.3$ pF to 1,440 pF.

Voltage across condenser:
$= 1{,}680$ to $(12{,}840 - 1{,}680)\ V_{peak}$

Circulating current $= 3.15$-$15.8\ A_{r.m.s.}$

(b) Series tuning reactances:
Inductive 0.08 to 30 μH
Capacitive 3.9 to 1,334 pF
(to carry 1.69 amps.)

Conclusions

From the foregoing analysis, it may be concluded that the method suggested is a practicable one.

The realisation of the scheme might present considerable difficulties when rapid changes of frequency are made; for example, when the frequency of Transmitter I is changed, the tuning of the filters in the lines from Transmitter II will have to be carried out anew, involving the closing down of that transmitter also.

The use of more than two transmitters would greatly complicate both the circuit arrangements and the tuning procedure, a change in the frequency at any one transmitter involving the closing down of all the others working into the same aerial while all their filter circuits were adjusted to suit the new conditions.

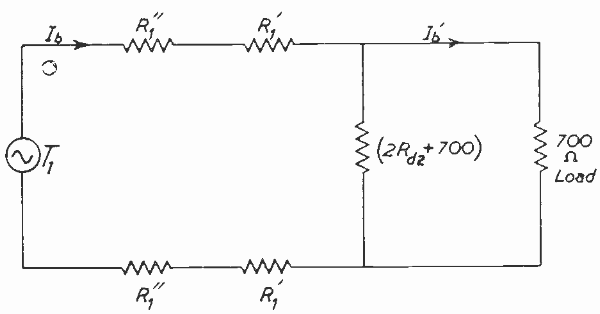


Fig. 7. To calculate circuit conditions and component ratings

A Single Sweep Time-Base

By V. ATTREE*

A simple timebase circuit is described which will provide a single brightened sweep on a cathode ray tube. The circuit consists of capacitors and resistors only and derives its H.T. from the E.H.T. supply which feeds the cathode ray tube. The timebase is suitable for sweep durations of from 10 milliseconds to about 2 seconds.

In physiological research it is frequently necessary to examine phenomena which have a time period between 10 milliseconds and 10 seconds. As such phenomenon are associated with living material and are not in general repetitive, it is convenient to use a single stroke timebase for their examination. The timebase can be started by a key or relay having auxiliary contacts which impress some special condition on the living material (*e.g.*, stimulus, tension, illumination, etc.). The response can then be studied either by means of a camera or by using a special cathode-ray tube having a long afterglow screen. The present circuit is designed for the G.E.C. E4504 cathode-ray tube. The tube runs from an E.H.T. supply of 2.5 KV and at this voltage the X-plate sensitivity is 24 V/cm.

Circuit Description

The circuit diagram is shown in Fig. 1. The timebase and brightener are generated by the components R_1, R_2 and C_1, while the maximum voltage on the X deflection plate is determined by the neons N_1 and N_2. It is convenient to describe the action of the circuit with the positive supply derived from a 150 V battery. Consider the timebase to be in the quiescent state with the actuating contacts closed. The condenser C_1, will be discharged and there will be no potential across the resistor R_2. The cathode-ray tube bias is set so that the spot is not quite visible and as the X-plate is at 150 V the position of the spot, were it to be brightened, would be near the edge of the screen. The 150 volts across the neons is insufficient to strike them and the effect of the two 30 MΩ resistors may be neglected. A small current flows from the battery to the negative E.H.T. supply via the key contacts and the charging resistor R_1. Let the time base be started by opening the key contacts. The charging current will now pass through R_2 and C_1. The voltage drop across R_2 will give a negative going brightener pulse which is applied to the C.R.T. cathode via the blocking condenser C_2. The pulse is also applied to the X-plate and the brightened spot will appear at a point just inside the quiescent position. The condenser C_1 will now commence to charge exponentially to the E.H.T. supply through the resistors R_2 and R_1, giving a time base which will fully scan the tube face and continue to run until the potential of the X-plate is sufficiently negative to strike the neons. When the neons strike, the timebase will remain stationary until the contacts are closed, thus returning the spot to its initial position.

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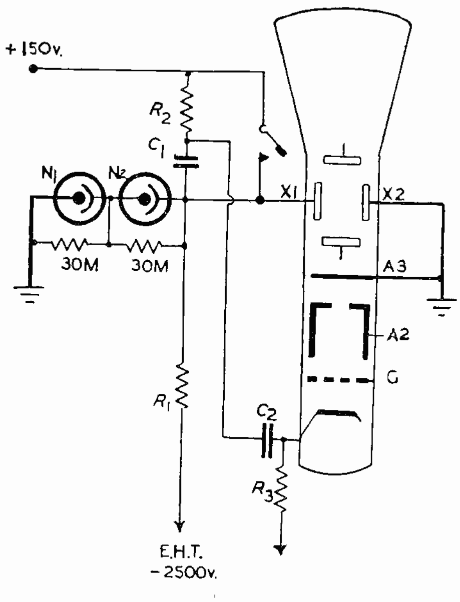


Fig. 1 (left). Single Sweep Time-Base circuit diagram

Design Considerations

The design of the timebase for the E4504 based on the following information:

(i) Cathode-ray tube E.H.T. is 2.5 KV.
(ii) Voltage required for full scan at this E.H.T. is 300 V.
(iii) The amplitude of brightener pulse required is 25 V.
(iv) The time of scan required is 20 milliseconds.

1. The positive battery voltage required to shift the spot to the edge of the tube is half the scan voltage. Hence the battery supply should be 150 V.

2. A reasonable mean value for the charge current is 0.25 mA. With an E.H.T. of 2.5 KV R_1 becomes 10 megohms. In order to prevent possible flash-over, R_1 is made up of five 2-megohm resistors in series.

3. The brightener voltage required is 25 V, hence with a current of 0.25 mA, R_2 must be 100 KΩ.

4. With a mean current of 0.25 mA the condenser must charge by 275 V in 20 milliseconds.

$$C = \frac{Q}{V} = \frac{it}{V} = 0.018\ \mu F$$

For timebase durations of other than 20 milliseconds, it is only necessary to change the value of the charging condenser.

5. The full width of the tube will have been scanned when the X-plate potential is 150 V negative to earth. As a single neon may conduct

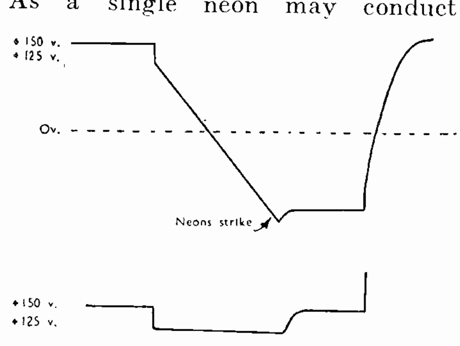


Fig. 2 (top right). X-plate Waveform

(lower right) brightener Waveform

before the end of the trace, two neons in series are used. The high resistance leaks are to obtain reliable striking.

Linearity

The timebase consists of the beginning of an exponential waveform. It is convenient to estimate linearity from the reduction in the *rate* of rise of voltage at the end of the timebase as compared with the beginning. The initial charging voltage is the E.H.T. plus the battery voltage and minus the brightener, *i.e.*, 2,500 + 150 − 25 = 2,625 V. The final charging voltage is 275 V less than this as the condenser has charged by that amount. Hence the percentage reduction in *velocity* of the end of the timebase,

$$= \frac{275}{2,625} \times 100 = 10.5\%$$

This figure is, of course, independent of the actual speed employed. The effect on the linearity of the two 30-megohm neon leak resistors may be considered as follows. At the beginning of the trace the current in the resistors is 2.1 microamps (125 V and 60 megohms) and at the end of the trace it is 2.5 microamps in the opposite direction. Hence, the change in the current available for charging the condenser is 4.6 microamps in a mean current of 250 microamps. Thus the percentage reduction in the speed at the end of the timebase due to this cause is 2 per cent.

Alternative Arrangement

The use of a battery for the positive D.C. shift may be avoided by "floating" the E.H.T. power supply and earthing the C.R.T. resistor chain at a point 150 V below its positive end. A decoupling condenser of, say, 4 μF should be connected between the positive terminal and earth. The A_3 electrode and the X_2-plate of the cathode-ray tube should be earthed.

From the brief discussion on linearity above, it will be seen that the linearity is approximately equal to the ratio of the E.H.T. voltage to the voltage required to scan the tube *at that* E.H.T. For this reason, the timebase will have rather poor linearity on those cathode-ray tubes having scan voltages which are larger than, say, one-fifth of the corresponding E.H.T. voltage. The following table gives these particulars for a few cathode-ray tubes.

	Usual E.H.T.	X-scan	Ratio
Cossor double beam 9 in. dia.	2 KV	600 V	30%
E 4504 G.E.C. VCR 517C. 6 in. dia.	2.5 KV	300 V	12%
VCR 97 6 in. dia.	2.5 KV	350 V	14%
Cossor double beam 3½ in. dia.	1.2 KV	180 V	15%
E 4412 G.E.C. VCR 138A 3½ in. dia.	3 KV	440 V	22%

The scan voltage quoted on the above table is the voltage required to move the spot across the full width of the tube screen. In most applications only about two-thirds of the screen width is scanned, resulting in improved linearity. If the ratio of the initial (or final) horizontal spot velocity to the *mean* velocity is considered, the deviation from the mean will become half of the figure given in the table, but will change in sign between the beginning and the end of the trace. Thus, with two-thirds of the maximum scan, the greatest deviation from the *mean* velocity on the E4504 will be about 4 per cent.

Where it is required to operate the timebase at regular intervals, the actuating device should be arranged so that the contacts close soon after the end of the trace, and, if possible, remain closed for at least ten times the trace duration before opening again to start the next timebase. This precaution is required to permit the charge on the brightener condenser C_2 to leak away. If the waiting time is less than about ten times the trace duration, the initial position of the spot and/or the trace brightness will differ somewhat over the first few traces and then will reach a steady state appreciably different from that obtaining with a single isolated sweep.

