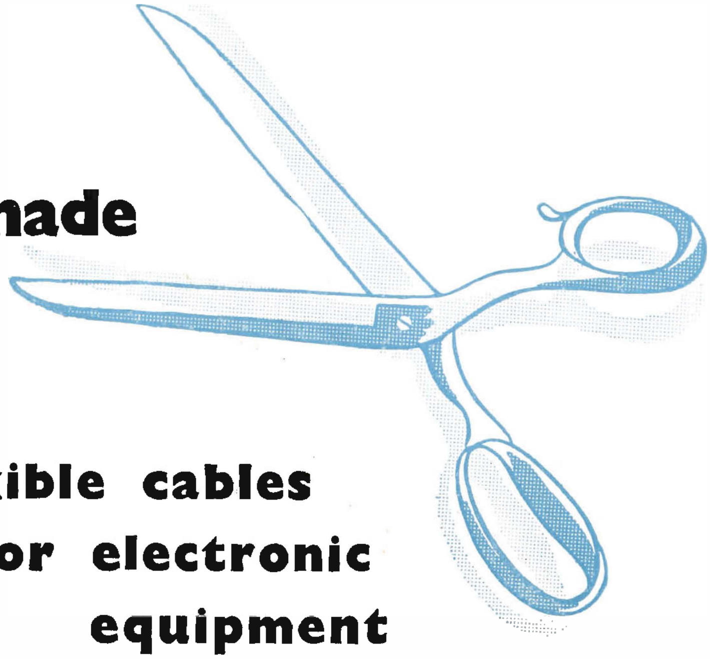
Electronic Engineering

MARCH 1951

TWO SHILLINGS



tailor-made

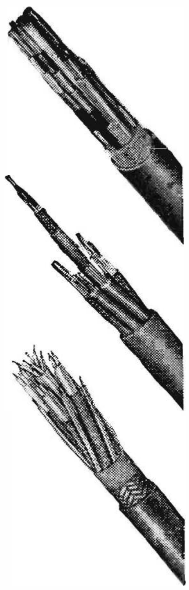
flexible cables for electronic equipment

If you need special multi-unit low-loss cables for electronic equipment—let us design and manufacture them to your requirements. They may include coaxial, twin, quad and small power or control cores in any combination.

BICC can offer you specialised production facilities for this work, as well as the services of skilled engineers who have tailor-made low-loss cables for all current requirements.

Why not take advantage of this opportunity? Write to-day and let us assist you with your problems.

Cables on right are examples which have been designed and manufactured by BICC to meet specialised needs.



Polythene-insulated P.V.C. sheathed multicore cable with microphone and control cores for film studio use.

Multicore polythene-insulated and sheathed television camera cable. Overall diameter 0.5 inches.

P.V.C. sheathed multicore polythene-insulated flexible television camera cable. Overall diameter 0.8 inches.

B.I. Callender's

multi-unit LOW-LOSS CABLES

BRITISH INSULATED CALLENDER'S CABLES LIMITED
NORFOLK HOUSE, NORFOLK STREET, LONDON, W.C.2

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements at the LINE RATE (if under 1" or 12 lines) is: Three lines or under 7/6, each additional line 2/6. (The line averages seven words.) Box number 2/- extra, except in the case of advertisements in "Situations Wanted," when it is added free of charge. At the INCH RATE (if over 1" or 12 lines) the charge is 30/- per inch, single column. Prospectuses and Company's Financial Reports £14 0s. 0d. per column. 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 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

APPLICATIONS are invited by the Ministry of Supply for unestablished appointments in Tropical Testing Establishment, Port Harcourt, Nigeria. (1) Senior Scientific Officer, to lead a group of Physicists and Engineers studying the effects of tropical conditions on Service materials and equipment. Candidates must be at least 26 years of age, have a 1st or 2nd Class Honours Degree or equivalent in Physics or Electrical Engineering, and experience of radio communications or methods of physical and mechanical testing. (Reference A.23/51A.) (2) Scientific Officer, to work on analytical or biochemical investigations in deterioration of equipment under tropical conditions. Candidates must have a 1st or 2nd Class Honours Degree or equivalent in Chemistry, with experience of micro-analysis or biochemistry. (Reference F.53/51A.) (3) Experimental Officers or Assistant Experimental Officers to assist in the work described above. Candidates must have minimum qualification of Higher School Certificate, or equivalent, with either (*a*) Biology as a principal subject and preferably experience in Mycology and/or Entomology ; or (*b*) Physics as a principal subject (equivalent qualification in Electrical Engineering acceptable), preferably with knowledge of radio and experience of performance testing of communications equipment ; or (*c*) Chemistry as a principal subject, preferably with knowledge of Physics or Physical Chemistry. For this post experience of Analytical Chemistry is essential. (Reference G.18/51A.) Candidates for post under (3) will not normally be considered for the Experimental Officer grade under 28 years of age. Posts are open to men only. Appointments are for an initial tour of 18 months, but further tours may be arranged by mutual agreement. Consideration will be given to further employment in U.K. at end of service in West Africa. Salaries will be assessed on age, qualifications and experience within following ranges: Senior Scientific Officer, £700-£900 ; Scientific Officer, £400-£650 ; Experimental Officer, £525-£675 ; Assistant Experimental Officer, £230 (at age of 18)-£490. A Foreign Service Allowance (exempt from Income Tax under P.A.Y.E.) is payable in addition varying from £200 to £350 per annum, according to marital status and is liable to alteration in the light of experience. S.S.O. and S.O. posts carry benefits of F.S.S.U. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting appropriate reference number. Closing date, 16th March, 1951. W 2739

APPLICATIONS are invited by the Ministry of Supply for three unestablished posts in the Scientific Officer Class at an R.A.F. Signals Experimental Establishment in Norfolk. Candidates should have a 1st or 2nd Class Honours Degree or equivalent qualification in Physics or Electrical Engineering, with some experience on aerial problems, radio receivers and small transmitters for airborne or mobile use. For the senior posts the minimum age is 26 years with at least three years' post-graduate research experience. Salary will be determined on age and on an assessment of the successful candidates' qualifications and experience within the following ranges (male): Senior Scientific Officer, £670-£860 ; Scientific Officer, £380-£620. Rates for women somewhat lower. Post carry benefits of F.S.S.U. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific, Register (K) York House, Kingsway, London, W.C.2, quoting D.32/51A. Closing date, 16th March, 1951. W 2740

B.B.C. invites applications for post of Engineer in Planning and Installation Department, London. Applicants should have a good basic knowledge of Electrical Engineering and Television. A University Degree in Electrical Engineering is a desirable but not essential qualification. Preference will be given to applicants who have had practical experience of cinematographic equipment used for sound and picture recording and who have a wide knowledge of photography and the control of film processing. A knowledge of optics and the mechanical design of film cameras would be an advantage. The work is in connexion with the development of television recording processes and the duties of the post will include the preparation of appropriate specifications for the manufacture of such television equipment, the supervision of its installation, subsequent acceptance trials and the conduct of relevant correspondence. Starting salary, £745 per annum (may be higher if qualifications and experience are exceptional), rising by annual increments on a five-year progression to £965 per annum. The successful applicant will become eligible for consideration for appointment to established staff (contributory pension scheme) after two years' qualifying period. Applications, stating age, qualifications and experience, to reach Engineering Establishment Officer, Broadcasting House, London, W.1, within seven days. W 2729

ADMIRALTY. Vacancies exist for Electrical and/or Mechanical Engineering Draughtsmen in Admiralty Research and Development Establishments located in the vicinity of Weymouth, Portsmouth, Teddington (Middlesex) and Baldock (Herts.). Draughtsmen experienced in light current, electro-mechanical, precision mechanical and electronic equipment are particularly needed. Candidates must be British subjects of 21 years of age and upwards, who have had practical workshop experience (preferably an apprenticeship), together with drawing office experience. Appointments will be in an unestablished capacity, but opportunities may occur for qualified staff to compete for established posts. The salaries offered, depending on age, experience, ability and place of duty, will be within the range £283-£510 per annum. Exceptionally well-qualified candidates may be considered for appointment in a higher grade within the salary range £470-£610 per annum. Hostel accommodation is available at some establishments. Applications, stating age and details of technical qualifications and apprenticeship (or equivalents) and workshop and drawing office experience, should be sent to Admiralty (C.E.II, Room 88), Empire Hotel, Bath. Original testimonials should not be forwarded with application. Candidates required for interview (at London or Bath whichever is nearer) will be advised within two weeks of receipt of application. W 2770

SITUATIONS VACANT

A COVENTRY FIRM has vacancies for men with an understanding of electronic circuits ; experience in the testing or the maintenance of radio, radar or public address systems, would be an advantage. Applications, in the first instance, stating age and experience, to Box No. W 1260.

ELECTRONIC INSTRUMENT makers, Central London, require experienced Tester. Receiver or instrument design experience an asset. Box No. W 2752.

RADAR DESIGNER, Development Engineer required immediately. Work Central London ; excellent prospects for qualified experienced man. Leland Instruments Limited, 22-23, Millbank, London, S.W.1. W 2753

LABORATORY ASSISTANT required for Electronics Section to assist in work on noise in vehicles. Minimum qualification, Matriculation or equivalent. Reply, giving age, qualifications, experience and salary required, to Motor Industry Research Association, Great West Road, Brentford, Middlesex. W 2751

SENIOR DRAUGHTSMAN, capable of undertaking the mechanical design on the drawing board of precision electronic equipment, required by large Light Engineering Company, East London district. Applications, giving details of age, past experience and salary required, to Box No. W 2750.

CHEMIST (General) required for chemical processes relating to radio valve manufacture. Applicants with Inter. B.Sc. will be considered. Write, in confidence, to the Personnel Officer, Brimar Valve Works, Footscray, Sidcup, Kent. W 2743

ELECTRICAL AND MECHANICAL Engineers, preferably graduates, urgently required on electronics development for factory near Manchester. Five-day week ; good conditions. Attractive salaries to suitably qualified persons. Full particulars to Box No. W 2745.

CHEMIST (Male or Female) required for control of chemical processes relating to radio valve manufacture. Applicants must possess B.Sc. (Chem.) Degree. Write, in confidence, giving experience, age and salary required, to the Personnel Officer, Brimar Valve Works, Footscray, Sidcup, Kent. W 2742

DRAUGHTSMEN required to asist Designers. Capable of producing detail drawings from layouts and sketches to standards suitable for quantity production of radio and radar equipment. Apply, giving full details, to Personnel Department, Murphy Radio Ltd., Welwyn Garden City, Herts. W 2749

ELECTRONIC DEVELOPMENT ENGINEERS. Vacancies exist for: (1) Senior Development Engineer, to be responsible under Technical Director, for the development and design of a wide range of C.R.O. and associated electronic equipment. Applicants must have an Honours Degree in Physics or Electrical Engineering (Telecommunications) and some industrial experience. First-class opportunity for a man with original ideas and a keen interest in the subject. (2) Development Engineer for work on interesting development projects. A Degree in Physics or Electrical Engineering is essential and some industrial or research experience desirable. Salaries according to age and qualifications. Apply, with full details, to Southern Instruments Ltd., Fernhill, Hawley, Camberley, Surrey. W 1256

PHYSICIST wanted for thermionic valve research. Good Honours Degree or equivalent and vacuum or high-frequency circuit experience essential. Salary, £600 per annum, or according to experience. Apply Personnel Manager, Standard Telephones and Cables Limited, Ilminster, Somerset. W 2738

ELECTRONIC DEVELOPMENT ENGINEERS. An important West London Manufacturing Company invites applications from both qualified Electronics Development Engineers and Junior Engineers. The positions available are permanent, carry good commencing salaries and offer considerable opportunity for advancement in salary and status. The following qualifications are required: (*a*) Senior Electronics Development Engineers, at least 3-5 years' experience in valve circuit technique. Preferably with a University Degree. Aged 25-50. (*b*) Junior Electronics Development Engineers. Preferably with some experience and holders of a University Degree. Aged up to 30. Applicants should, in the first instance, write in confidence, giving full particulars of qualifications, experience age and salary desired, to Box No. W 2737.