On some tubes, the Y-plate sensitivity is considerably higher than the X-plate sensitivity and a corresponding improvement in linearity may be obtained by scanning the Y-plate. However, this arrangement may cause some deterioration in the focus.

Preventing Damage to C.R. Tubes

BECAUSE C.R. tubes operate at relatively high voltages and low currents, they are most efficiently used with highly specialised power supplies usually having limited current capabilities. For this reason it is generally feasible to design television cathode-ray tubes with a lower factor of safety against surges and over-voltages than is required in other high-voltage apparatus. When the stored energy available is low and the peak current is adequately limited, an internal arc in a cathode-ray tube clears quickly and does not damage the tube. When the current and energy of the power supply are not limited, the desired protection may be provided either by utilising a series resistor which limits the maximum possible peak current to a safe value, or by restricting the storage of energy in the by-pass or filter circuit to a maximum value of 250 microcoulombs.

If the stored energy in the filter capacitance of the power supply exceeds 250 microcoulombs, it is recommended that the power supply be designed to limit the peak instantaneous short-circuit current to one ampere.

In order to limit the peak electrode current to this valve, it is recommended that the resistance in the circuit between each electrode (grid No. 1, grid No. 2, anode No. 1, and anode No. 2) and the output capacitor of the power supply be not less than the minimum value given in the table below. If *CE* is 250 microcoulombs or less, the limiting resistance may be omitted, although the use of such a resistance provides an additional safety factor.

Minimum Values of Resistance Between Indicated Electrode and Output Capacitor

Electrode	Tube Type				
	5TP4	7DP4	7JP4*	10BP4†	
Grid :					
No. 1 ...	180	150	220	150	ohms
No. 2 ...	390	450	—	470	ohms
Anode :					
No. 1 ...	6800	2700	3000	11000	ohms
No. 2 ...	30000	9100	6800	—	ohms

* Type 7JP4 has grid No. 2 and anode No. 2 connected internally.
† Type 10BP4 has only one anode.

From R.C.A. Application Note AN-128. Jan. 1948.

High Frequency Baking

Some False Impressions Corrected

IN order to dispel the false impressions caused by the publication of certain articles dealing with high frequency baking, The General Electric Company, Ltd., under the auspices of the Unilever Bakery Service, recently gave a lecture and Demonstration at Unilever House to representatives of the bakery industry.

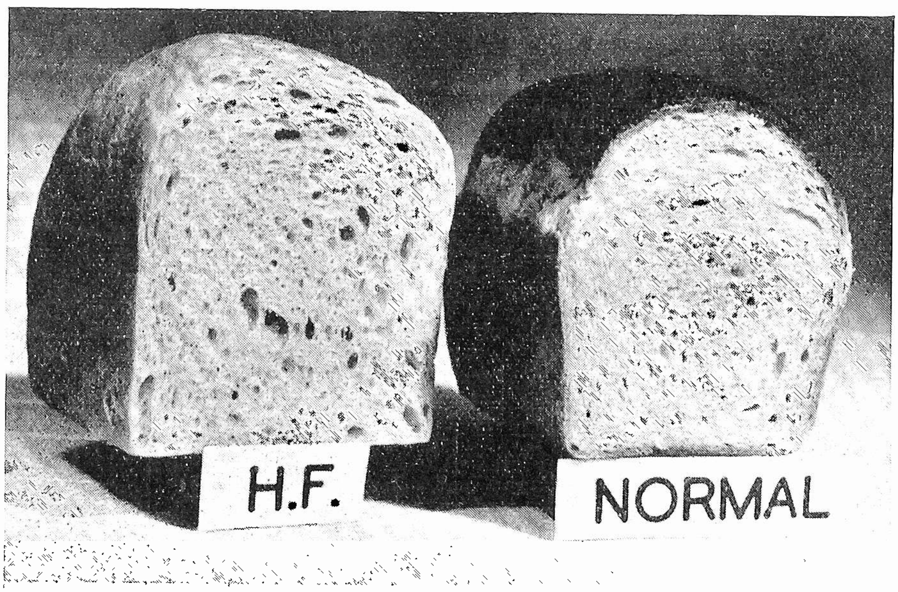
The lecture, by L. D. Price, B.Sc., A.M.I.E.E., of the G.E.C. Research staff, surveyed the present state of knowledge of the use of H.F. heating for baking, outlined its special features and difficulties and reviewed possibilities of its practical application on a commercial basis.

Judged purely from a technical point of view, some of these applications, such as the baking of bread and cake and the melting of chocolate couverture, showed some promise, while others had not yet been successful. A large gap exists between a successful laboratory experiment and a practical commercial installation.

On the question of cost, a superficial examination of the comparative costs between, say, an electrical oven of the double-deck draw-plate type and a H.F. generator revealed the economic disadvantages of the latter. This comparison, however, did not take into account such features as possible saving in floor space and labour, modification to handling technique, or methods of supplying the additional heat necessary to put a crust on the bread.

The time required to bake a loaf seems to be about five minutes, while that for cake varies between four and seven minutes. Comparison with a normally baked loaf and cake can be seen in the illustration. Results so far with biscuits are not very promising, but chocolate and fondant can be melted in two to four minutes. Frozen fruits have been thawed in three minutes, while blocks of frozen eggs take from three to five minutes, but the thawing is not always uniform.

The present state of knowledge of H.F. heating as applied to baking is far from being conclusive in any one direction. Technically it has possibilities, but economically it seems doubtful, and before one can be certain that the time and money required to develop the experiments to a commercial basis would be justified, much more preliminary laboratory work is necessary. As yet there is no indication that H.F. baking is "just around the corner."



Comparison between a H.F. baked loaf and one baked in the normal manner. Note the absence of crust and rather coarser texture of the former.

NOTES FROM THE INDUSTRY

Report of Telecommunication Research Committee

An example of co-operation between Industry and Government on research matters is provided in "Fundamental Research Problems of Telecommunications," published in April for the D.S.I.R. by H.M.S.O., price 1s. 6d. net, by post 1s. 8d. The Report states the problems that should be investigated during the next few years and in some cases indicates the degree of priority that should be accorded.

The Report has been prepared by the Telecommunications Research Committee, which was constituted in 1946 as an "ad hoc" committee of the D.S.I.R. Its purpose was to provide for exchange of ideas and experience between industry and Government departments concerned with telecommunications and so to identify the basic research problems in the whole field of telecommunications that would require investigation in the next few years.

The committee appointed nine working parties to deal with: Wave propagation, line propagation, valve fundamentals, properties of materials, contact phenomena, circuitry, luminescence, photo-emission, television appraisal.

The working parties each submitted a report and these were adopted by the committee. A brief summary and the full text of each report is given in the publication.

Taylor Instruments now "Windsor"

In future all radio test equipment made by Taylor Electrical Instruments, Ltd., Montrose Avenue, Slough, will be sold under the name Windsor instead of Taylor, and suitable nameplates will be affixed.

This change is being made to enable the firm's instruments to enter certain export markets which have hitherto been closed to them on account of the name conflicting with that of the Taylor Instrument Co., of America, with whom Taylor Electrical Instruments, Ltd., have no connexion.

Correction

On page 114 of the April issue the addresses of United Insulator Co., Ltd., and Static Condenser Co., Ltd., were accidentally transposed. They should read:

United Insulator Co., Ltd.,
Oakcroft Road,
Tolworth, Surbiton, Surrey.

and

The Static Condenser Co., Ltd.,
Wokingham, Berks.

High Vacuum Pumps

Their History and Development **Part 5—Conclusion**

By R. NEUMANN, Dipl. Ing., A.M.I.Mech.E.

FIG. 30 gives an outside view of a series of all-metal two-stage oil fractionating diffusion pump in water-cooled design, manufactured by Distillation Products, Inc., covering a speed range between 2 and 100 l/sec. at 10^{-4} mm. Hg. The cross-section of a modern metal fractionating pump having an Embree jet for the final stage is shown in Fig. 31.[96]

This is a horizontal design having the boiler fastened lengthwise to the pump chamber as mentioned before with the free end for the large fine-vacuum connexion on the left and the small fore-vacuum connexion on the right. There are three fractionating stages, one of them serving as a kind of a booster. The vapour is condensed in the water-cooled short pipe leading from the pump chamber towards the fore-vacuum and the condensed oil is led back to the boiler from a baffle chamber adjoining the condenser.

While the boosting effect is in many cases obtained by a separate boosting pump some designs prefer to incorporate the intermediate step between diffusion pump and box pump in one or more stages inside the chamber of the diffusion pump proper. In some cases the stages for the higher pressure work on the ejector principle and only the stages for highest vacuum on the diffusion principle. As an early example the Gaede four-jet pump of 1921[121] may be mentioned. The whole system may easily be withdrawn from the pump chamber for inspection or repair. More modern designs shown in Fig. 32[104] and 33[122] are manufactured by the National Research Corporation.[122a]

The main feature of these pumps is an U-shaped pump chamber with water-cooling on both arms. In Fig. 32 the oil vapour produced in a gas-fired boiler is passing the two diffusion stages arranged in one of the arms, while the other arm contains baffles which may be either cooled or heated. In Fig. 33 the electrically heated boiler feeds a three-stage diffusion pump in the left arm and a single-stage booster in the right arm. The same arm contains ordinary baffle plates.

The combination of ejector pump and diffusion pump in separate casings has repeatedly been proposed,[123, 124, 125] while the principle of multi-stage nozzle in a single casing was first proposed by Volmer.[126]

Finally, one of the smallest and one of the largest diffusion pumps of recent design are illustrated. The one (Fig. 34) is a two-stage pump of Pyrex glass, operating with any of the pump oils on the market. Its outside dimensions are $5'' \times 5\frac{3}{4}'' \times 2''$. It has a speed of 2 l/sec. and attains a vacuum below 10^{-5} mm. Hg. It is cooled by a miniature motor blower and used for a portable electron microscope.[127] The other one is a primary pump designed by Westinghouse for use on the atomic bomb project and for handling large volumes of rare

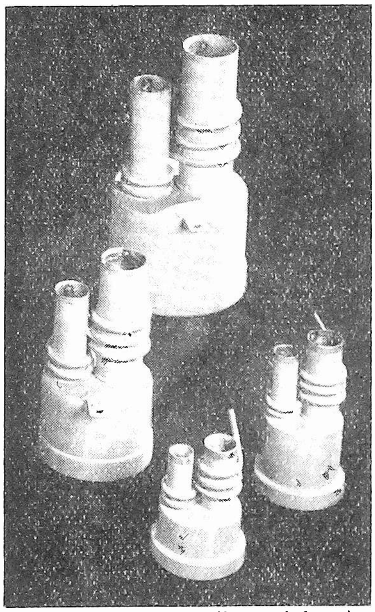
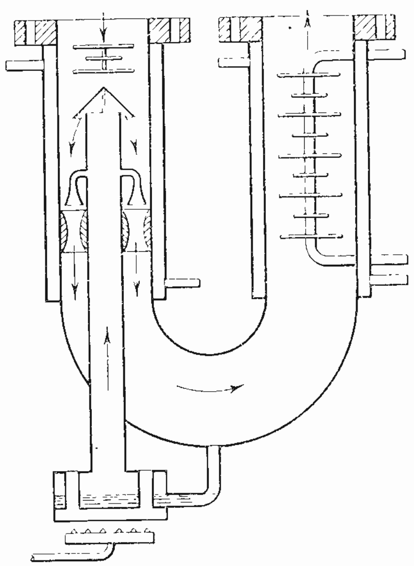
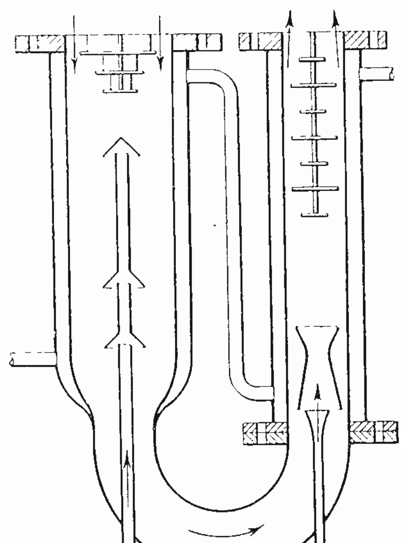


Fig. 30. Two-stage all-metal fractionating pumps
—*Distillation Products Inc., U.S.A.*





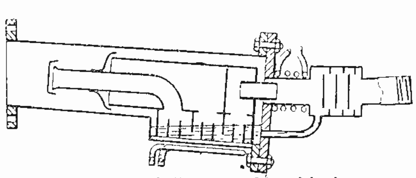


Fig. 31 (*bottom left*). Modern metal fractionating pump with Embree jet
Fig. 32 (*top right*). and Fig. 33 (*top left*). Pumps made by the National Research Corpn.

gases. It is a three-stage pump in which the throat or "pumping radius" is gradually decreased from first to last stage. The pump chamber has a diameter of 32 in. and a height of 80 in. The highest speed attained is 1,600 l/sec. and the ultimate vacuum is 10^{-6} mm. Hg. As it only works against a back pressure of 0.02-0.15 mm. Hg, a booster diffusion pump is inserted between rotary pump and primary pump.[119] A pump of still larger capacity is built by Distillation Products Inc.[57] It has a speed of 5,000 l/sec. at 2×10^{-4} mm. Hg, attaining an ultimate vacuum of 5×10^{-5} mm. Hg with a fore-pressure of 0.05 Hg, or if worked with a booster, it may operate against a fore-pressure of 0.35-0.4 mm. Hg. But details of this pump have apparently not been published so far. The gradual decrease of the throat mentioned above may also be obtained by making the walls of the pump chamber conical.[128]

The arrangement of multiple nozzles in series is used for obtaining a large difference between ultimate and fore-pressure. If the primary consideration is the increase of suction speed with moderate pressure differences the parallel connexion of nozzles is frequently used. Thus Ho investigated the use of 4 or 7 or 19 nozzles of the Crawford type, leaving sufficient space between the nozzles for the additional path of the gas molecules and thus making use of all the vapour. With 19 nozzles a speed of 320 l/sec. was obtained at 10^{-3} to 10^{-5} mm. Hg with a back pressure of 0.1 mm. Hg.[129] Zabel prefers a 4- or 7-nozzle system with a short large tube, leading from the boiler to the nozzles and not passing through the condensation chamber.[130] In a design due to Bancroft[131] about 50 parallel nozzles are arranged in a common leader for obtaining a high throughput with moderate vacuum (0.01-0.2 mm. Hg).

These kinds of pumps fill the gap between 10 and 10^{-3} mm. Hg where the suction speed of rotary pumps is already markedly reduced and where ordinary high vacuum diffusion pumps do not yet work properly.[22]

Performance of Diffusion Pumps

The performance of any high vacuum pump is characterised by the ultimate pressure obtainable by the back pressure against which it

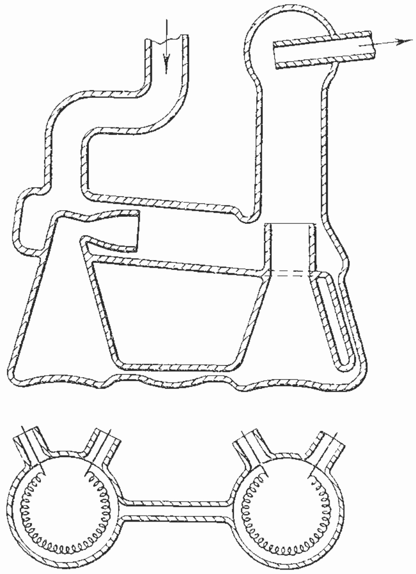


Fig. 34. Small Pyrex pump by Bachman

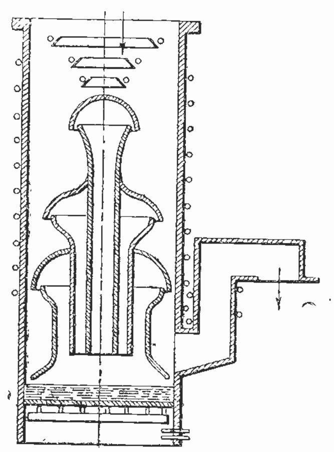


Fig. 35. Large all-metal pump for use on atomic bomb project
—Westinghouse

is able to work and by its speed of evacuation. The first designers of diffusion pumps held the opinion that no limit was set to the ultimate pressure and that the speed could be considered as constant down to the lowest pressures.[46,65] Actually a limit is set to the ultimate pressure by the evolution of gases from the working fluid and from the walls of the glass or metal vessels and tubing used, by unavoidable leaks and by the vapour pressure of the working fluid and greases and the like used for sealing the joints in the system.

An investigation carried out by J. Blears[78] showed that in measuring the ultimate pressure of an oil diffusion pump by means of an ionisation gauge this should have free access to the oil molecules and should be provided with a large evaporation surface.

The suction speed may have a well-defined maximum at some definite pressure, or it may keep a constant value over a considerable range of pressure, but it will certainly decrease to zero at the lowest attainable pressure[132] and when reaching a certain back pressure. Some characteristic speed pressure curves are reproduced here (Figs. 36 and 37) from the catalogues of Distillation Products, Inc. They show that the speed is dependent to a large degree on the heat input and that there exists a certain maximal speed obtained with a certain heater current, increase and decrease of which reduces the speed.[133] They also show that increasing the capacity of the fore-pump may result in a considerable extension of the pressure range, over which the speed remains constant.[125] The opinion that the vapour pressure of the working fluid sets a limit to the ultimate vacuum was quite recently challenged by Ray and Sengupta[134] who trapped the barrel of a duffusion pump at different distances above and below the jet and measured the partial pressure of air with a McLeod and the total pressure with a Pirani gauge. They found partial air pressures well below the vapour pressure of the working fluid.

The speed is usually expressed by

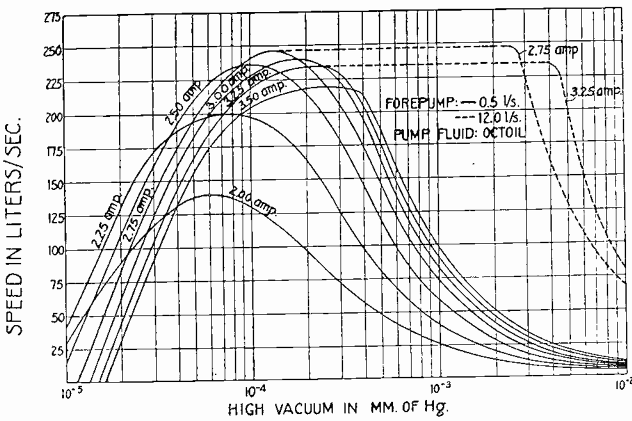
$$S = \frac{V}{t_2 - t_1} \log \frac{p_1}{p_2}$$

according to Gaede, or—under consideration of the lowest pressure p_0 attainable—by:

$$S = \frac{V}{t_2 - t_1} \log \frac{p_1 - p_0}{p_2 - p_0}$$

according to Langmuir. V designates the volume of the vessel to be exhausted, p_1 and p_2 the pressures measured in the vessel at times t_1 and t_2. S is assumed to be constant over this pressure range.

Measurement of the speed is made either according to the constant volume or the constant pressure method. In the latter either a small amount of atmospheric air is admitted, *e.g.*, by a needle valve and measured by the movement of a mercury pellet in a capillary, or a flow tube between two terminal bulbs is used in which the pressures are measured separately, and the speed is determined in using Knud-



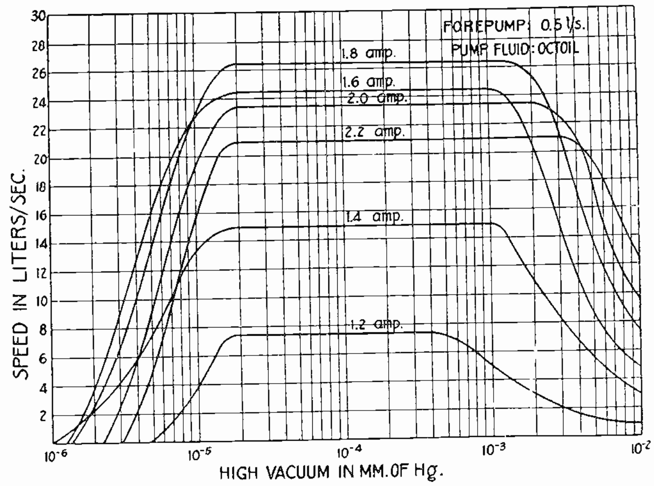


Fig. 36. Speed-pressure curves

Fig. 37 (*right*). Speed-pressure curves showing the effect of back pressure

—*Distillation Products Inc., U.S.A.*

sen's investigations and formulae.