RADIO ENGINEER required for Factory Laboratory, with experience of technical problems associated with the manufacture of radio and television receivers. An engineer with some design experience, wishing to apply his knowledge in the factory, would be considered. Write, giving full particulars, age and salary required, to Personnel Department, Murphy Radio Ltd., Welwyn Garden City, Herts. W 2736

RADIO ENGINEER required for Test Instrument Laboratory, with experience of design and manufacture of test apparatus. One without experience but having good qualifications and an interest in the subject would be considered. Write, giving full particulars, age and salary required, to Personnel Department, Murphy Radio Ltd., Welwyn Garden City, Herts. W 2735

ELECTRONIC RESEARCH and Development. There are vacancies for Honours Graduates for work in the following fields: (1) Measurement technique on V.H.F. and microwaves. (2) High power R.F. generation. (3) Carrier telephony. (4) General scientific instruments and high-grade components. Some of these posts require a thorough experience in one of the fields and there are others for recent graduates. Apply to Personnel Officer, Mullard Research Laboratories, Salfords, nr. Redhill, Surrey. W 2765

ASSISTANT wanted on staff of Research Department in Midlands, for work on special valves and radar. State experience and qualifications to Box No. 837, T. & G., 101, St. Martin's Lane, W.C.2. W 2757

CLASSIFIED ANNOUNCEMENTS
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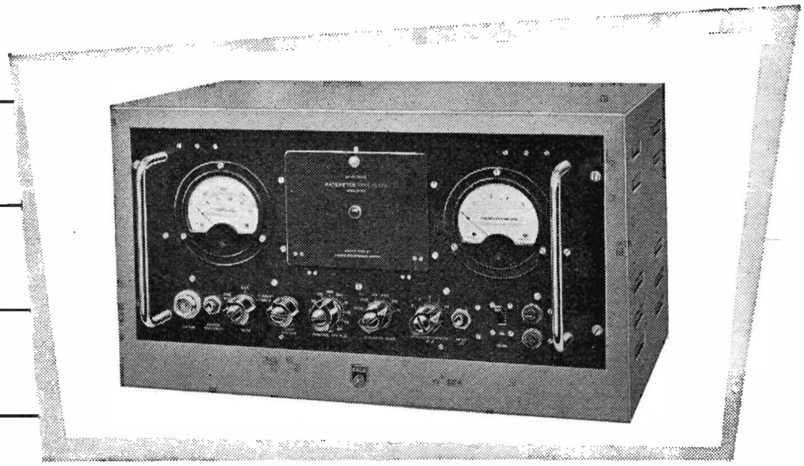
EKCO
RATEMETER
1037A



Developed in conjunction with the Atomic Energy Research Establishment, this general purpose Ratemeter has a self-contained high voltage supply, suitable for polarising Geiger-Muller tubes, etc. It gives a direct and almost instantaneous reading of the mean repetition rate of incoming pulses up to a maximum of 100,000 per second. Pulse height discrimination and paralysis facilities are provided and a suitable external recorder may be used as desired. An amplifier for use with G-M tubes is incorporated.

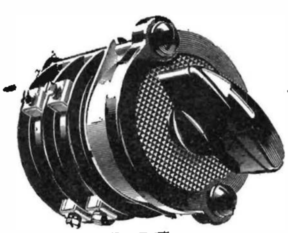
Please write for the complete catalogue of Ekco equipment for the radiochemical laboratory.

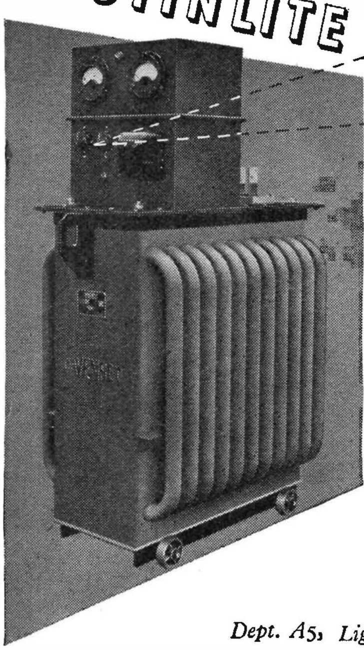
EKCO ELECTRONICS

E. K. COLE LIMITED, ELECTRONICS DIVISION

Sales Office : 5, Vigo Street, London W.1. *'Phone :* Reg. 7030/9.

AUSTINLITE controls the current





Austinlite Rotary Switches are used to control the Auto-Transformer regulating the A.C. supply to these Electro Plating Rectifiers, manufactured by Partridge, Wilson & Co. Ltd.

Full details of the Austinlite 50 amp. Rotary Switch and of the **new** 30 amp. switch will be gladly supplied on request.

A Chance PRODUCT

AUSTINLITE LIMITED, *(A subsidiary of Chance Brothers Limited),*
Dept. A5, Lighthouse Works, Smethwick 40, *Birmingham. Telephone: West Bromwich* 1051.

TECHNICAL SALES ASSISTANTS required by Company specializing in equipment for high vacuum work. Applicants 25/30 of good personality and appearance and high integrity, should have suitable training e.g., Physics, Electrical or Chemical Engineering, Electronics to Inter B.Sc./Graduate standard. Technical and commercial training will be given for subsequent service in sales office or travelling at home or abroad as positions arise. A real enthusiasm and flair for sales work is essential. Progressive and superannuated posts. Apply, with full details to Box No. W 2761.

DEVELOPMENT ENGINEER, 25/35 years, with Degree or at least H.N.C. standard, for development work on equipment for photo-telegraphy and facsimile. Mainly electronic and electrical but with some optical work. Physicist with engineering background on light current work would be suitable. Salary £450-£550 p.a. Beckenham area. 5-day week. Permanent position and Contributory Pension Scheme. Applications, in writing, giving full particulars of age and experience, to Box No. W 2763

RADIO. Technical Correspondence Clerk required by manufacturers in London. Education not below School Certificate Standard and with adequate technical training. Ability to deal fully with practical and theoretical problems arising from the servicing of radio receivers and good command of English essential. Successful candidate will be required to spend some part of his time in repair and overhaul of domestic receivers. Applications, in own writing, must include full details of education, technical training, experience and age, and salary required to Box No. 460, c/o, Era Publicity Ltd., 7, Fitzroy Square, London, W.1. W 2762

ENGINEER or Physicist required to take charge of section developing thermionic transmitting valves. Honours Degree in Physics or Electrical Engineering or equivalent, essential. Previous experience of transmitting valves desirable. Salary according to experience and suitability. Apply, Personnel Manager, Standard Telephones and Cables Limited, Ilminster, Somerset. W 2771

GRAYLINGWELL HOSPITAL, Chichester. Laboratory technician required for electro-encepholography department. The duties will include routine clinical recording and maintenance, electronic constructional work under supervision, and some assistance with experimental work. Preference will be given to a candidate with some E.E.G. experience and practical knowledge of electronics or electro-physiological techniques, and membership of the British Institute of Radio Engineers (or equivalent) is desirable. The appointment is on a temporary basis and will be limited to a period of two years in the first instance, the salary being £360 for the first year and £375 for second. The post will be subject to the provisions of the National Health Service (Superannuation) regulations. Applications, stating age, experience and full particulars, together with the names and addresses of two referees, to be sent as soon as possible to the Medical Superintendent W 1267

PROMINENT AIRCRAFT firm in Greater London area, commencing new project of great National importance, offers unique opportunity for advancement. High salaries with monthly staff status and Pension Scheme offered to suitably qualified applicants. Electronic Engineers with 1st Class Honours Degree in Mathematics or Engineering preferably with several years' practical experience, though not essential. Apply, stating age, nationality and experience, to Box Ac.58212, Samson Clarks, 57-61, Mortimer Street, W.1. W 131

MARCONI'S WIRELESS TELEGRAPH Co. Ltd. invite applications from persons interested in joining teams which will spend a considerable time in various parts of the world carrying out wave propagation experiments leading to the selection of sites for the erection of wireless stations. Preferably applicants should possess a University Degree, but consideration will be given to those possessing other qualifications. Selected applicants will be trained under expert guidance in this country before taking up duties, and will be employed in the laboratory during intervals of home service. In addition to normal home pay, successful applicants will receive an overseas allowance and liberal expenses whilst abroad. The Company operates a Staff Pension Scheme. Apply, quoting Ref. 833, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2672

ELECTRICAL ENGINEERS wanted by large firm in the Manchester area to specialise in the laboratory development of servo-operated and process control instruments. Apply, in writing, stating age, qualifications, experience, salary required, etc., marking envelopes "Meter," to Box No. W 2669.

SPERRY GYROSCOPE CO. LTD., Great West Road, Brentford, Middlesex, require Electro-Mechanical Engineer. Good academic qualifications and recognised apprenticeship desirable. Experience in electrical and electro-mechanical methods of computation; servo theory, and instrument design preferred. Apply with full details of experience and salary required to the Personnel Manager. W 124

SPERRY GYROSCOPE CO. LTD., Great West Road, Brentford, Middlesex, require Electronic Engineer. Good academic qualifications and recognised apprenticeship desirable. Required for development work on control systems. Experience of D.C. amplifiers and computing devices an advantage. Apply with full details of experience and salary required to the Personnel Manager. W 126

SPERRY GYROSCOPE CO. LTD., Great West Road, Brentford, Middlesex, require Mechanical Engineer. Good academic qualifications and recognised apprenticeship desirable. Preferably experienced in one or more of the following: precision mechanical design; hydraulics or pneumatic servo systems; servo theory, aerodynamics. Apply with full details of experience and salary required to the Personnel Manager. W 128

REQUIRED by the British Telecommunications Research, Ltd., at their research and development laboratories in Bucks., several senior radio communication engineers for project work in the V.H.F. and U.H.F. fields. Salary range £400 to £800 per annum. Application forms available from the Senior Radio Engineer, B.T.R., Ltd., Taplow Court, Taplow, Bucks. Suitable applicants will be invited for interview. W 2692

DEVELOPMENT ENGINEERS required by firm in N.W. London manufacturing an extensive range of industrial instruments and controls. Candidates should have a good theoretical background, preferably with a Degree, or equivalent, in Physics or Electrical Engineering, and in addition should have experience in one of the following : (*a*) Industrial instruments and process control. (*b*) Servo mechanisms. (*c*) Magnetic amplifier design. (*d*) Application of electronics to industrial measurements and control. The starting salary will be according to the experience of the applicant, ranging from £400 per annum for Junior Engineers, to £650 per annum for specially qualified applicants. Write Box No. W 2696.

EX-R.E.M.E. Officer or Mechanical Engineer, with organising ability, required to assist in the organising of light engineering constructional work, and supervise field trials of a novel device. Apply, giving full details, and mentioning Ref. 487, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2706

HOUSE (married accommodation) available for Senior Engineer for experimental work on servo-mechanisms required for important defence project in special English Electric Company laboratory. Permanent post. Good experience in servo loop design essential. Commencing salary, £700-£900 per annum. Apply, giving full details and quoting Ref. 844A, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2707

WANTED, experienced Electronics Engineer, to take charge of investigations with effects of vibration or electronic gear and development of anti-vibration measures, in special English Electric Company laboratory. Starting salary, £600-£800 per annum, according to qualifications. Apply, giving full details and quoting Ref. 850, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2708

HOUSE married accommodation) available for Senior Engineer for experimental work on radar, radio and/or electronics for important defence project in English Electric Company laboratory. Honours Degree preferable. Commencing salary, £700-£900 per annum. Apply, giving full details and quoting Ref. 456C, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2704

FERRANTI LIMITED have vacancies at their Radio Works, Moston, Manchester, for : (*a*) A young Graduate in Physics or General Science, to assist in the General Physics Section of the Laboratory (Reference G.P.). (*b*) An Honours Graduate in Physics, interested in Thermionic Emission, Electron Optics, Vacuum Techniques and General Electronic Process work, to assist in the Physical Laboratory on production control of cathode-ray tubes (Reference, C.R.P.). Liberal salary, according to qualifications and experience. Pensionable appointment. Application forms from the Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote appropriate reference. W 2714

ELECTRONIC ENGINEER required for development work by expanding industrial electronic team of well known manufacturing company. Previous experience of servo mechanisms and industrial process control together with Degree of H.N.C. essential. Write giving full details quoting reference GBH to Box No. W 2684.

HIGH FREQUENCY Induction Heating Applications Engineer required by progressive and expanding company specialising in the manufacture of high frequency equipment. Experience in induction heating essential and a good knowledge of metallurgy would be considered as an additional qualification. The position offers excellent opportunities for advancement to a really energetic man having the requisite experience. Write giving experience and salary required to Box No. W 1213.

RADIO VALVE ENGINEERS. The M.O. Valve Company have vacancies for qualified engineers in connection with the development manufacture and application of radio valves. Please apply by letter stating particulars and salary required to Personnel Department, The M.O. Valve Co., Osram Works, Brook Green, Hammersmith. W 2624

AN EXPERIENCED Valve Engineer is required for employment at Chelmsford. Applicants should be 25-35 years of age, qualified engineers and preference will be given to those with previous design or production experience of small transmitting valves. Write giving full details of experience mentioning ref. 497C to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2632

APPLICATIONS are invited from men aged 21-40 years for work of a permanent nature which offers considerable scope for advancement. Applicants should have experience in the development and construction of Laboratory Test or Instrumentation Equipment or Sub-Miniature U.H.F. Gear. Ordinary or Higher National Certificate or C. and G. Telecommunications (Parts II and III) desirable. Salary commensurate with qualifications and experience. Apply to Box No. W 2637.

RADIO-RADAR Development, Engineers urgently required, accommodation available. Applications are invited from Senior and Junior Development Engineers, preferably with experience of Radar or microwave technique, who are capable of developing equipment or components to Service Specifications. Successful candidates will be employed on work of great National importance. Write quoting reference CHC (5) to Personnel Officer, General Electric Co. Ltd., Radio & Television Works, Spon Street, Coventry. W 2642

A NUMBER of Senior and Junior vacancies for Radio, Radar, Electronic, Television, etc., Development, Service Engineers, Draughtsmen, Wiremen, Testers, Inspectors, etc. Urgently required, 30 Television Service Engineers. Write in confidence: Technical Employment Agency, 179 Clapham Road, London, S.W.9. (BRIxton 3487.) W 113

CHEMIST or applied Chemist with Honours B.Sc. for research and development. Initially in London, later at Maidenhead factory. Age up to 30. Write experience and salary expected. Vandervell Products, Western Avenue, London, W.3. W 1261

LONDON HOSPITAL, Whitechapel, E.1, has vacancy for man or woman, age 25-35, for training as an Electro-encephalogram Recordist. Applicants should have matriculation, knowledge of and interest in electronics and an interest in the application of them to clinical work. Apply, in writing, giving details of age and experience to the Secretary. W 2774

CLASSIFIED ANNOUNCEMENTS
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CLASSIFIED ANNOUNCEMENTS (Cont'd.)

THE G.E.C. is re-organising and expanding its radio engineering development and production units, both for its peacetime needs and for Government Contract work. It requires additional men of calibre and experience in its Coventry group of factories for work of considerable importance. Suitable Engineers, Physicists, Designers, Draughtsmen, Testers and Production Engineers, with experience of electronics, telecommunications and radio are offered an unusual opportunity of joining this developing side of the Company's business. Good conditions, excellent social facilities, interesting work, pension scheme. Considerable scope exists for men with energy and determination to overcome day to day difficulties. Write, giving precis of training, experience, etc., and salary required. Interview either Coventry or London, to: The General Electric Co., Ltd., Radio and Television Works, Spon Street, Coventry. W 2773

BUSINESS OPPORTUNITIES

SWISS wholesale dealer of the radio trade wants connexion with manufacturers of wireless parts and accessories. Write, General-Trading, Menziken, Ct. Argovie (Switzerland). W 1257

SITUATIONS WANTED

AMBITIOUS, Energetic Electrical Engineer, Nat. Dip., H.N.C., Grad.I.E.E., desires interesting post in/near Leeds (Yorks), experience includes electrical instruments, light electrical machines, radar (four years R.A.F.), electronic development work. Box No. W 1251

LABORATORY TECHNICIAN. Layout and construction valve operated equipment from theoretical diagram, without supervision. Carry out designers ideas. London or Home Counties preferred. Box No. W 1252

FOR SALE

VALVE-voltmeters. R. Kitai's versatile design (Oct. issue). DC to 300 Mcs; 1v to 100v ranges, all linear; overload protected meter; overall accuracy 2% FSD; automatic HT stabilization and zero adjust; one scale all services; Rinput-20 Megs; a 50 guinea specification; price, assembled chassis form, 12 gns. Repetition and experimental coilwinding capacity available. Bel Sound Products Co., Marlborough Yard, Archway, N.19. Tel.: Arc 5078 W 2747

GOVERNMENT SURPLUS VALVES. EBC33, EF36, EF39, EL32, EF50, EF54, 6SA7, 6AC7, 807, 6J7, 4s. each. EA50, VR78, SP41, EB34, 6H6M, 1s. 6d. each. SP61, 6J5, VR118, ARP12, 2s. 6d. each. VR116, VU111, CV73, 3s. each. All guaranteed. Quotations for quantities. Carriage extra. J. H. Dakin, 13, Church Road, Birmingham, 15. W 1262

FIRST BOOK about transmitters "Radio Communication Transmitters" by J. J. Hupert, Prof. de Paul University, Chicago, USA, published by ATA Scientific Progress Ltd., 19, Effra Road, S.W.2, price, 24s. W 1263

KERAMOT Loaded Ebonite for sale. Sheets, 24 in. by 24 in. by ½ in. and 36 in. by 24 in. by ½ in. Samples on request. Box No. W 1266.

SELENIUM RECTIFIERS. FW, 12V, 1A, 5s. 6d. 4A, 14s. HW 250V, 70 MA, 4s. Sliding resistances, 1 ohm 12A, 4 ohm 6A, 6s. Fixed 1 ohm 12A, 3s. 6d. Vitreous, 800, 30W, tapped 2s. 2,000 30W, 1s 3d. 1,500 15W, 10d. 50 200 5W, 5d. 25, 1,000, 1,500, 3W, 4d. 45, 100, 1,200 2W, 3d. Tone controls 15,000, 6d. Voltmeters AC/DC 0-15, 5s. Motors squirrel cage, 24V, 3ph, 5s. Reduction quantities. Letters answered: Parker, 3, Longdene Road, Haslemere, Surrey. W 1271

GLASS-TO-METAL SEALS and High Vacuum by Hall, Drysdale & Co. Ltd., of 58 Commerce Road, Wood Green, London, N.22. 'Phone: BOWes Park 7221. W 117

COILS. Special inductances 1μH to 2H at RF, singly or quantity, wound to order. Bel Sound Products Co., Marlborough Yard, Archway, N.19. Archway 5078. W 112

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. W 102

MERCURY SWITCHES are made by Hall Drysdale & Co. Ltd., of 58 Commerce Road, Wood Green, London, N.22. Phone BOWes Park 7221-2. W 107

AMERICAN MAGAZINES. One year post free. "Radio Electronics," 32s. 3d.; "Audio Engineering," 28s. 9d.; "Radio and Television News," 36s.; "Popular Science," 28s. 6d. S.A.E. for full list from Willen Ltd., (Dept. 9), 101 Fleet Street. London, E.C.4. W 108

MAGSLIPS at 1/10th to 1/20th of list prices. Huge stocks. Please state requirements. K. Logan, Westalley, Hitchin, Herts. W 116

PROF. KITAI'S ingenious valve voltmeter, assembled complete, 12 gns. Coils, transformers wound, singly or quantity. Bel Sound Products Co., Marlborough Yard, Archway, N.19. ARC. 5078. W 2698

BARREL PLATING capacity available. Cadmium, copper, tin, and electro-galvanizing. Packer & Son, Sion Place, Clifton, Bristol, 8. 'Phone: 38368. W 1246

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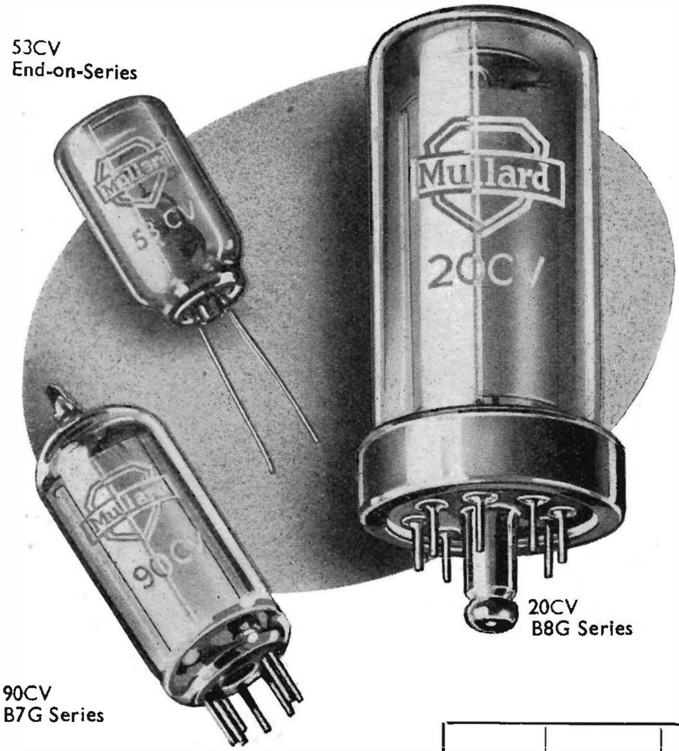

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End-on-Series

20CV
B8G Series

90CV
B7G Series

As a result of extensive research both in material and design Mullard now make available a comprehensive range of photocells ideally suited for industrial applications.

The range falls into two main groups. The caesium-silver-oxide cathode (C type) cells, with a high sensitivity to incandescent and iufra-red radiation; and the caesium-antimony cathode (A type) cells, with a high sensitivity to daylight.

Brief technical details are listed below. Fuller information on these and special photocells is available on request.

Type	Base	Max. Anode Supply Voltage (V)	Max. Cathode Current (μA)	Max. Dark Current (μA)	Sensitivity to colour temp. 2,700°K (μA/l)	Max. Gas Amplification Factor
20AV	B8G	150	10	0.05	45	—
20CG	B8G	90	5	0.1	150	10
20CV	B8G	250	20	0.05	25	—
90AG	B7G	90	2.5	0.1	200	7
*90AV	B7G	100	5	0.05	45	—
*90CG	B7G	90	2	0.1	125	10
*90CV	B7G	100	10	0.05	20	—
58CG	Wire-in	90	1.5	0.1	85	9
58CV	Wire-in	100	1.5	0.05	15	—

* These valves are included in the new Government list of preferred valves for the services.

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If you are not already on the mailing list for this service of advance information on new valves, please write to us for full particulars on your business letterheading.

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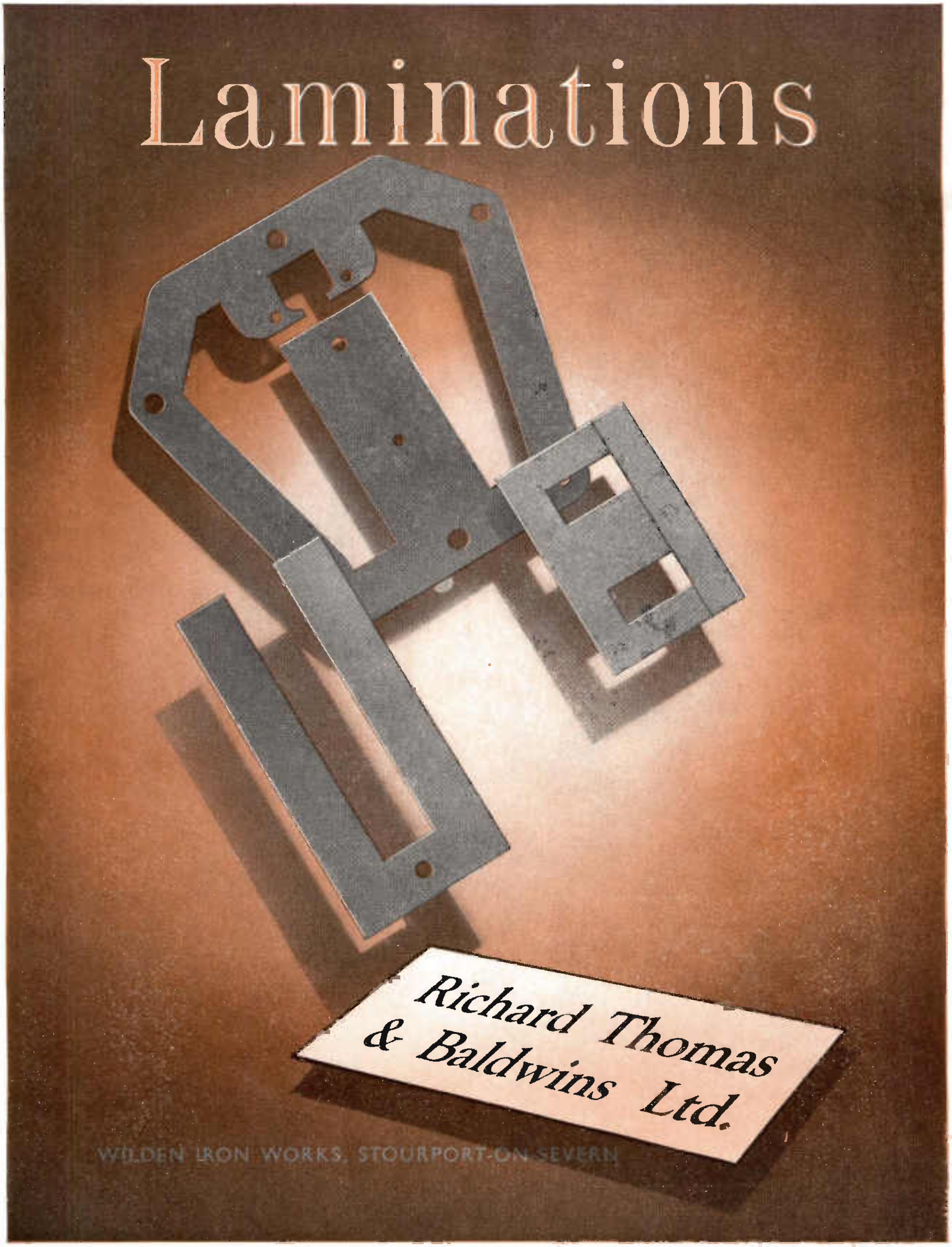

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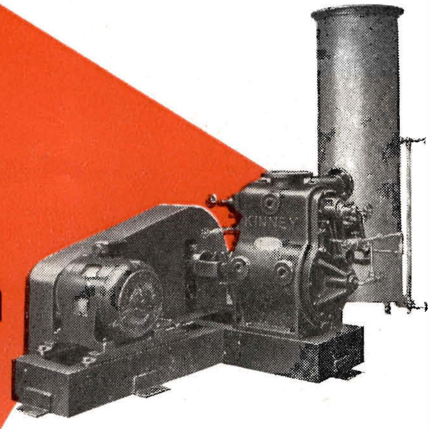

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Compound pumps absolute pressures of 0.5 microns, single stage pumps absolute pressures of 10 microns.