The method of measuring the pumping speed at constant pressure using a mercury pellet moving in a capillary requires too long a capillary if high pumping speeds are concerned. Also for other reasons the method is not considered to be accurate. In measuring at constant volume the rate of fall of pressure must be measured within so narrow limits that no pressure gauge is accurate and instantaneous enough for the purpose. P. Alexander[134a] describes an instrument for the measurement of high pumping speeds at constant volume and varying pressures which avoids the difficulties by making the readings at nearly atmospheric pressure. He also describes a needle valve in which the flow of air is not impaired by grease or oil.

For further details about speed measurement the interested reader must be referred to the book literature.

Matricon[135] gives an empirical formula for the speed of a diffusion pump:

$$S = \frac{CA}{\sqrt{2\pi\rho}}$$

where C is an experimental constant found to be 9×10^{-2}, A is the area of the diffusion zone and ρ the density of the gas exhausted at a pressure of 0.75×10^{-3} Hg.

The ideal maximum speed according to Ho[72] is:

$$V = \left(\frac{RT}{2\pi M}\right)^{\frac{1}{2}} \times A$$

where V is the volume of gas escaping in unit time, R the gas constant, T the absolute temperature, M the molecular weight of the gas and A the slit area. The "speed factor" defined, as was mentioned above, as the ratio between the actual speed and the value of V, depends on the ratio between mean free path and width of slit, on the shape of the nozzle and intensity distribution of the vapour stream below the nozzle, on the dimensions of the chamber and the density of the vapour. In the examples tabulated by Ho the speed factor varies between 0.019 and 0.30, the latter being obtained in Ho's 4-nozzle design, while it decreases with a decrease and an increase of the number of nozzles.

While the speed is usually measured in l/sec. or in cu. ft./min. (1 CFM = 2.12 l/sec.) and is occasionally called the capacity of the pump, this latter expression is in some cases also used for the so-called throughput of the pump, measured in lμ/sec. or in micron cu. ft./min. With uniform temperature and the absence of leaks this latter value may be considered as constant for the whole pumping system and on this basis the speed of the backing pump may be determined if its pressure and the speed and pressure of the fine-pump is given.[78]

In all calculations the flow resistance W of the tubing plays an important part. Calling S_s the speed of the system, and S_p the speed of the pump, the so-called "impedance law" gives the relation:

$$\frac{1}{S_s} = W + \frac{1}{S_p}$$

For pressures of about 0.75×10^{-3} mm. Hg and for air the value of W in dm^{-3} may be equalled to l/r^3, where the length l and the radius r of the tube are measured in mm., and for combinations of tubes:

$$W = l_1/r_1^3 + l_2/r_2^3 + l_3/r_3^3$$

Numerous examples for the application of these relations are given by Mönch.[10]

The correct dimensioning of the tubing plays a specially important part in evaporation plant used in chemical processing. The problem is exhaustively dealt with in a paper read by H. Griffith before the Institution of Chemical Engineers which will appear in their Proceedings 1945.[135]

As appears from the relations given above the speed of the diffusion pump is greater for lighter gases (contrary to the molecular pump).

A general idea of the performance of modern pumps may be given by the following table although, as was stated before, even higher speeds have been obtained.

Type of pump	Ultimate Vacuum mm. Hg	Back pressure mm. Hg	Speed l/s
Rotary ...	5×10^{-3}	760	½–356
Oil diffusion Booster	5×10^{-5}	0.3–2	50–300
Primary	10^{-6}	0.02–0.15	30–1600

Higher back pressures are permissible with some multi-step mercury diffusion pumps.

Accessories

If in using mercury as working fluid pressures below about 10^{-3} mm. Hg are required, a cold trap must be arranged between recipient and pump as the vapour pressure of mercury at room temperature is about 1.1×10^{-3} mm. Hg. The cold trap may be formed by an U-shaped glass tube or a reentrant glass vessel immersed into a Dewar beaker filled with solid carbonic acid and acetone, alcohol or trichlorethylene, or—for obtaining lower temperatures—with liquid air. For avoiding the considerable resistance to gas flow caused by such a glass trap and the corresponding reduction of suction speed, and also in order to make the trap more suitable for use in an all-metal system, Edwards & Co. designed an all-steel trap to be bolted directly to the high vacuum connection of the pump (Fig. 38). The liquid air boils off only slowly as the inner container is surrounded by an evacuated space. Cold traps are in exceptional cases also used in connexion with oil pumps,[64] but in general mechanical baffles are sufficient with these pumps for preventing reverse pumping action, back streaming and the appearance of oil in distant parts of the system. It is considered to be one of the principal advantages of the oil diffusion pump that it allows of obtaining very low pressures without the necessity of using liquid air or cooling mixtures. Such baffles are, for instance, arranged on the upcast pipe between the boiler and the tube, leading to the fore-pump,[136] or between the cowl and a point below the mouth of the fore-vacuum pipe[137] (*see* Fig. 25) A special study of the action of different baffles was made by Morse[138] from which it appears that, while in general cooled baffles are preferred, also hot baffles[139] and electrically charged baffles have been proposed. In this latter case a kind of a pumping action by inducing a migration of ions is produced.[140] Conical or spiral baffles as proposed by H. W. Edwards[141] have proved specially effective in connection with fractionating pumps, where they are made of thin aluminium rings held in jaws conducting the heat to the walls of the intake and reduce the pumping speed not more than about 30 per cent.[90,138] Mechanical baffles are occasionally also used for mercury diffusion pumps.

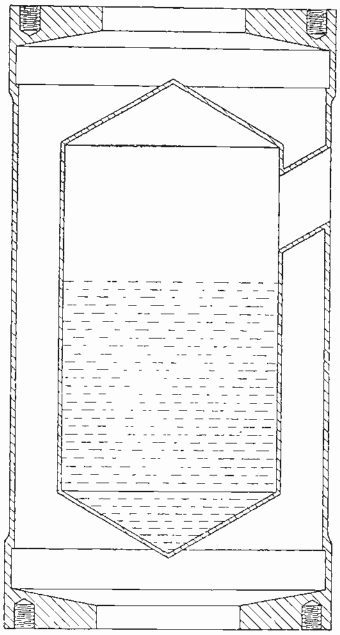


Fig. 38. Edwards' cold trap

A combination of baffle and cold trap used on a mercury diffusion glass pump was described by Bull and Klemperer.[120] Here effective cooling is obtained with least possible obstruction to the flow of gas.

In some cases it has been proposed to use the evaporator of a refrigerator machine as a cold trap.[142] Mechanical refrigeration is, for instance, also used in a large dehydration outfit designed by the National Research Corporation.[122] Here a "rotary condenser" and ice receiver is arranged between the oil diffusion pumps and the drying cabinets. Perhaps it is not quite correct to call this arrangement a "cold trap." It fact, it is an outfit for "freeze drying," a method more and more used in recent years for the production or treatment of sensitive materials like penicillin, vitamins, blood plasma and the like. Also in mercury diffusion pump units designed by Barr & Stroud, Ltd., for the deposition of metallic mirrors, the production of anti-reflection films on glass and for similar operations the pumps are cooled by mechanically refrigerated coils placed internally in the throat of the pumps, one refrigerator serving to cool the coils of six pump units.[142a] According to a quite recent proposal, alkali metals may be used for trapping Hg vapour. An alloy of 3-5 per cent. K and 97-95 per cent. Na proved to be self-reactivating and suitable for permitting 5×10^{-7} mm. Hg to be reached within 40 min. after the diffusion pump has been started.[142b]

For smaller outfits the removal of condensable vapours may be efficiently accomplished by a P_2O_5 trap (Fig. 39) which is specially suitable in connection with rotary pumps.

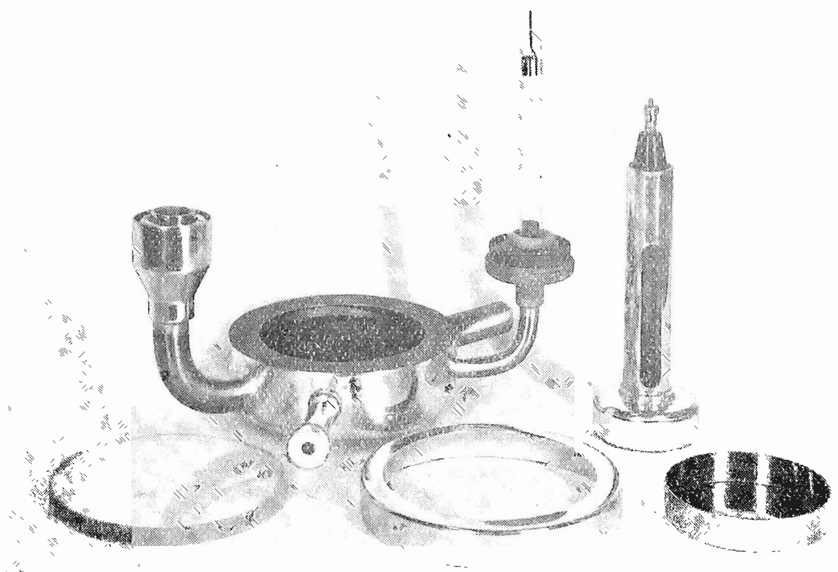


Fig. 39. Phosphorus pentoxide trap made by Metropolitan-Vickers Ltd.