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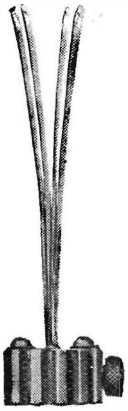

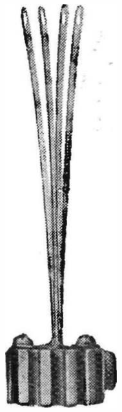

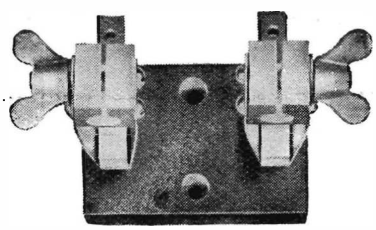

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The ES.833 is a high mu triode particularly suitable for use as an R.F. Power Amplifier, Oscillator or Class B Modulator. It is a direct plug-in replacement for the American type 833A.

The anode and grid connections are brought out at the top and are taken through metal-to-glass seals to heavy current terminals. As a result of this construction the valve is exceptionally efficient at higher radio frequencies, and may be operated under Class 'C' CW conditions at a maximum input of 2 kW at frequencies up to 30 Mcs. At a reduced input rating it is possible to operate the valve as high as 75 Mcs.

RATING

Filament Voltage (volts)	V	10.0
Filament Current (amps)	I_f	10.0
Maximum Anode Voltage (volts)	Va (max.)	3,000
Maximum Anode Dissipation (watts) (Radiation Cooled)	Wa(max.)	300
Maximum Anode Dissipation (watts) (Forced Air Cooled)	Wa(max.)	450
Amplification Factor	μ	35
Maximum Operating Frequency at full rating		30 Mcs*

** At high frequencies the maximum permissible anode voltages and inputs must be reduced*

Prices for valves and holders upon application.

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THE EDISON SWAN ELECTRIC CO. LTD., 155 CHARING CROSS RD., LONDON, W.C.2

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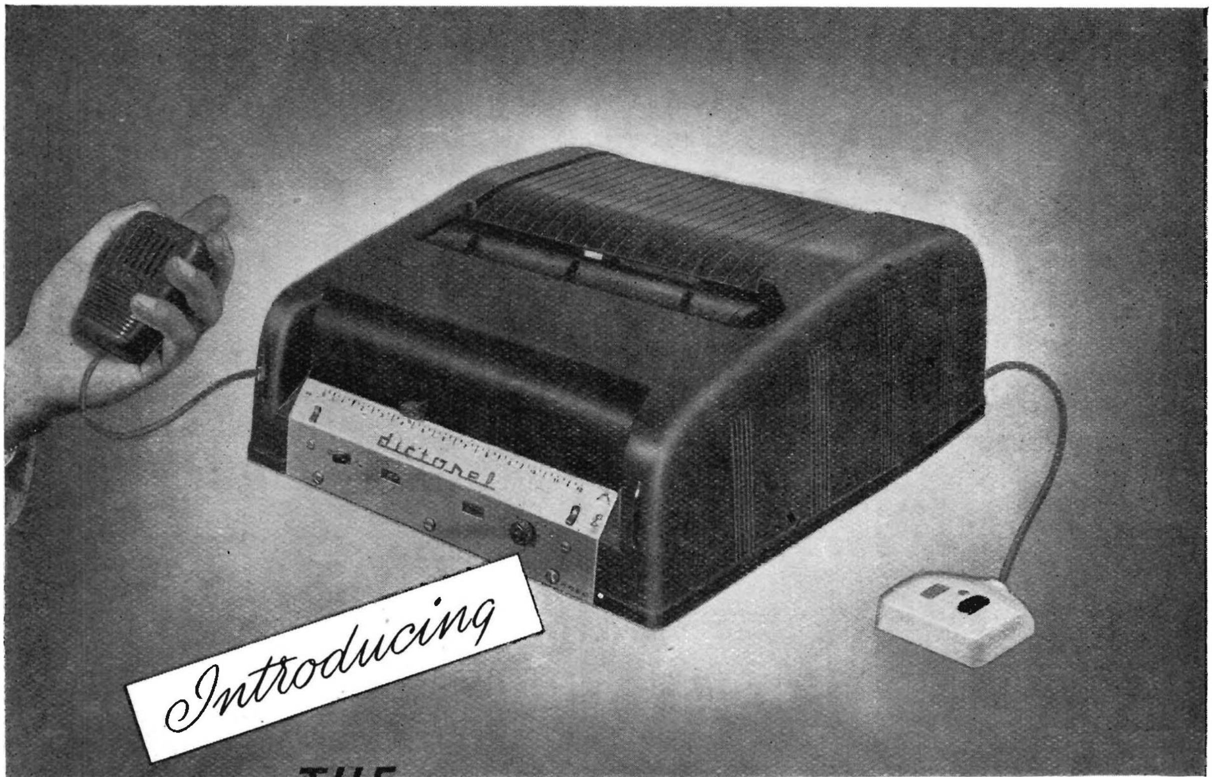

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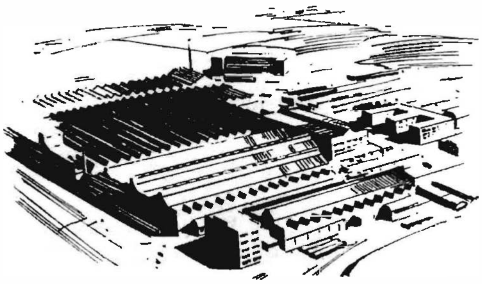

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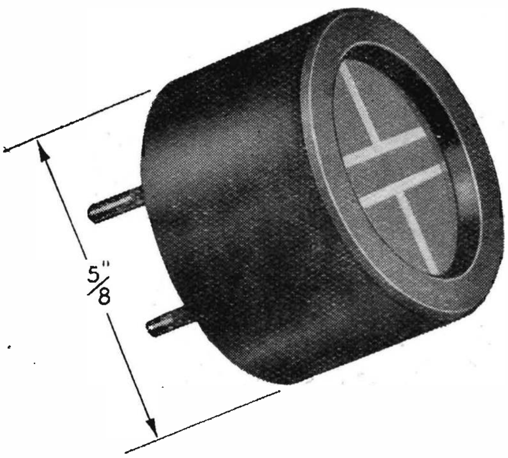
Infra - red Photo - conductive cells

For Pyrometry, Spectroscopy, and the Detection of Radiant Heat

These lead sulphide cells are the fastest and most sensitive devices for the detection and measurement of infra-red radiation in the 1 to 3 micron wavelength region of the spectrum. They are sensitive to source temperatures as low as 200°C, and they respond to temperature variations within 100 microseconds.

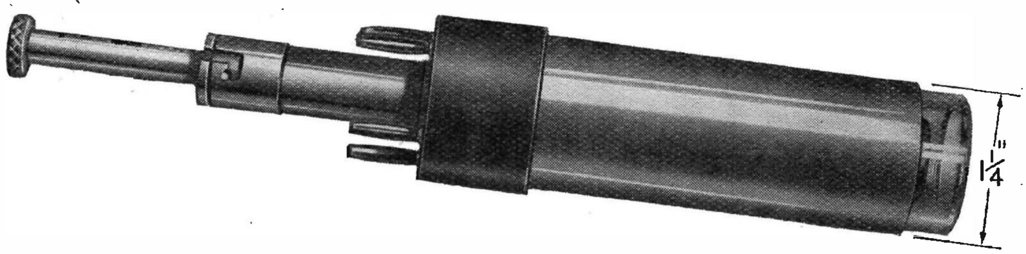


Left: Type "M", for detection and pyrometry, is of minimum dimensions and simple mechanical construction.

Below: Type "C.1", for detection and spectroscopy. This cell has provision for cooling by carbon dioxide, a feature which considerably increases its sensitivity.

Other BTH infra-red devices include: Nernst filaments (as infra-red sources), special infra-red transmitting glass, and semiconductor bolometers.

Full particulars on application.



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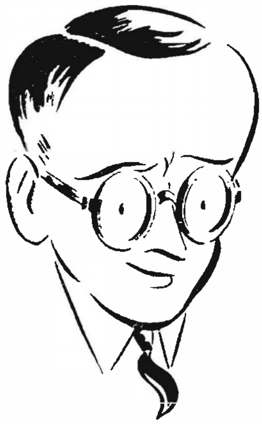
THE BRITISH THOMSON-HOUSTON CO., LTD., RUGBY, ENGLAND

We've no YES-MEN at Keighley



...they're all KNOW-MEN

IT isn't always easy to resist the suggestion that price is the final consideration when selling in a competitive market. That is why we employ a team of knowledgeable, strong-willed " know-men " specially briefed to reject any compromise with quality.

We at Keighley are not satisfied by the knowledge that each switch we turn out will function correctly when it leaves our hands — we must also know that it will continue to do so throughout the life of the appliance it is designed to control.

Only then can our " know-men " feel satisfied that their job is well done. And—secure in the knowledge that fundamental simplicity of design, meticulous inspection at each production stage and rugged construction have provided a more than adequate margin of electrical and mechanical safety—they can then turn their attention to the unravelling of the next knotty problem.

And how much extra does the discriminating appliance manufacturer pay for this higher standard of quality? In a word — nothing. For the price he pays for his Cutler-Hammer Switches is immediately reflected in longer trouble-free service, reduced maintenance costs and enhanced goodwill for his product.

NSF

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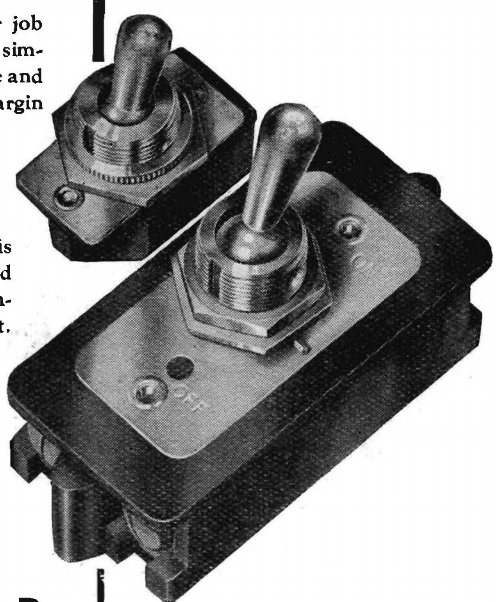
APPLIANCE SWITCHES

C-H

"THE SWITCH PEOPLE"



● Other British N.S.F. Products include: 'OAK' Rotary, Push-button and Slider switches; Carbon and wire-wound potentiometers for Television and Radio applications.

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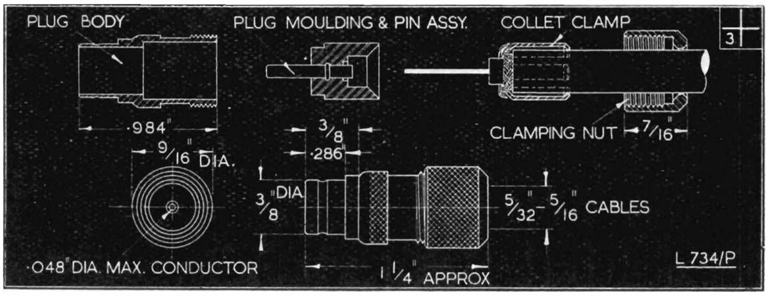
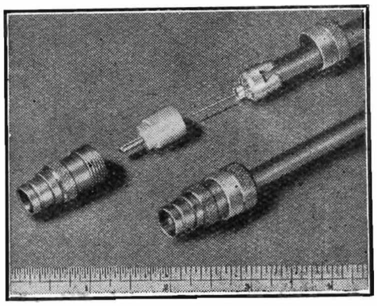
~~L642/P~~ ~~L632~~ ~~L727~~ = L734/P One new coaxial plug to fit all "Belling-Lee" coaxial sockets, termination boxes and cables.





LIST NUMBERS
L734/P

Other plugs and sockets available.

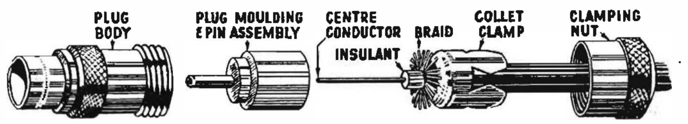
- L604/S Chassis socket.
- L614 Right angle plug.
- L615 Twin right angle.
- L616 Line coupling.
- L617 Through chassis connection.

This newly developed coaxial plug replaces three others. It accepts coaxial cables of outside diameters from $\frac{5}{16}$" semi-air-spaced to $\frac{5}{32}$" solid, thus providing for 50 ohm impedance feeders. It contains fewer piece parts, and is easier to load than any other good quality coaxial plug.

Conforms with the draft R.E:C.M.F. specification for television inlets.

The outer body being turned from solid is robust, the pin being slightly recessed for protection. The lead may be soldered before assembly thus facilitating cleaning, etc. P.V.C. outer cable cover is securely gripped.

METHOD OF LOADING



1. Trim feeder by removing 1" outer cover, $\frac{3}{4}$" of braid and $\frac{7}{8}$" of insulant
2. Slide clamping nut and collet onto feeder and splay the braid.
3. Push centre conductor, as far as possible, through plug pin and bend sharply for soldering. Solder and trim.
4. Slide collet up to splayed ends of braid and trim braid flush with plug moulding, using knife against collet.
5. Push assembly home into plug so that collet enters it, screw nut on firmly to grip feeder. The plug pin must be firm.
6. (See No. 2). In the case of feeder larger than $\frac{1}{4}$" diameter over cover, the circular hole in the collet clamp goes over the braid only.