Charcoal traps are frequently used in small physical systems,[143] although they retard the gas flow to a considerable extent. In the design of Litton Engineering Laboratories they are used for pumps, having a speed of 100 l/sec. at 10^{-5} mm. Hg measured at the flange above the nozzle and are arranged on top of the pump in a similar manner as the cold trap with Edwards' mercury pumps. During service they are cooled by an extension of the pipe, cooling the pump chamber and, for outgassing of the activated charcoal, necessary after about 30 days service, the latter is electrically heated to about 500° C. for one hour.

Ground glass joints, seals and the numerous designs of stop cocks shall not be dealt with here. Only a few examples of more recent valves affording more or less large openings to the flow of gas and suitable mainly for all-metal systems shall be briefly mentioned. The disk valve developed by Burch and Sykes[144] and manufactured by Audley Engineering Co. has oil-filled grooves around the ports of the fixed and movable member. The grooves communicate with the oil bath in which the movable member moves, thus preventing all leakage of gas ("Audco" valve"). Although the pumping speed is somewhat reduced by the comparatively small bore and the meandering of the pumping channel, this causes usually only a slight rise of the back pressure. With large gas quantities this kind of tap is avoided. Standard sizes are $\frac{3}{8}$ in., $\frac{1}{2}$ in. and $\frac{5}{8}$ in. bore, but also larger sizes (up to 6 in.) have been made. While these taps are mainly used in the pipe line between fore-pump and diffusion pump, taps of large cross section are occasionally required between the diffusion pump and the vessel to be evacuated. In Bull and Klemperer's design[129] the shutter consists of a circular disk operated by a tilting motion. Other large opening taps based either on the sliding or on the swinging principle were recently described and illustrated by Geismann.[145] A series of packless valves with specially low impedance to gases at low pressure for the range between 1 in. to 16 in. bore have been developed by the National Research Corporation. The valve disks are mounted on bellows arranged in a short pipe branched in an angle from the main pipe.

Numerous proposals have been made for actuating taps automatically, *e.g.*, if the pressure in the vessel to be evacuated or between diffusion pump and backing pump exceeds a certain value, if for some reason, *e.g.*, interruption of the power supply, the fore-pump stops working.[146] Special designs have been developed for the purpose, *e.g.*, a magnetically released Audco valve (Metropolitan-Vickers).

Future Developments

A great drawback of the diffusion pump is its very low overall efficiency. The energy consumed for heating the working fluid and for cooling the condensing surface, though in itself not deterrent, is large if compared with the energy required in compressing the gas volume concerned from the ultinate pressure to the pressure of the fore-pump. To use Hickman's words: "The evolution of the high vacuum pump is likely to continue for many years and it would be rash to speculate on an ultimate design. The very large pumps required to maintain vacua in the "wet" system of heavy chemical industry—the molecular distillation of natural oils, for instance—employ many operating stages and subsidiary equipment and warrant the term "vacuum engines" rather than pumps. Evidently a small increase of efficiency of jet, boiler or fluid may have cumulative effects of considerable moment in reducing operating costs."

No doubt, also the smaller outfits used in electronic engineering work will profit by such developments. If this survey "from Hero to Hickman" serves for helping to further such developments, it will have fulfilled its purpose.

Acknowledgment

The author wishes to express his thanks to the following firms which supplied him with valuable information. Distillation Products Inc., Rochester, N.Y.; W. Edwards & Co., Ltd., London; The General Engineering Co. (Radcliffe) Ltd.; Litton Engineering Laboratories, Redwood City, Cal.; Metropolitan-Vickers Electrical Co., Ltd., London; National Research Corporation, Boston, Mass.; Pulsometer Engineering Co., Ltd., Reading; The Thermal Syndicate, Ltd.; W. M. Welch Manufacturing Co., Chicago, Ill.; Westinghouse Electric International Co., London.

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A New Broadcast Receiver for Overseas Reception

THE Eddystone Type 659 Broadcast Receiver has been developed specially for the export market and will give consistently good reception of both short- and medium-wave broadcasts in any part of the world.

Two models are manufactured: One, the 658/AC, operates from 110 or 240 V A.C. mains of 40-60 c/s., and the other, 659/B, has a vibrator power unit consuming 5.9 A from a 6 V accumulator.

Four switched ranges cover the principal short and medium wavebands. These are:

Band 1. 30-12.8 Mc/s. (10-23.5 M).
Band 2. 13-5.8 Mc/s. (23.1-51.7 M).
Band 3. 2.75-1.2 Mc/s. (110-250 M).
Band 4. 1220-522 Kc/s. (248-575 M).

Tuning Mechanism

The tuning mechanism has a high reduction ratio and is flywheel controlled. A special logging scale is provided at the top right-hand corner of the dial, giving an actual scale length of 90 in. There is a Magic Eye tuning indicator, and the dial is edge-illuminated.

Circuit Details

A single R.F. amplifier stage is followed by a triode-hexode frequency changer and I.F. amplifier. The detector provides A.G.C. to counteract fading, and supplies a 3-watt output beam tetrode with negative feedback. A noise limiter is fitted.

The console speaker is arranged to provide a stand for the receiver cabinet.

It should be pointed out that this receiver is solely for export and is not available in this country except to persons proceeding abroad. The price is £47 10s. complete, for either the battery or mains model.

Overseas visitors to the B.I.F. in London can have a demonstration of this receiver at Messrs. Webbs Radio, Soho Street, W.1.

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One Point of View

Dr. Arthur W. Allen, of Boston, President of the American College of Surgeons, was high in his praise of television as an educational medium after viewing from his room in the Waldorf-Astoria a stomach resection for duodenal ulcers.—*R.C.A. News Bulletin.*

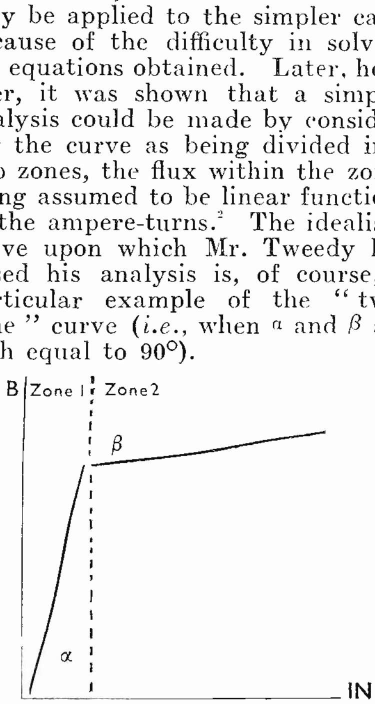
CORRESPONDENCE — Magnetic Amplifiers. Stabilised Power Supplies.

Magnetic Amplifiers

Dear Sir,—With reference to Mr. Tweedy's recent articles on the magnetic amplifier, I should like to add a few remarks on, firstly, the early history of the device and, secondly, its use in providing a continuously variable A.C. or D.C. supply voltage.

Although saturable chokes have been fairly extensively used in A.C. control circuits since about 1916, it would appear that the first investigator to propose the use of feedback in such circuits was A. S. Fitzgerald in a U.S. patent,[1] dated July 23, 1934, which related to a "magnetically operated amplifying and control system." Soon after this, intensive theoretical and practical investigations on the magnetic amplifier were begun in several European countries. Noteworthy among these is the work of Lamm,[2] in Sweden, and of Buchhold,[3] Geyger[4] and Krämer[5] in Germany.

As regards the theoretical side of the subject, the strict mathematical analysis of transductor circuits is rendered rather complex by the fact that the magnetisation curve of the core is difficult to express accurately in mathematical terms. Several early attempts were made to analyse the transductor by expressing the magnetisation curve in terms of a power series,[6] but this method could only be applied to the simpler cases because of the difficulty in solving the equations obtained. Later, however, it was shown that a simpler analysis could be made by considering the curve as being divided into two zones, the flux within the zones being assumed to be linear functions of the ampere-turns.[2] The idealised curve upon which Mr. Tweedy has based his analysis is, of course, a particular example of the "two-zone" curve (*i.e.*, when α and β are both equal to 90°).



The two-zone magnetisation curve

Turning to the application of the transductor to the control of A.C. voltage, it has been found that between the condition which results in a rectangular A.C. current (*i.e.*, with the D.C. smoothed) and that which results in a "peaky" A.C. current (with the D.C. unsmoothed) there exists a condition, with partial D.C. smoothing, for which an almost sinusoidal A.C. current is produced. Since the D.C. excitation of the transductor can be easily varied with very little power dissipation, this method provides an effective means for controlling A.C. voltage. The D.C. excitation can be adjusted most effectively in a self-excited system by providing a variable shunt across the feedback windings of the transductor. In this way the fine control of A.C. voltage (or of D.C. obtained by rectification) can be achieved with quite simple equipment. In more highly developed systems, further D.C. windings which are fed with currents derived from the output voltage can be provided which give the transductor a regulating function.

Michael C. Johnson

Kingston-on-Thames.

REFERENCES

1 British Patent No. 456,828.
2 Lamm, *Aseas Tidning*, 31 (1939), p. 18-31; *Asea Journal*, 16 (1939), p. 66-80.
3 Buchhold, Th., *Arch. f. Elektrot.*, 37 (1943), p. 197.
4 Geyger, W., *Wiss. Veroff. a.d. Siemens-Werken*, 19 (1940), pp. 4-47; *ibid.* 21 (1943), p. 47.
5 Kramer, W., *E.T.Z.*, 59 (1938), pp. 1295-98; *E.T.Z.*, 60 (1939), pp. 393-5.
6 Haufle, G., *Arch. f. Elektrot.*, 33 (1939), pp. 41-47.

Dear Sir,—May I comment on the Magnetic Amplifier article in your February issue. The equation quoted for the voltage across the transductor is:

$$V_A^2 = V_s^2 - I_A^2R^2 \quad \text{.................} \quad (1)$$

where the voltages and currents are R.M.S. values. Certain geometrical considerations, from which power amplifications and output are deduced, then follow.

This equation has been used by Aggers and Pakala[1] and more recently by Kirschbaum and Harder.[2] It is usually derived by considering an A.C. voltage applied to a linear inductance in series with a load resistor. Unfortunately a transductor is not a linear inductance and cannot be treated as such for design purposes.