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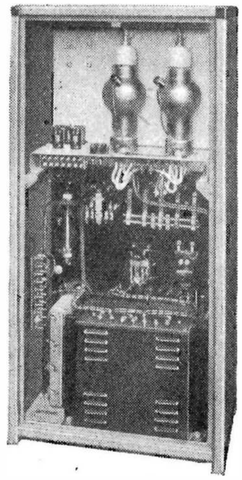
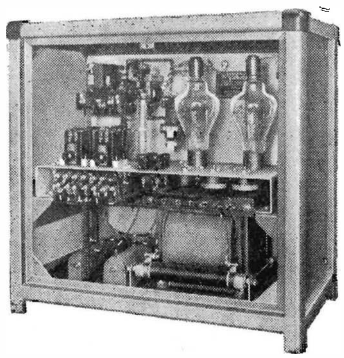
MAGNETIC AMPLIFIER/THYRATRON CONTROL SCHEME



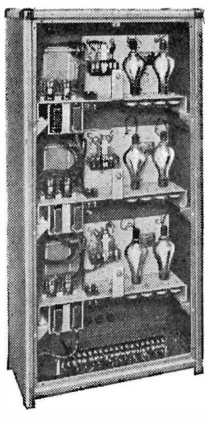
This latest Metrovick contribution to electronic engineering has been developed to give control facilities not easily provided by non-electronic means, but with minimum consumable components for maximum reliability, adequate performance for a variety of industrial applications and adaptability for automatic control requirements.

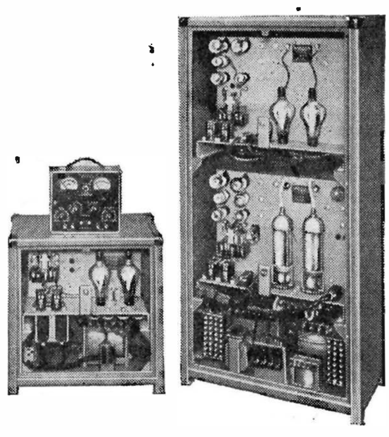


Fully electronic apparatus is also available where extremes of performance are required at the expense of increasing the number of valves required.

The illustrations show typical examples as used in machine tool, printing, plastic and rubber industries, where the ease, range and accuracy of control obtained have proved highly satisfactory.

Write for descriptive leaflets Nos. 98/1-1 and 98/2-1 which give further details of speed and torque control systems.





METROPOLITAN-VICKERS ELECTRICAL CO. LIMITED, TRAFFORD PARK, MANCHESTER 17

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METROVICK *for simplification in electronics*

H/A 102

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"DUREX" Magnetic Recording TAPE
FOR HIGH-FIDELITY RECORDING
1/4 x 1200 Ft.
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FOR ALL TYPES OF RECORDING, INCLUDING HIGH-FIDELITY RECORDING AND FOR SCIENTIFIC MEASURING TECHNIQUE
★ DUREX Magnetic Recording Tape is a medium-coercivity tape on a plastic base and is generally supplied in the form of 1200 ft. reels of standard width. . . . Other lengths, however, such as 1000 m. on Professional Spools, or 600 ft., can be provided. It is a tape of high sensitivity with a uniformity within ± 0.5 db throughout a reel.
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Electronic Engineering

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and SHORT WAVE WORLD

Managing Editor, H. G. Foster, M.Sc., M.I.E.E.

Vol. XXIII **MARCH 1951** No. 277

In This Issue

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Telegrams 'LECTRONING, ESTRAND, LONDON'

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Classified Advertisements, Page 1.
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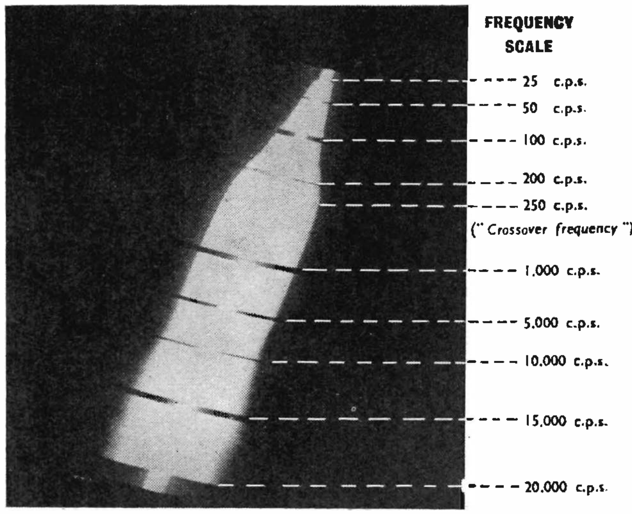

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DOMESTIC RECORDING EQUIPMENT DIVISION

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Electronic Engineering

Vol. XXIII. **MARCH 1951** No. 277.

Commentary

UNQUESTIONABLY, the outstanding event of recent weeks has been the publication of the long awaited Report of the Broadcasting Committee 1949 under the chairmanship of Lord Beveridge. This Committee, set up in 1949 jointly by the Lord President of the Council and the Postmaster General, was asked "to consider the constitution, control, finance and other general aspects of the sound and television broadcasting services of the United Kingdom (excluding those aspects of the overseas services for which the B.B.C. are responsible) and to advise on the conditions under which these services and wire broadcasting should be conducted after December 31 1951."

With such wide terms of reference it is not surprising therefore that the Committee's Report should be a massive document of some 320 pages supported by an appendix of another 580 pages containing memoranda submitted to the Committee.

The Committee held its first meeting on June 24 1949 and, in all, 62 meetings of the full Committee were held in private besides interviews and inquiries by sub-committees or by individual members on behalf of the Committee. After examining some two million words of evidence they "feel justified in saying that the achievement of broadcasting in Britain is something of which any country might be proud." They recommend, as most of us expected, that except for what are relatively minor modifications, the new Charter of the B.B.C. shall continue on existing lines, and after a detailed examination of the Report we are inclined to agree.

Apart from memoranda submitted by various Government Departments and B.B.C. advisory committees, much of the evidence comes from those sections of the community classified as "Disinterested Outsiders", "Minorities with a Message" and "Outside Interests" and with broadcasting and television entering so much into our daily lives it was obvious that "the brute force of monopoly" of the B.B.C. would be hotly attacked.

In the main, the criticisms are aimed at those highly controversial matters such as sponsored programmes, Regional autonomy, lack of impartiality and so on; and on all these matters we refrain from lengthy comment merely on the ground that they are non-technical and therefore outside our scope.

It is true that the B.B.C. has become overcentralized in London and that in consequence, Regional interests and outlook have suffered; but the Committee is not unaware of this and proposes measures for devolution. We remain unimpressed by the evidence in support of sponsored programmes and we are convinced that in spite of its many shortcomings there is no real alternative to the monopoly of the B.B.C.

One of the most pressing technical problems with which the B.B.C. is faced arises from the present congestion of the long and medium wavebands. It has been appreciated for some time that considerable areas of the United Kingdom, notably North and West Scotland, the Border Country and a large part of Wales, are still without what the B.B.C. considers a satisfactory service and the re-allocation of transmitting powers and wavelengths under the Copenhagen Plan, which came into operation last March, provided no real solution. Indeed, in many areas conditions have actually deteriorated as a direct result of this Plan.

How important the B.B.C. considers it to provide a more satisfactory service may be judged from an actual passage in the Report itself, which states that "If we were forced to the choice, we would say that it was more important that isolated schools and villages in the country districts of Wales, Scotland or of England should be able to get good reception of sound broadcasts than that urban populations already amply provided with sound broadcasting should at once get television as well."

Under the Copenhagen Plan the B.B.C was given the exclusive use of one long and two medium wavelengths, together with a further eleven medium wavelengths, which it shared with other European countries. With these wavelengths the B.B.C. estimated that in the last quarter of 1950 the Light Programme was available to 98.5 per cent of the total population at a reasonably good standard of reception by day and by night, while the Third Programme was similarly available to 68 per cent. It was also estimated that 85 per cent of the population could receive their own Regional Programme and 92 per cent any Regional Programme.

These figures by themselves, however, do not tell the full story and they should be studied in conjunction with those provided by Listener Research, who show that at any given time, 63 per cent listen to the Light Programme, 36 per cent to the Home Service and only one per cent to the Third Programme.

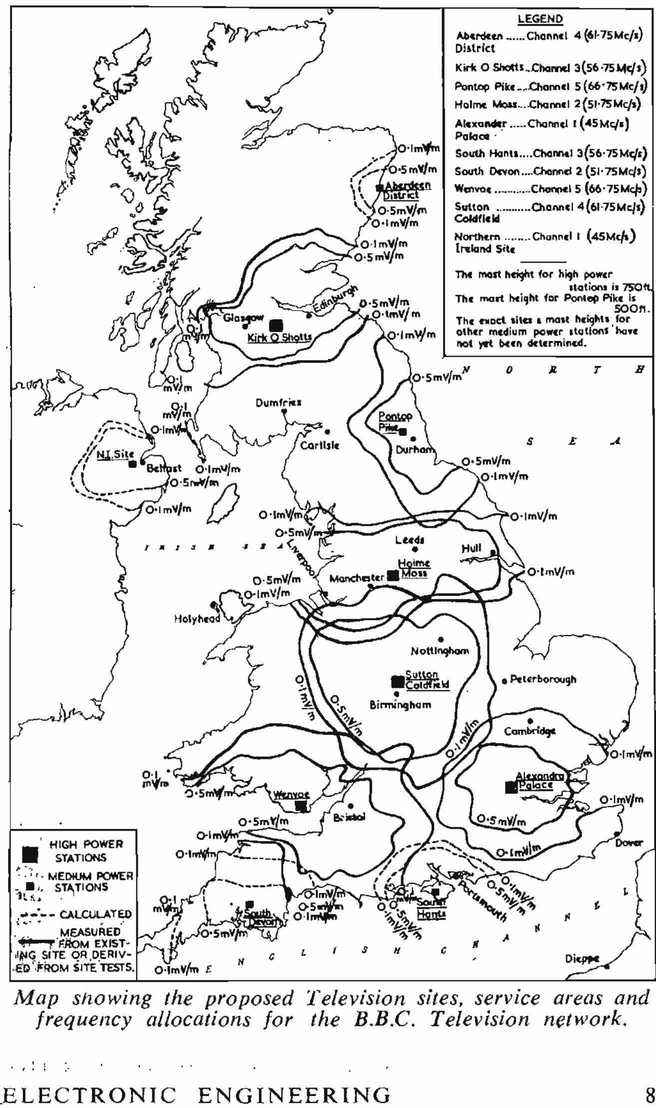
One may therefore be tempted to jump to the conclusion that the Third Programme should be abandoned entirely, in spite of its high cultural appeal, and so free for other purposes the B.B.C.'s two shared channels on which this programme is radiated. This might make available the Third Programme transmitters during the daytime for broadcasts to schools, but in our opinion no amount of juggling with the programmes and the wavelengths will provide the solution.

Nor do we think the answer is contained in the suggestion that the Relay Services should take over these areas of poor service.

If the B.B.C. is to remain a complete monopoly in the dissemination of programmes, then it must set out to give complete coverage over the whole of the United Kingdom by the best methods it has at its disposal. The Post Office is an example of an established monopoly and nobody suggests that their postal and telephone services should be confined to the larger cities, leaving say the Outer Hebrides to private enterprise. That private enterprise if it took over the monopoly completely, might provide a better and cheaper service is, in this case, beside the point.

In our view, the only solution is that suggested by the Committee which recommends "the developing of V.H.F. broadcasting with a view both to better coverage of the whole country and to increasing the possibility of local stations." It is apparent from the Report that the Committee has given considerable thought to the scheme for V.H.F. development now in preparation by the B.B.C., and we may look forward to the not-too-distant future when the transmitter at Wrotham is operating on a regular schedule.

As some of our readers already know, the Engineering Research Department of the B.B.C. began a series of tests immediately after the war. These tests, although lengthy, did not settle the question which of the two systems of modulation—A.M. and F.M.—would provide the better service, nor did they indicate what range of high-quality service could be provided by a high power transmitter.



Map showing the proposed Television sites, service areas and frequency allocations for the B.B.C. Television network.

With these objects in view, the B.B.C. embarked on the erection of the Wrotham station. From this station regular experimental transmissions are now taking place, the two transmitters radiating the same programme, one using A.M. and the other F.M.

We have had several opportunities of listening to the F.M. transmissions with a receiver and loudspeaker designed for such reception and we are struck by the remarkable improvement in quality over normal broadcasting. The difference is so outstanding that we cannot appreciate the statement by the Post Office in their evidence to the Committee which suggests that the higher fidelity is not of great practical importance, and doubts whether even a listener with exceptional musical qualifications could detect the resulting improvement.

Almost universal support has been given to the Committee for the V.H.F. project, although the reasons given by the various bodies spring from a variety of causes. The Regional Advisory Councils in their evidence all complain that while it may be necessary for the administrative headquarters of the B.B.C. to be centred in London, there is far too much central planning of programmes with consequent loss of cultural life in the Regions, and in the proposed V.H.F. scheme they see the answer to their plea for more regional autonomy.