Another equation which has been sometimes applied by German technicians is:

$$V_A = V_s - I_AR \quad \text{....................} \quad (2)$$

Although this equation is true for instantaneous values of voltage and current, there is no fundamental reason why it should apply when the values are R.M.S. or mean.

An experimental investigation, begun in 1946 by Mr. C. S. Hudson with Radiometal cores, has shown that Equation (2) is not valid except for instantaneous values. More recent work by myself using Radiometal and Mu-metal cores has confirmed that neither Equation (1) nor Equation (2) is satisfactory for predicting transductor characteristics on load.

A. G. Milnes.

Farnborough, Hants.

REFERENCES

1 Aggers, C. V., and Pakala, W. E., "Direct Current Controlled Reactors," *The Electric Journal*, 1937, p. 55.
2 Kirschbaum, H. S., and Harder, E. L., "A Balanced Amplifier using Biased Saturable Core Reactors," *A.I.E.E. Paper*, 47-48.

Mr. S. Tweedy Replies:

Regarding Mr. Johnson's remarks about the mathematical expression of the magnetisation curve, I used the highly idealised "two-zone" curve for the analysis of the transductor with D.C. smoothed since it gives an insight into the physical actions taking place, and because the particular properties of this circuit are dependent on how closely this ideal magnetisation curve can be approached in practice.

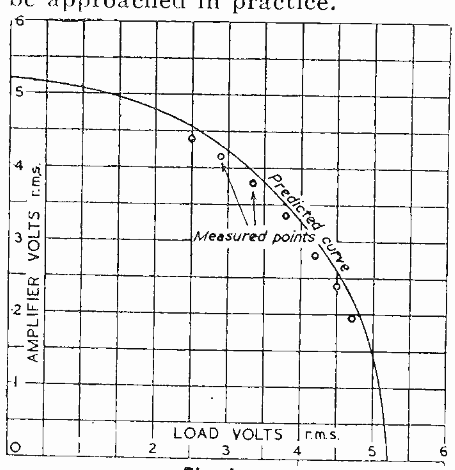


Fig. 1.

Most attempts to obtain an analysis in terms of a mathematical expression for the magnetisation curve fail because the resistance has to be ignored or the equations become quite unmanageable. In actual fact, the resistance is usually of paramount importance when the flux density attains saturation value, and consequently the saturated part of the B-H curve does not fully control the performance of magnetic amplifiers in this range.

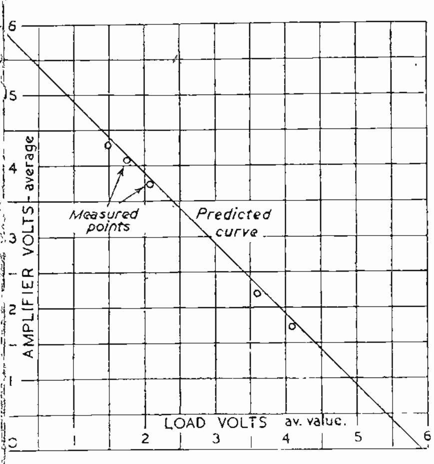


Fig. 2.

An analysis taking into account the effect of resistance becomes rather complex, and I felt that it was beyond the scope of the two articles. Considerable work, both theoretical and practical, has, however been done in the laboratory with which I am associated on this aspect, and the results are of interest in conjunction with the points raised by Mr. Milnes. Provided that the actual magnetisation curve is made to approach the idealised case as closely as possible, our analysis predicts that Equation (1) is correct for R.M.S. value, while Equation (2) holds for average values, as would be measured with a rectifier instrument. The attached figures show that experimental results confirm these results well within the accuracy normally required for design purposes, Fig. (1) relating amplifier and load R.M.S. voltages, and Fig. (2) relating amplifier and load average values, in two representative tests from our records. These results are obtained for transductors cored with Mu-metal.

In order to correctly predict and present experimental results, it is necessary, particularly for R.M.S. values, to consider the resistive losses actually in the transductor and to include these in the load. A possible explanation of Mr. Milne's failure to reproduce these results may be that this factor has not been taken into account.

Stabilised Power Supplies

Dear Sir,—In the interesting article by Dr. E. J. Harris on power supply stabilisation in the March issue of Electronic Engineering there appears to be an error in the formula for the "output" or generator impedance, Z_o. This can be seen by a conclusion drawn therefrom, namely that if $R_a > R_s$, this impedance is negative.

For this condition would be satisfied if R_s were negligible, in which case the only stabilising effect would be due to $r_1 m_1$, which by itself could not possibly cause the output voltage to rise with increase of current drawn.

The error appears to result from the inclusion of Z_s and R_L in the equation for ΔI in column (1), which does not, however, affect the condition $m_2 r_2 = 1/\mu$.

The correct formula for Z_o is:

$$Z_o = \frac{R_a + Z_s(1 - \mu r_2 m_2)}{1 + \mu r_1 m_1}$$

In practice, $\mu r_1 m_1 >> 1$, so that

$$Z_o \approx \frac{R_a + Z_s(1 - \mu r_2 m_2)}{\mu r_1 m_1}$$

Where there is no voltage compensation, *i.e.*, $\mu r_2 m_2 = 0$,

$$Z_o \approx \frac{R_a + Z_s}{\mu r_1 m_1}$$

In the condition for perfect stabilisation against variations in input voltage, *i.e.*, $\mu r_2 m_2 = 1$,

$$Z_o = R_a / (\mu r_1 m_1)$$

showing that the output current stabilisation is improved by eliminating the influence of Z_s.

The condition for perfect output current stabilisation, *i.e.*, $Z_o = 0$, is:

$$\mu r_2 m_2 = 1 + (R_a / R_s) \text{ and } X_s = 0.$$

For best all-round stabilisation, therefore, R_a should be as small as possible compared with Z_s.

In attempting to apply Dr. Harris's multi-grid valve (his Fig. 3) to a variable-voltage power unit I have experienced difficulty in obtaining a gain which is large and constant under all working conditions comparable with that of a pentode of the EF.36 class, and recommend the device due to Lindenhovius and Rinia (*Philips Tech. Rev.* 6, No. 2, 1941) in which $r_2 m_2$ *is* obtained by a high resistance from the anode of V_1 to the grid of V_2.

M. G. Scroggie.

Bromley, Kent.

Dr. Harris Replies:

Thank you for sending Mr. Scroggie's letter. He is quite correct, and in addition (as he mentioned to me) the equation for $\Delta V_1 / \Delta V_2$ in column (1) should be:

$$\frac{\Delta V_1}{\Delta V_2} = \frac{R_L(1 - \mu m_2 r_2)}{R_a + R_L(1 + \mu m_1 r_1)}$$

the Z_s and R_L in the denominator of the first fraction being unwanted. This modifies $\Delta V_1 / \Delta V_2$ in column (3) top to:

$$\frac{R_L(R_1 + R_{a1} - \mu r_2 \mu_2 R_1)}{(R_L + R_a)(R_1 + R_{a1}) + R_L \mu (\mu_1 r_1 R_1 - R_{a1})}$$

and $\Delta V_1 / \Delta V_2$ in column (3) above Fig. 3. modifies to:

$$\frac{R_L(R_1 + R_{a1} - \mu \mu_2 r_2 R_1 + \mu R_{a1})}{(R_a + R_L)(R_1 + R_{a1}) + \mu r_1 \mu_1 R_1 R_L}$$

In the last case the condition for maximum stability (under Fig. 3) comes to:

$$\frac{R_1 + R_{1a}(1 + \mu)}{R_1} = \mu \mu_2 r_2$$

The Reactor Valve

Dear Sir,—The fact that the "reactor valve" was a British invention appears to be known to very few engineers who, largely because the first literature on the subject was published in American journals, naturally assume that the circuit was first used in the United States. I was pleased, therefore, to see a letter from Mr. G. F. Hawkins, of Murphy Radio, Ltd., pointing out that his company owns the original patents, though he was too modest to add that he himself made the invention.

At that time I was employed by Murphy Radio, Ltd., and I can well remember the morning on which Mr. Hawkins came into the laboratories full of this idea which he had worked out the previous evening. The idea seemed very revolutionary at the time—for one thing here was a valve working without a load—but nowadays the principle is taken very much for granted.

The first programme we received on a set incorporating automatic tuning by means of a reactor valve was the launching of the "Queen Mary," in October, 1934. It was also our first experience of a set which automatically tried to reject a station, for in our haste the oscillator control connexions had been accidentally reversed—this produced a novel, though not exactly useful effect!

P. Williams.

London, N.21.

BOOK

Electrons in Gases

Sir John Townsend, F.R.S. (Hutchinson's Scientific and Technical Publications). 166 pp. with 31 diagrams. 25s. net.

Sir John Townsend needs no introduction to readers of Electronic Engineering. He is one of the few survivors of that distinguished band of physicists who, more than fifty years ago, helped the electron into the world of science. He was, indeed, the first to measure the charge on a gaseous ion; his demonstration, from a study of the motion of electrons in gases, that this charge is indeed identical with that of a monovalent ion in solution, distinguished alike for the ingenuity of its method and the fundamental importance of the result, stands out as one of the classics of the subject. The Townsend formula for the electric discharge in gases, published over forty years ago, still holds its place. Since the early days of the subject, Sir John's interest in the subject of the behaviour of electrons and ions in gases has never wavered, and we have had a steady stream, interrupted only by two world wars, of publications from the Electrical Laboratory at Oxford of which he has been the head for so many years.

The present volume is, in the main, a logical, co-ordinated and very welcome summary of this forty years of research. The work of other experimenters is touched on, not always with approbation, insofar as it is relevant to the main topic; but the book is not a complete or exhaustive survey of the whole subject. It is rather a statement of Sir John's considered conclusions; and, as such, merits the closest attention of all interested in the subject. The method adopted by Sir John Townsend and his numerous collaborators has been to study the small currents, usually generated by photoelectric action, in various gases at low pressure, and in uniform fields of electric and magnetic force; and to interpret them in terms of the principles of the kinetic theory of gases. In this way information is deduced on the energy of agitation and the mobility of electrons in gases, on their mean free path and mean loss of energy in elastic collisions and the dependance of these quantities on the velocity of the electrons, and on the production of ionisation by collision. In a final chapter the author deals with the actions of positive ions in discharges, and puts up a vigorous defence of his well-known theory (which has been recently rather strongly challenged by certain physicists) that ionisation produced by collision of the positive ions plays an important part in producing the electric discharge in gases.