There are, in fact, two schools of thought regarding the best method of V.H.F. coverage. One favours a relatively few high power transmitters suitably sited and intended to cover the country as a whole and possibly in the future to take the place of existing medium and long wave network; the other prefers a number of low power stations serving local centres of population, particularly where there are keen cultural and artistic activities.

The B.B.C. has already incorporated V.H.F. aerials on the television mast at Sutton Coldfield, and is doing so at Holme Moss, Kirk O' Shotts and Wenvoe. One would judge from this at any rate that the B.B.C. does not favour the prospect of the "parish pump" type of radio network, but intends to proceed with the high power transmitter scheme which would presumably give a somewhat similar area coverage to the television network.

At the present moment there is no suggestion of congestion in the V.H.F. bands, and the Post Office, which is the ultimate authority as regards frequency allocation and the granting of licences, suggests that V.H.F. sound broadcasting could be accommodated in the 88-95 Mc/s band: but there are already a number of competing claims from other services such as air navigation, police and radio telephone links. We dealt at some length in the August 1950 issue of ELECTRONIC ENGINEERING with the application of V.H.F. to these services, and elsewhere an article in the present issue describes the extent to which the Ministry of Civil Aviation is employing V.H.F. for air control purposes.

Television, too, has had its critics and a considerable portion of the Report is devoted to how this lusty young infant should be brought up, but on the purely technical side there is little on which we can comment.

The activities of the B.B.C.'s Research Department are summarized in a succinct manner in the Report which states that the objects are to determine:—

(a) The most desirable standards for television, in relation to the technical and economic factors involved.

(b) The most efficient means of covering the country within the limits of the waveband at present available.

(c) Possible means of extending coverage by the use of wavebands not yet brought into service.

(d) The conditions in which it might be possible to introduce a higher definition in monochrome, or colour.

These problems are obviously interconnected, and with regard to the first it appears that the present 405 line system is their solution and that the appropriate time for change will be when a proved colour system has been evolved and possible new wavebands brought into use.

ELECTROMECHANICAL REGISTERS
as used in
Radioactive Counting Systems

By A. E. Bennett, B.Sc. *

The use of electromechanical registers (counters) in electronic scaling units is discussed and the requirements which an ideal register must fulfil are outlined. Development work has been undertaken, three designs being described in detail. An outline is given of probable future developments.

In many branches of atomic physics and radiochemistry it is necessary to measure the amount of radiation which is being emitted by a radio-active element. This measurement takes the form of counting the number of particles or photons that emanate from the element within a given time. A typical counting system is shown in Fig. 1. It comprises a radiation detector, a counting or scaling circuit, and an electromechanical counter. (The electromechanical counter will be referred to as a " register ', to avoid any confusion with a Geiger Muller Counter). The detector may be either an ionization chamber, a Geiger Muller counter, or a scintillation counter. In all cases its function is to produce a voltage impulse each time a photon or particle passes through it. Since the rate of arrival of

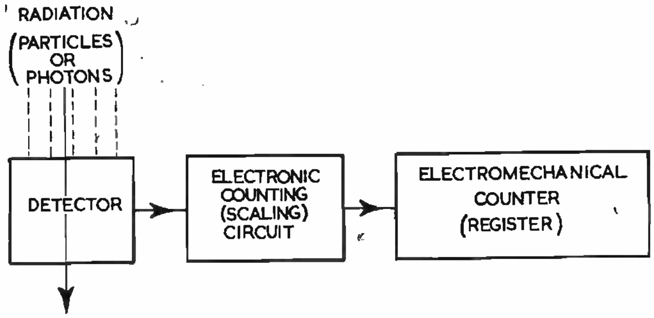


Fig. 1. Typical radioactive counting system

particles at the detector may be as high as 60,000 per minute, it is often impossible to feed these output pulses into any form of register. Consequently, a scaling circuit capable of high speed operation is interposed between the detector and the register. This reduces the mean rate of pulses at the input of the register to a figure which is within the capability of that unit.

In a counting system such as this the various component parts have finite resolving times, i.e., after they have been actuated a certain recovery time must elapse before they are able to respond to another pulse. Also since the photons or particles are randomly distributed in time, a certain fraction will arrive during the insensitive periods, and in consequence will not be counted. A number of theoretical papers[1,2,3], have been written which explain in detail the relationship between the maximum counting rate (for a specific counting loss), and the characteristics of the component parts of the counting system. In all counting experiments careful consideration must be given to these factors in order that the unavoidable losses may be kept within prescribed limits.

It is known that the resolving times of some detectors (ionization chamber, scintillation counter) are comparable to or less than that of the input stage of an electronic counting unit, and in general these two times must be taken together. If N_0 is the actual or true counting rate and τ is the combined resolving time, the maximum rate at which particles will be recorded N_t is given approximately by $N_t = N_0 (1 - \tau)$. The value of τ for a good scaling circuit may be as low as 1 microsecond or less and consequently it will be able to count at quite high rates with small losses. On the other hand, it has been shown that the counting losses due to the register depend not only on the resolving time of the register, but also on the scaling factor of the preceding electronic stages. This is well illustrated by Figs. 2 and 3, which have been taken from a paper by Blackman and Michiels.[1] Fig. 2 shows how the maximum counting rate (for a 0.1 per cent loss) depends on the scaling factor, and the resolution time of the register. Fig. 3 shows how the counting losses vary with the average rate of entry of particles into the detector, and the scaling factor, in the case of a register with an effective resolution time of 1/10th second. These curves show that if a system with such a register has to handle a range of counting rates which may go up to 40,000 or 60,000 per minute, then it is necessary to precede the register with at least a scale of 100.

When a counting system is being designed it is customary to include the register in the electronic scaler, the whole system being referred to as a scaling unit. Since most registers are considerably smaller and cheaper than the equivalent number of electronic stages, an ideal unit should

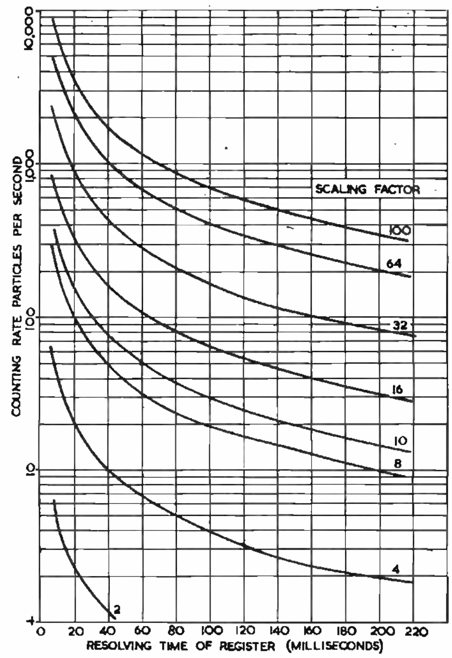


Fig. 2. Graph showing counting rate/resolving time of register.

* *A.E.R.E., Harwell.*

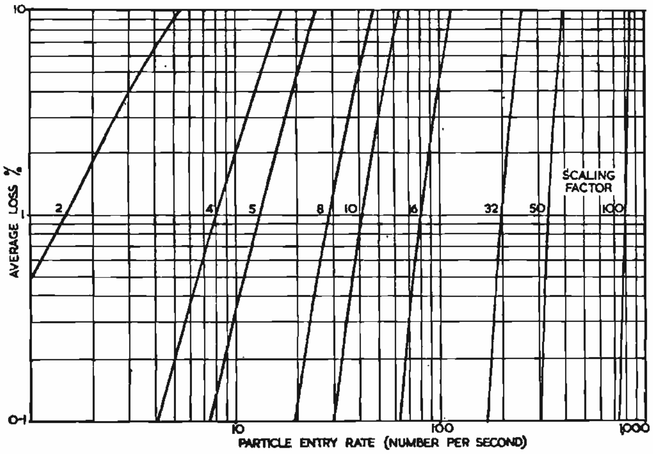


Fig. 3. Graph showing average loss/counting rate of particles

comprise a minimum number of electronic stages, followed by a compact reliable register, capable of the highest possible counting speeds and long life. However, before a decision can be reached on the number of electronic stages to be included in a scaling unit, careful consideration must be given to the losses introduced by the relatively slow speed register, power consumption, presentation of display, reliability of components, life of the register and the cost. With these points in mind a detailed study has been made of numerous existing types of registers, and as a result of the survey several new types have been designed and tested.

Observations on Existing Registers

When the first scaling unit was designed at A.E.R.E. it was essential to use the most readily available register. Because of this, and the fact that it was both small and cheap, the Post Office telephone call meter was chosen.

The P.O. telephone call meter is a four digit, non-resettable register with a small face area requiring an operating current of 15 milliamps (0.5 watt), and as its name implies it was originally designed to record the number of calls made by a telephone subscriber. The test specification only calls for a register to be operated 300,000 times at a rate of 30 counts per minute (a speed far in excess of its normal operating speed): each register should be capable of operating 75,000 times without a failure and the total registration failures in the complete test should not be greater than 5. In its scaling unit application it may be used at speeds of at least 8 counts per second, and in fact it has been known to count as high as 15-20 per second after suitable adjustment. Consequently it cannot be reasonably expected to have a very long life. Tests made on a large number of registers have shown that when they are operated at a speed of 4 impulses per second they can be relied upon to count consistently up to approximately 300,000-500,000 counts (2-3 weeks life). Beyond this figure they begin to lose occasional counts, this loss steadily increases until finally the register develops a major mechanical fault. This loss of an occasional count is a very insidious fault which may remain undetected for a considerable time, and can of course give rise to endless reading errors.

The only method of detecting this type of fault is to make an independent check on the counting rate, i.e., use two or more registers in parallel.

Another disadvantage of the P.O. call meter is that it cannot be reset to zero. This may appear on first sight to be trivial, and indeed may not prove a disadvantage to the individual research worker, but it is well known that when one is dealing with a large number of results, considerable errors may be introduced through incorrect subtraction of register readings.

These tests also showed that a number of registers did have reliable lives of several million operations, but a good register could only be identified by testing it to destruction in conjunction with a number of other registers. Consequently, it is not safe to assume that any register has a life longer than 300,000-500,000 operations.

Subsequent to this series of tests several commercial registers (including both low and high speed models) were examined and life tested, and it was found that although most of them were satisfactory in the application for which they had been originally designed, none was ideally suitable for use in a scaling unit, since they had inherent disadvantages such as short life, unreliability, high power consumption and in addition they would not be reset.

As a satisfactory commercial register was not available, a programme of work was initiated with the object of developing one. It was known that several laboratories had built high-speed registers for particular applications, and that speeds between 200 and 2,000 counts per second[4] had been achieved. A number of these designs were investigated, one or two to the extent of actually building and testing models. However, it was found that these speeds were obtained by virtue of the fact that the registers were small and delicate instruments, and it was felt that they could not be used for general purpose counting where they would be handled by operators who were not instrument makers.

This method of approach was therefore abandoned, and effort was concentrated on building several completely new designs.

New Developments

High Speed Impulse Motor

The first model which showed any success was developed around a new type of Impulse Motor.* This was an unorthodox type of motor in which the actuating member gyrated instead of rotated. It was originally designed to produce high torque at low speeds. A sectional view of the motor (B.T.M. Type) is shown in Fig. 4. It was built in the form of a cylindrical shell $1\frac{1}{4}$ in. in diameter by 3 in. long, divided into two equal parts by a thin metal diaphragm. Each half was provided with a field coil assembly very similar to that of a conventional two-pole motor, but the two sets of poles were arranged at 90° to each other, thus virtually making a four-pole motor.

Instead of a normal rotor assembly the diaphragm carried a hollow steel shaft, of such a length that the

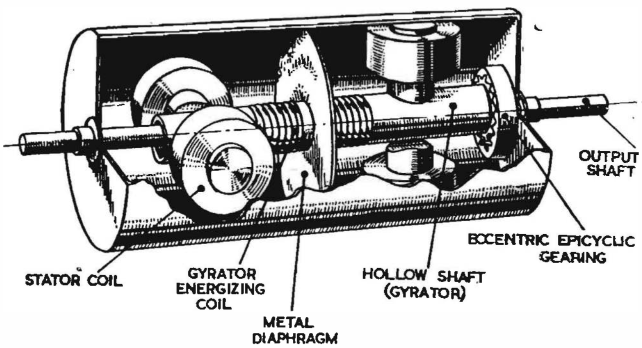


Fig. 4. Exploded view of impulse motor

ends of the tube lay between the respective stator poles. This hollow shaft was magnetically polarized by an energizing coil wound on either side of the diaphragm, and as the stator coils were energized in sequence so the ends of the shaft were attracted to the four stator poles in turn.

One end of this shaft was fitted with a 99-toothed gear which moved inside an internally cut 100-toothed gear. The latter gear was mounted on the output shaft of the

* Manufactured by Scophony Ltd.

motor, which passed through the hollow tube, having a bearing at each end of the cylindrical case.

When the stator coils were energized in sequence, the ends of the hollow shaft were attracted to the 4-stator poles in turn, and the 99-toothed gear traced a circular path within the 100-toothed gear, (gyrating instead of rotating). These two gears gave a single stage of eccentric epicyclic gearing, and further, since the 99-toothed gear could not rotate, the 100-toothed gear (mounted on the output shaft) was compelled to roll round the inner gear, and in fact one gyration of the hollow shaft resulted in the output shaft rotating 1/100th of a revolution.

The application of impulses to the stator coils thus produced incremental movements of the motor shaft, which could be used to drive a suitable indicator such as a revolution counter. Various methods were devised for impulsing the stator coils in turn; in one scheme the four stator coils were made part of the anode load of a four-valve ring circuit, which was driven by the incoming pulses. With this arrangement the register counted at speeds up to 1,300 impulses per second, but it was quite difficult to read, since one revolution of the output shaft was equivalent to 400 counts. A similar method of driving this motor has been described by K. J. Brimley,[5] who has incorporated it in an "Electronic Stop-watch" to count the number of cycles of a standard oscillator occurring within an unknown interval of time. To overcome this reading disadvantage the four stator coils were made the inductance arms of π or T section delay networks, so that as an impulse passed down the system it energized the four coils in turn, and consequently moved the output shaft 1/100th of a revolution. With this circuit it was possible to obtain counting speeds up to 300 pulses per second, but it was soon apparent that there were several serious limitations which would prevent this device from being generally used as an impulse counter. These included such limitations as the inherent bias of the metal diaphragm, which varied in magnitude and direction from motor to motor, the high operating current of the stator coils, and the need for the energizing coil on the gyratory shaft. Furthermore, as the number of components in the driving circuits was steadily increasing it would have been more economical to arrange them in the form of a decade of electronic scaling, followed by a slower speed register.

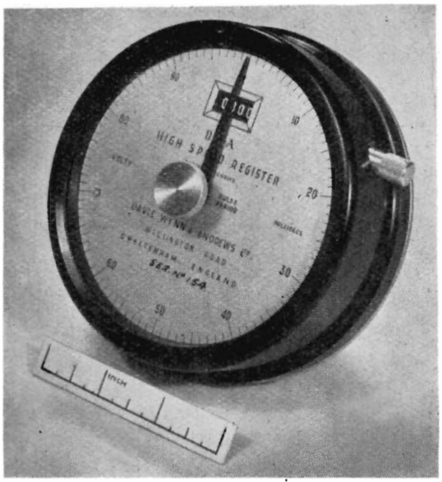


Fig. 5. High-speed escapement register

Consequently it was decided not to continue with any further work on very high speed registers, but to concentrate on developing a register with a maximum speed of 50-100 counts per second. It will be observed from Fig. 2 that the counting losses introduced by such a register when operating with a scale of 10 would be less than 0.1 per cent for entry rates below (9,000-18,000) counts per minute respectively, and similarly for a scale of 100 the limiting rates would be (216,000-426,000) counts per minute. A combination of scaler and register such as this would be satisfactory for most counting experiments.

High Speed Escapement Register

In this model † (Fig. 5) the units and tens digits are indicated by a pointer moving round a 100-position dial while a further 4 digits appear on a small resettable drum type register.

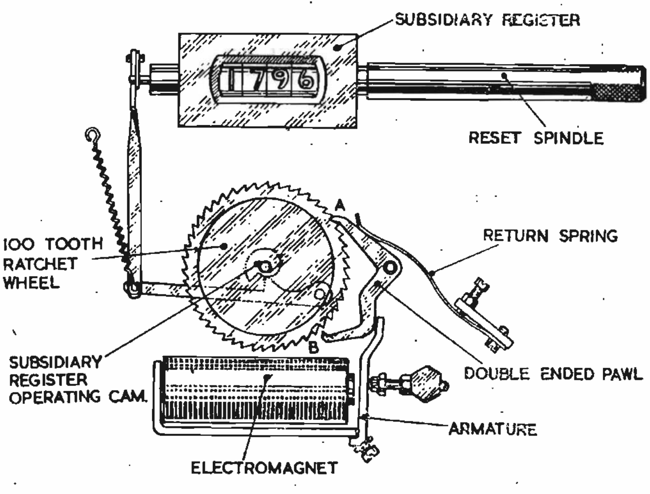
The register uses a novel driving mechanism which is in effect an inverse escapement. This type of movement entirely eliminates the need for adjustable pawls and stops, and thereby reduces mechanical adjustments to a minimum. In fact no provision is made for any further adjustments after the register has been assembled and tested by the manufacturer.

The inverse escapement comprises a double ended pawl, which when rocked by an electromagnet drives a 100-toothed ratchet wheel forward tooth by tooth. One end of this pawl (*A*) Fig. 6 is normally held in engagement with the ratchet wheel by a spring. When the electromagnet is energized this end (*A*) is lifted clear of the teeth, and simultaneously the other end of the pawl (*B*) engages the ratchet wheel and moves it round by half a tooth pitch. On releasing the electromagnet, the return spring forces the pawl back to its normal position, and in doing so, the end (*A*) moves the ratchet wheel forward again by a further half tooth, giving a total movement of one tooth.

The teeth of the ratchet wheel and the ends of the pawl are so shaped that the pawl acts as a catch in addition to its normal function of driving the ratchet, and thus it prevents any over-shoot. It is, however, possible to rotate the ratchet wheel by hand in the reverse direction; this enables the register to be reset to its zero position.

The shaft of the ratchet wheel is extended to carry a pointer which moves over a scale calibrated 0-99. It also carries a cam which controls the movement of the four-digit drum type register in such a way that this subsidiary register records one impulse as the pointer moves from 99 to 0.

Fig. 6. Schematic of escapement register



This discrete movement of the subsidiary register is a great improvement on the continuous gear train (Gas Meter type of display) which is used in several American models, since it eliminates the possibility of taking an ambiguous reading.

† The production version of this register is being made available as a commercial article by Davis, Wynn and Andrews Ltd., Cheltenham.

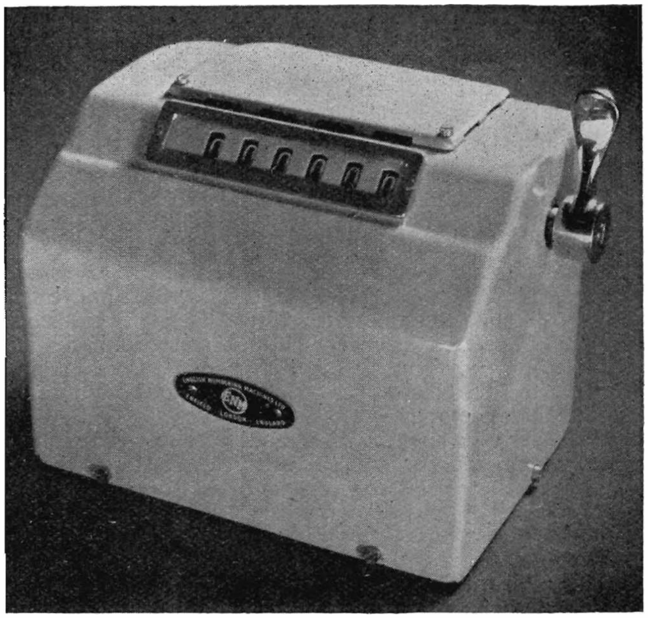


Fig. 7. Motor-driven register (outside view)

The "carry" mechanism for the drum type register imposes a considerable load on the register, and consequently it has been found necessary to design a low impedance magnet coil (100 ohm). The nominal operating voltage is 50 volts D.C., but the maximum permissible wattage dissipation of the coil is exceeded if it is left permanently energized, so it is essential that the length of the operating pulse be kept to a minimum. Tests have shown that this model has a maximum counting speed of 70 impulses per second (operating voltage 200-300 volts) when operating on a minimum pulse width of 8 milliseconds. At this counting rate the mean current consumption is approximately 100 milliamps.

Life tests have been carried out—the registers showed no signs of wear after operating 10^8 times at a rate of 50 per second. Comparative tests of the accuracy of counting gave good results, agreement being within 0.01 per cent, and although it has not yet been definitely established, it was felt that these errors were due to faulty operation of the subsidiary register.

The register has been designed to mount on any standard panel, its overall dimensions being 5 inches in diameter by 2 inches deep.

Various driving circuits have been designed to overcome the need for a large 50 volt D.C. supply; e.g., the register has operated in the anodes of thyratrons and pentodes, and in such circuits it was possible to increase the maximum speed up to 100 impulses per second. A novel circuit has been designed which enables the register to be operated from the charge held on a capacitor. Each incoming pulse triggers a Ferranti "Neostron" tube (this is a cold cathode discharge valve capable of handling large momentary currents) which in turn instantaneously charges a capacitor. The capacitor then discharges into the register, which is connected in parallel, and the register operates. With this circuit the large D.C. power unit is replaced by a relatively small H.T. supply, and further, the register is made more flexible because it can be operated from either a voltage pulse, or from the closure of a relay contact. It is important to note that this contact has only to be capable of carrying a few milliamps of current, since the large current required by the register is handled by the capacitor and the Neostron tube. Extensive tests have proved this method of operation to be both accurate and reliable.

Motor Driven Register *

This register (Figs. 7 and 8) has been developed around a conventional revolution counter, such as is used in all coil winding machines, because it was well known that this type of register was extremely reliable when run at speeds equivalent to 50 steps a second, i.e., 300 revolutions per minute.

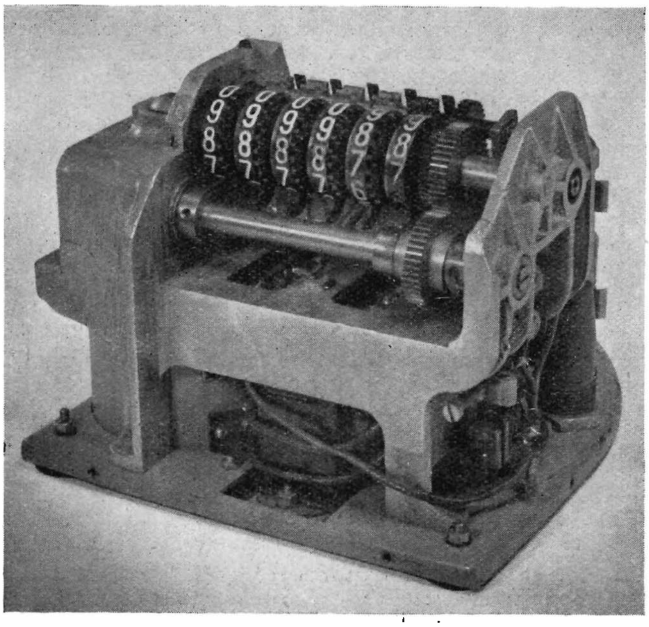
Some thought was given to the possibility of designing a magnet system which would be capable of starting and stopping a revolution counter at this speed. It was soon evident, however, that to obtain high reliability it would require large moving parts to handle the relatively high inertias of the counter. This would have resulted in a large, noisy and inefficient drive.

The difficulty was overcome by designing a novel high speed clutch which, when energized, couples a continuously running motor to the revolution counter, and remains operated until the register has moved through 1/10th of a revolution, i.e., recorded one digit.

The clutch (Fig. 9) is very simple in construction, being nothing more than a four-coil helical spring wound onto a shaft driven by the motor. One end of this spring is attached to the clutch housing, which in turn is coupled by an idler gear to the revolution counter. The other end of the spring is attached to a very shallow 10-toothed ratchet wheel, which runs concentrically on the driving shaft. The ratchet is held in position by the tip of a light electromechanical latch (a modified Siemens high-speed relay). When this latch is operated, the ratchet (and the spring) is free to move; friction between the spring and the shaft then causes the spring to coil itself on the shaft, instead of slipping over it. As the load increases the spring grips tighter and tighter, until it actually rotates with the shaft, thus establishing a positive drive to the revolution counter. The driving circuit is such that the latch is released immediately the ratchet tooth has passed beneath its tip, so that it is immediately ready to arrest the next tooth on the ratchet wheel. When this occurs the end of the spring which is fastened to the ratchet wheel is arrested, but, as the driving shaft continues to rotate, the other end of the spring rotates as well, and in doing so unwinds the spring until it just slips on the shaft, and consequently disconnects the drive to the

* United Kingdom Application No. 289/48. This register is being made available commercially by English Numbering Machines Ltd.

Fig. 8. Motor-driven register (inside view)



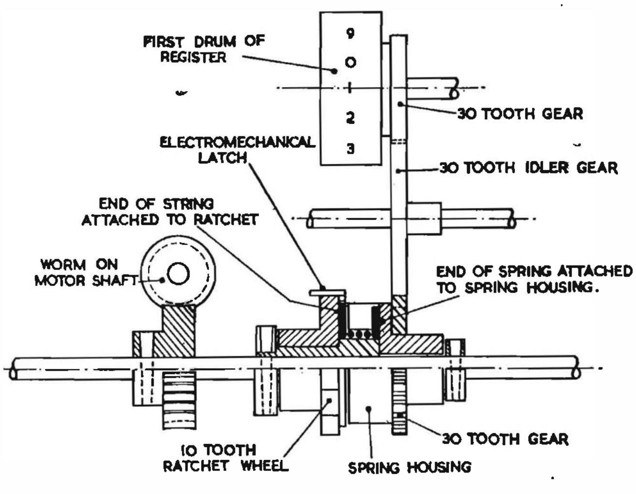
revolution counter. The spring then continues to slip on the shaft as long as the latch magnet holds the ratchet wheel.