Sir John writes with vigour and clarity. It has been a real pleasure to at least one reader to find the principles of classical physics handled with such power and ingenuity. The conclusions arrived at, which are not in all points in agreement with those reached by other methods, have in some quarters been discounted on the grounds that the method is indirect. There is probably substance in Sir John's retort that some results which appear to be in exact agreement with theories of molecular structure have been too readily accepted without considering the possibility of experimental error. It is not for a reviewer to enter the arena. The collected evidence presented in this book is impressive, and demands attention; let the reader weigh it for himself.

The book includes much valuable experimental data on the behaviour of electrons in gases, which it is useful to have in so accessible a form. Even in these days of paper shortage, one may perhaps be permitted to express the wish that the author had found it possible to provide his readers with an index.

J. A. Crowther

"Very High-Frequency Techniques"

Vols. 1 and 2. First Edition. By the Staff of the Radio Research Laboratory, Harvard University. 1057 pp. with 935 illustrations. Published. New York and London, 1947. McGraw-Hill Book Co., Inc. 84/- net.

The material collected together in these two volumes covers a surprisingly wide field and includes information on many aspects of v.h.f. technique. The treatment gives particular emphasis to practical considerations and experimental observations are recorded in a number of instances of results achieved. There are altogether 35 chapters, each written by one or more of a team of authors representing the group of scientists who worked at Harvard University during the last war and helped so much in the solution of problems concerned with radio counter measures. While the individual contributions are in themselves well conceived and competently executed, it is clear that the editors must have had a very difficult task in attempting to bring about a reasonable measure of order and logical development as the various chapters succeed one another.

The manner in which the information is presented makes it impossible to avoid repetition particularly of some of the more basic ideas which find frequent application. One cannot help feeling that it would have been preferable to summarise in the early chapters the fundamental principles vital to a proper understanding of the tech-

REVIEWS

niques described and to use this for reference as the need arises in the subsequent text. This would have made the book not only easier to read but also considerably smaller in size. As it is, Volume 1 opens with a discussion of broad band aerials and then because of the obvious immediate importance of measurement technique this is introduced as a necessary diversion before pursuing the study of various special types of antenna and auxiliary apparatus. Direction finding equipment, homing systems, V.H.F. generators, amplifiers and modulation arrangements are each considered in turn and the end of Volume 1 comes in the middle of a review of the behaviour of magnetrons. Having completed magnetron developments in the opening chapter of Volume 2 the book again reverts to measurement technique and deals with devices for determining power flow and absorption. At this point receivers, filters, resonators, and detectors are successively discussed before introducing problems of the local oscillator and I.F. amplifier. Finally some details of receiver circuits and associated measuring equipment are given followed by a bibliography supplementing the references given in the earlier pages.

The book is well illustrated throughout and this adds much to its value. The chapters on filters and particularly the section dealing with ridge wave-guide is perhaps the best part of the book incorporating as it does much new information on this subject. One cannot commend the use of mixed electrostatic and electromagnetic C.G.S. units, as for example on page 18 in Chapter 1. Telecommunications engineers generally have led the way in the adoption of the M.K.S. system and it is unfortunate that such a progressive step should have been overlooked in this book. The inclusion of one comprehensive Index at the end of the second volume only, is also likely to cause some inconvenience.

However critical one might be about the somewhat arbitrary manner in which the subject matter of this book has been put together there can be no doubt that it contains most valuable information which in some cases is presented for the first time. As Dr. Terman says in his foreword, the material given is a monument to the many engineers and scientists who contributed to the Radar Countermeasures programme. Theirs was a worthy achievement and the record set out in this book will not only preserve that material for the use of others who follow, but should also stimulate fresh ideas and bring further progress in this fascinating subject.

H. M. BARLOW

The Radio Amateur's Handbook

(Twenty-fifth Edition—1948). By the Headquarters Staff of the American Radio Relay League. 760 pp., including catalogue section. 1,712 figs., including 83 charts and tables. Price $2.00 in U.S.A. and Canada; $2.50 elsewhere.

THE 1948 handbook, in addition to its usual annual revision, contains several completely new chapters. Ultra-high-frequencies and the microwaves are treated separately and thoroughly. The problem of interference to broadcast reception is discussed in detail, from public relations to technical aspects. Emergency operation, assembling a station and ARRL operating organisation are also covered.

In addition to several chapters devoted to high-frequency receivers, transmitters and antenna systems, the 1948 edition contains five chapters of material, fully illustrated, devoted exclusively to the very-high-frequencies, ultra-high-frequencies and the microwaves. These chapters constitute in themselves a V.H.F.-U.H.F. textbook, offering to the reader up-to-date information on construction, techniques and propagation factors in that field.

Television Receiver Construction

Published on 5th March 1948 at 2/6 net (postage 3d.) for "Wireless World" by Iliffe & Sons Ltd. 48 pp. (58 diagrams and illustrations).

THIS reprint of ten articles which have appeared in *Wireless World* contains a full description of a modern television receiver. The information given is sufficient to enable anyone with some experience of wireless equipment to construct the receiver, and it includes full details of those special components, such as R.F. and deflector coils and scanning transformers, which are not always readily available as complete units.

A unit construction is adopted and the set comprises a straight receiver for vision, and the R.F. part of the sound channel is designed to feed into the pickup terminals of a broadcast set or amplifier. Electromagnetic deflection and focusing are used and either a 9 in. or a 12 in. cathode-ray tube can be employed.

The Trader Year Book, 1948

The Trader Publishing Co. Ltd., Dorset House, Stamford St., S.E. 1. 10s. 6d. post free. 224 pp.

THE new edition of this well-known trade directory and year-book is ¼-bound in cloth, with the directory sections printed on tinted paper for ease of reference.

It will be of great assistance to overseas firms seeking names of manufacturers or information on specific products, and is a "must" for British radio dealers.

MAY MEETINGS

Institution of Electrical Engineers

All meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Ordinary Meeting

Date: May 13. Time: 5.30 p.m.
Annual General Meeting.

Measurement Section

Date: May 21. Time: 5.30 p.m.
Lecture: "Great Personalities in the Fields of Electrical and Magnetic Measurements."
By: Professor J. T. MacGregor-Morris.

Radio Section

Date: May 11. Time: 5.30 p.m.
Lecture: "Carrier Frequency Shift Telegraphy."
By: R. Ruddlesden, M.Eng., E. Forster and Z. Jelonek.
Lecture: "Some Developments in Communication Point-to-Point Radio-telegraphy."
By: J. A. Smale, B.Sc.
The Secretary: I.E.E., Savoy Place, London, W.C.2.

Cambridge Radio Group

Date: May 18. Time: 6 p.m.
Held at: The Cambridge Technical College, Cambridge.
Lecture: "Some Aspects of Gramophone Reproduction."
By: K. N. Hawke, B.Sc.
Hon. Secretary: J. E. Curran, University Engineering Laboratory, Trumpington Street, Cambridge.

North-Midland Section

Date: May 4. Time: 6.30 p.m.
Held at: The Corporation Electricity Department, Whitehall Road, Leeds.
Annual General Meeting and visit of President.
Hon. Secretary: H. S. Moody, The Yorkshire Power Co., Manor Farm, Bramhope, Leeds.

The Television Society

Date: May 19. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Discussion: "Cathode Ray Tubes."
Hon. Secretary: T. M. C. Lance, 35 Albemarle Road, Beckenham, Kent.

Constructors' Group

A meeting of the Constructors' Group will be held on May 7, at 7 p.m. at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2, when a discussion on THE "ELECTRONIC ENGINEERING" TELEVISOR will be opened by Messrs. W. I. Flach and N. H. Bentley.

Tickets of admission for non-members of the Society must be obtained from the *Group Secretary, Mr. A. E. Sarson, 22 Union Road, Bromley, Kent.*

Institute of Physics

Electronics Group

Date: May 28. Time: 2.30 p.m.
Held at: The Institute of Physics, 47 Belgrave Square, London, S.W.1.
Discussion: "The Application of Electron-Multipliers to Spectroscopy."
Note: This is a joint meeting of the Electronics Group and the Industrial Spectroscopic Group.
Hon. Secretary: Dr. A. J. Maddock, "Sira," Southill Road, Elmstead Woods, Chislehurst, Kent.

Industrial Spectroscopic Group

Date: May 29. Time: 10 a.m.
Conference.
Held at: The Institute of Physics, 47 Belgrave Square, London, S.W.1.
Hon. Secretary: E. van Someren, Messrs. Murex Welding Processes, Ltd., Hertford Road, Waltham Cross, Herts.

British Sound Recording Association

Annual General Meeting, Conference and Dinner to be held at St. Ermin's Hotel, Caxton Street, London, S.W.1.

Date: May 29. Time: 2.15 p.m.
Annual General Meeting.

Date: May 29. Time: 4.30 p.m.
Opening of Conference.

Date: May 29. Time: 7.15 p.m.
Annual Dinner.

Date: May 30. Time: 10.30 a.m.
Paper and discussion on "Magnetic Recording with Special Emphasis on Tape Recording."

Date: May 30. Time: 2.30 p.m.
Paper and discussion on "Sound Film Recording and Reproduction."

During the whole of the time an Exhibition will be held of sound recording and reproducing equipment.

Hon. Secretary: R. W. Lowden, Napoleon Avenue, Farnborough, Hants.

Society of Instrument Technology

All meetings are held at the Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, London, W.1.

Date: May 25. Time: 6.30 p.m.
Annual General Meeting followed by—
Lecture: "Proposed System in Instrumentation Symbols."
By: J. K. Burkitt, B.Sc.(Eng.).
Secretary: L. B. Lambert, 55 Tudor Gardens, London, W.3.

Brit. I.R.E.

London Section

All meetings are held at the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.

Date: May 13. Time: 6 p.m.
Lecture: "The Calculation of Electrode Temperatures in the Radio Valve."
By: I. A. Harris.
The Publications Officer, 9 Bedford Square, London, W.C.1.

South-Midlands Section

Date: May 28. Time: 6.30 p.m.
Held at: The Technical College, The Butts, Coventry.
Lecture: "An Automatic Audio-Frequency Response Curve Tracer."
By: G. L. Hamburger, A.M.I.E.E.
Local Secretary: C. Stokes, 6 Esterton Close, Coventry.

North-Western Section

Date: May 13. Time: 6.45 p.m.
Held at: College of Technology, Sackville Street, Manchester.
Lecture: "The Wave Analysis of the Low Frequency Potentials of the Human Body."
By: W. E. Boyd, M.A., M.D.
Local Secretary: B. E. P. Ritson, 38 Parswood Court, East Didsbury, Manchester, 20.

North-Eastern Section

Date: May 12. Time: 6 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-on-Tyne.
Annual General Meeting followed by—
Lecture: "Supervisory Control."
By: L. G. Brough.
Local Secretary: M. A. Boardman, 20 Princes Avenue, Gosforth.

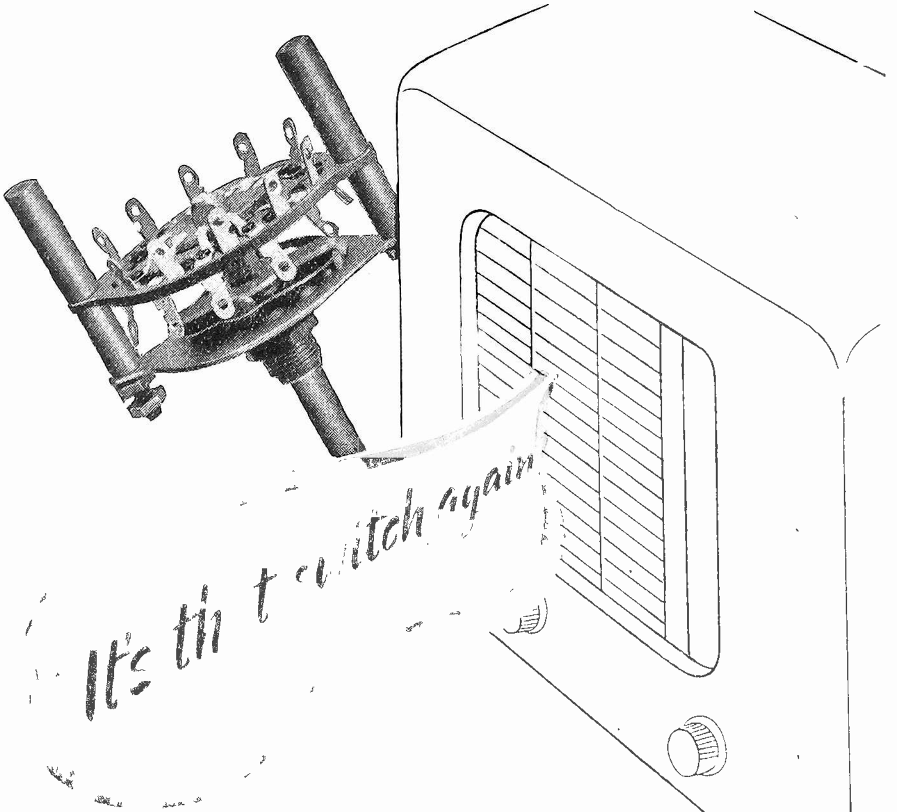
Merseyside Section

Date: May 12. Time: 6.45 p.m.
Held at: The Lecture Room, Liverpool Engineering Society, 9 The Temple, 24 Dale Street, Liverpool 2.
Lecture: "Factors Governing the Performance of I.F. Amplifiers."
By: H. Stibbe and K. G. Lockyer.
Local Secretary: J. Gledhill, B.Sc., 123 Portelet Road, Liverpool, 13.

Radio Society of Great Britain

All meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Date: May 14. Time: 6.30 p.m.
Lecture: "Aspects of High Quality Sound Recording."
By: W. S. Barrell.
General Secretary, New Ruskin House, Little Russell Street, London, W.C.1.



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sers, and separate 100 Kc/s and 1,000 Kc/s Crystals, which feature gives a greater accuracy and reliability than the dual type Crystal. Incidentally the Crystals alone would cost more than our price. Contained in neat metal case with hinged top lid, overall size 7¾ in. x 7⅜ in. x 6¾ in. high, and with stout outer wooden case for rough transport use. Each instrument has been tested and adapted by Webb's for either operation of 6.2 volts A.C. or 6 volts battery. The Wavemeter comes to you ready for immediate operation from 6.2 volts A.C. with easy internal provision for changeover to 6 volts D.C. The original Army Service Manual of 26 pages, with full circuit diagram is included, also a copy of Webb's " Simplified Instructions."

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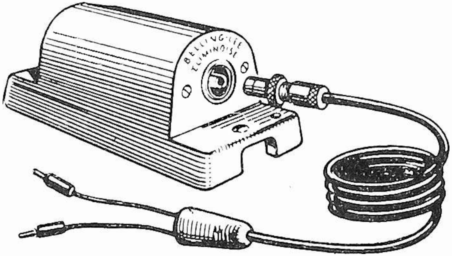

Question 36 : *Can an " Eliminoise " receiver transformer be nt out?"*

Answer 36 : It is surprising how many people in the trade d out of it—do not realize that this can happen until the bility is pointed out to them—then the reason seems ous. It invariably happens with AC-DC Sets, in which the n allows the chassis to be alive at mains voltage, with ect to earth. If an earth terminal is fitted, it should be ected to chassis via a capacitor, thereby isolating the chassis. rtunately, some manufacturers omit the earth connection ether ; in other cases the earth capacitor breaks down. Vhen an *" Eliminoise " aerial is used in these circumstances, eceiver " Eliminoise " transformer is earthed. If there is no citor (or one that has broken down) between earth and is, or between aerial and chassis, current from the chassis through the " Eliminoise " coil and may burn it out.

Unfortunately, there are AC-DC Sets where the aerial mes alive through the same cause, and should the aerial own on a garden or metal clothes line, the results might be trous.

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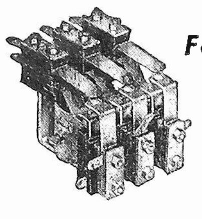

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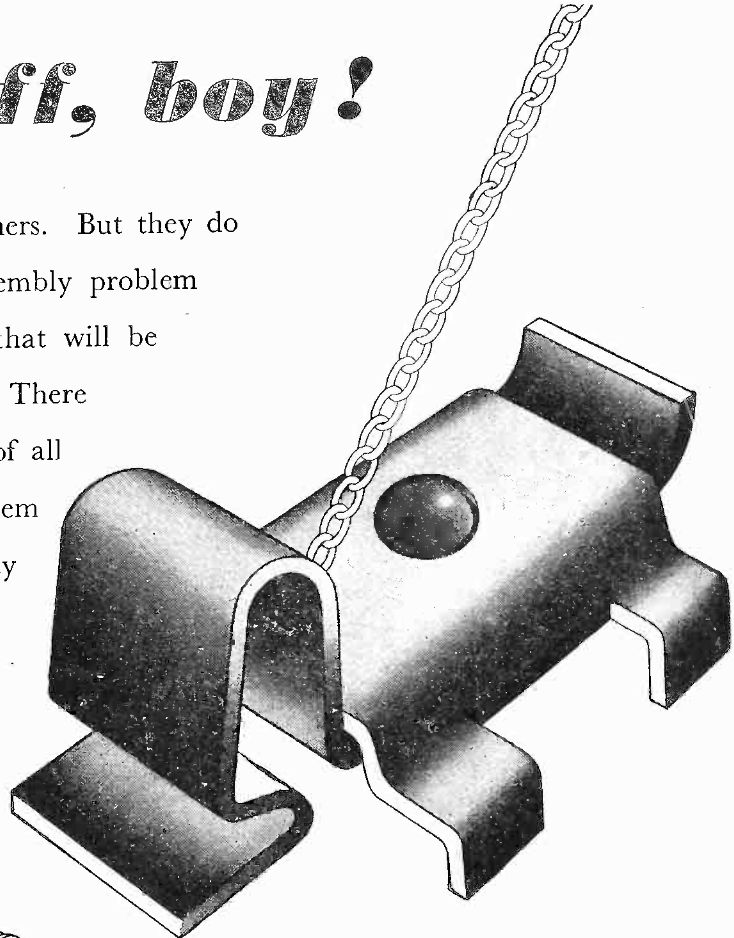

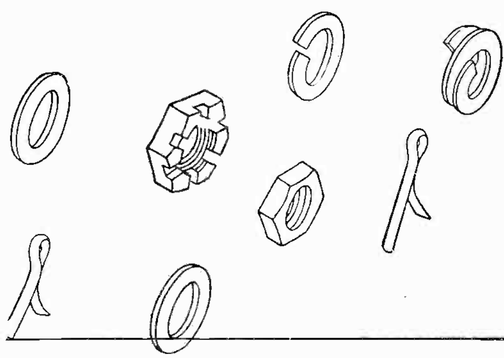

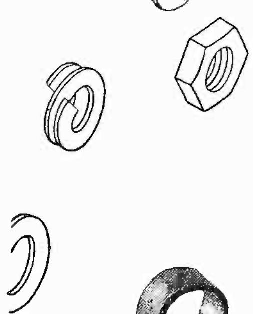

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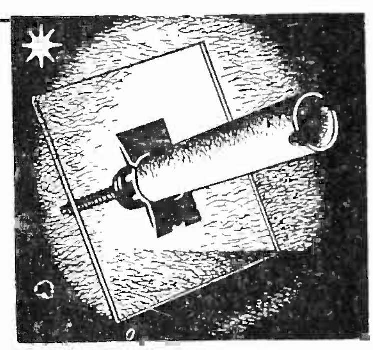

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