The instrument has been designed as an entirely self-contained unit operating from the 230 volt A.C. mains (power dissipation 25 watts). It incorporates a 230 volt A.C. hysteresis motor, and also a very small power pack which provides the necessary D.C. voltage to operate the latch magnet. The register records an impulse each time the input leads are short circuited. It is made independent of the length of the input pulse by a clipping circuit (within the unit) which ensures that the electromagnetic latch is only energized long enough to allow *one* ratchet tooth to pass the tip of the latch. It will not respond to a pulse of less than six milliseconds. The maximum counting speed is limited by the speed of the driving motor and the gear train to approximately 60 counts per second.

The model is fitted with six counting wheels, i.e., it will record up to 999,999 impulses, and it may be reset to zero by depressing a single lever. In its present form it is intended for bench use, the overall size being approximately 6 in. cube.

Several models have been tested for periods of 1,000 hours and more, at a rate of 20 impulses per second, and have proved to be both accurate and reliable, the total error for this extended period being less than 1 per cent. No appreciable wear has been detected on either the spring or the associated driving shaft. No trouble was experienced with the revolution counter since it was specially chosen to give a long life at high speeds, the units drum and carry pinions being made of hardened steel.

Fig. 9. Schematic of motor-driven clutch mechanism



Future Developments

The advent of a new cold cathode decade counting tube (announced by Messrs. Ericssons, S. T. and C. Ltd., and Remington Rand Ltd.), has made it possible to design an extremely simple electronic register which may replace the electromechanical register in many applications. These valves (Dekatrons)[6] are gas filled tubes which have ten stable glow positions. The discharge moves from position to position as impulses are fed into the valve, and by a special arrangement of the electrodes an output signal is given as the glow passes from the 9 to the 0 position. Another useful facility is that the Dekatrons may be easily reset to their zero positions. One small difficulty is that the output signal is not large enough to impulse another Dekatron; but it has been found possible to use a triggered neon (G240/2D) as a buffer valve between successive scaling tubes.

An experimental register has been built with these valves and found to be capable of counting at rates up to 400 counts per second. This model is built on a standard 3-in. Post Office panel, the valves being mounted on the panel so as to facilitate viewing the position of the glow. The unit occupies considerably more space than either of the two registers previously described, because it is necessary to provide a stabilized H.T. power supply, but the current consumption is very small, being only 2-3 milliamps. However, if a scaling unit was designed to incorporate only one decade of hard valve scaling followed by a number of Dekatrons it would be satisfactory for a large number of applications; and its overall size might be slightly less than an existing scaling unit, since there would be a reduction in the size of the power pack, and the Dekatrons would be mounted on the front panel instead of the chassis.

There is still a requirement for a small resettable electro-mechanical register when it is necessary to mount a large number of units together, e.g., in a pulse amplitude analyser. An experimental model has recently been produced which will meet this specification. This new register is almost identical with the Post Office call meter, having the same frame and magnet system. The final models will have number wheels similar to the Post Office register, but the total face area will be increased by approximately 10-20 per cent to accommodate the reset mechanism.

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Bristol Channel Television Transmitting Station

AFTER negotiations for a site for the high-power television transmitting station to serve the Bristol Channel area, the B.B.C. has now agreed to buy land on St. Lythan's Downs, near Wenvoe, about five miles to the west of Cardiff. This site has been approved by the Postmaster General, and the station will be known as the Wenvoe Television Transmitting Station.

The Wenvoe site is 400 ft. above sea-level and covers an area of about 25 acres near the Cardiff-Swansea road. On it will be constructed a building for the transmitters, a sub-station, and a 750-ft. mast similar to the one at Sutton Coldfield. The contract for the mast has been placed with British Insulated Callenders Construction Co., Ltd., and for the buildings with Gee, Walker & Slater, Ltd.

The vision and sound transmitters were ordered in January 1950. The vision transmitter, which is being designed and manufactured by Electric and Musical Industries, Ltd., is to have a power of 50 kilowatts, and the sound transmitter, which Standard Telephones and Cables, Ltd., are making, will have a power of 12 kilowatts. A novel feature of the vision transmitter is that the carrier wave will be modulated by the vision signal in a low-power stage instead of in the output stage as has been customary in previous television transmitters.

It is expected that the boundary of the service area of the Wenvoe station will be that shown in the contour map published in the Beveridge Report which is reproduced on page 80. This area has a population of three and a half million, and among the principal towns within it are Tenby, Carmarthen, Llanelly, Swansea, Cardiff, Bristol, Bath, Dorchester and Taunton.

The Development of

V.H.F. AREA COVERAGE NETWORKS

for Civil Aviation Communication

By D. P. Taylor, M.B.E., A.M.I.E.E.*

PRIOR to the outbreak of the recent war, communication with civil aircraft was carried out exclusively on medium and high frequencies, although the limitations to the use of such frequencies from the point of view of congestion had already made themselves felt, particularly in cases where radio-telephony was used.

During the war years great strides were made with the development of V.H.F. radio-telephone equipment for communication with aircraft using frequencies of the order of 150 Mc/s, and after the end of hostilities it was obvious that use would have to be made of such frequencies to meet the greatly increased channel requirements for civil aviation. The frequency band 118 to 132 Mc/s was set aside by international agreement for this purpose.

Adequate stocks of surplus military airborne equipment capable of operating within this frequency range were available to bridge the gap until the radio industry could be switched from military to civil production. This phase is now ending, and the use of multi-channel equipment designed and produced to meet civil requirements is now widespread. A similar state of affairs prevailed in the case of ground V.H.F. equipment, although the most readily available transmitters were of somewhat higher power (50 watt) than was necessary or indeed desirable for short-range communication with aircraft in the vicinity of aerodromes. This problem was largely overcome by the improvisation of low-power transmitters from airborne equipment operated from 50 c/s power supplies.

It was at once obvious that, whereas the use of V.H.F. provided an excellent service for communication with aircraft approaching aerodromes, a need existed for communication with aircraft remote from aerodromes on an area basis. This requirement was essential for the exercise of Air Traffic Control in respect of "en route" aircraft. Such communication could at first only be provided by the continued use of M.F. and H.F.

Area Coverage

Investigations were therefore initiated with the object of devising area coverage using V.H.F., and thus, not only effecting an economy in the equipment carried by aircraft, but in addition taking advantage of the ample frequency spectrum available, the freedom from static, and the much simpler aircraft aerial systems.

The most promising line of attack seemed to be the use of a spaced-frequency multi-carrier V.H.F. system of the type used by the Home Office for communication with mobile police units. This system was first described by J. R. Brinkley,[1] but a brief description may not be out of place.

When it is required to effect V.H.F. communication over a large area in which mobile units are operating, a number of V.H.F. transmitter-receiver stations are sited at strategic points within the area and modulated from a common operating centre. By careful choice of sites the chances of a mobile unit being in a "shadow area" of all the transmitters can be reduced to a negligible value. The difficulties in setting up such a network are:

(a) If the transmitters are radiating on the same channel frequency then the carrier frequencies must be maintained in synchronism, if hetrodyne beats are to be avoided. Severe fading and distortion, can still occur due to changing phase differences between incoming signals at the mobile unit from the various transmitters, even if, by rigid frequency control such beats are reduced below the lower limit of audibility.

(b) If the transmitters radiate on different channel frequencies then the number of channels required increases enormously. Operational difficulties arise from the fact that the mobile units are required to explore the different channels to determine that most suitable for communication in any given place. Further, in practice, the relative levels of signal received on the various channels vary greatly over quite short distances traversed by the mobile unit. The difficulties of operating in this manner are obvious, particularly in the case of aircraft, where by reason of their speed, their rate of movement relative to the ground transmitters is very high.

The disadvantages of the two systems described can be overcome by operating the ground V.H.F. transmitters on slightly differing frequencies within the same channel, but sufficiently widely spaced to cause the resultant beat to be above the upper limit of audibility or to be greatly attenuated by the receiver audio-frequency response characteristic. At the same time the frequencies are sufficiently closely spaced so as to lie within the receiver R.F./I.F. passband. Such a network of transmitters simultaneously modulated can be used to "flood-light" a considerable area, and it is found in practice that the combination of the various signals in the mobile receiver produces an effect akin to diversity reception, with a marked reduction of fading or "flutter" when the mobile unit is in motion. Associated with each transmitter is a receiver and the outputs of these receivers are combined at the central control point.

The M.C.A. Area Coverage Scheme (1947)

Such a network of V.H.F. stations was set up by the Ministry of Civil Aviation in 1947 to determine the possibility of its use for communication with aircraft over the Southern part of England. The transmitter-receiver stations are located in Norfolk, Surrey, Kent and Gloucestershire, and connected by GPO land-lines to the Air Traffic Control Centre at Uxbridge. The sites adopted were located on existing MCA stations, rather than chosen for ideal topographical considerations. The transmitters used are standard Air Ministry type T1131B having a power

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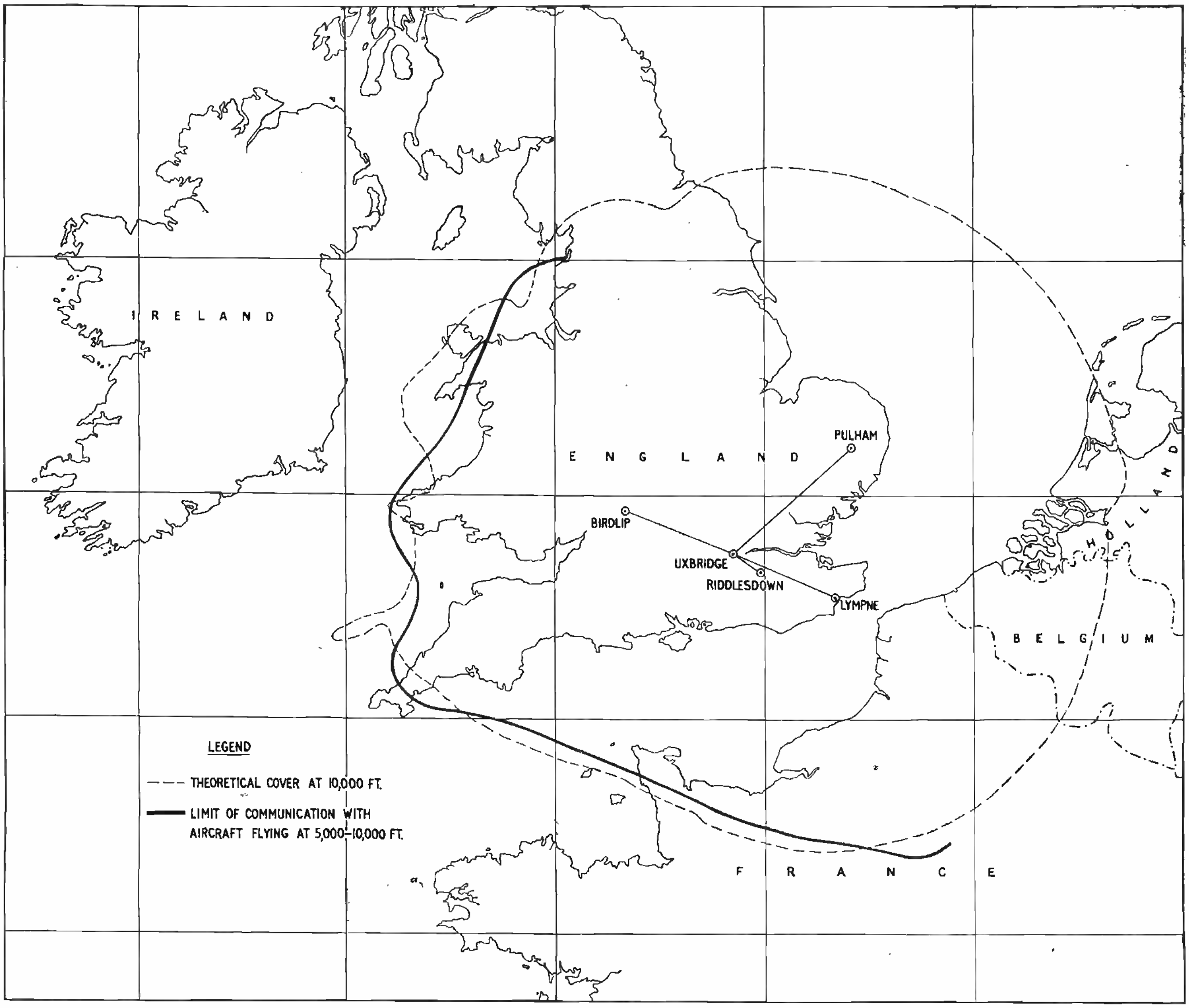

Fig. 1. Location of the stations and Air Control Centre for the MCA "Climax" V.H.F. area coverage network (1947)
The close relationship between the calculated average and practical results is clearly shown

output of somewhat less than 50 watts. The spacing of frequencies adopted was 15 kc/s between stations, that is the four transmitters are spread over 45 kc/s centred on the nominal channel frequency. These transmitters were originally designed for use with 10X type crystals having a frequency stability of about 0.01 per cent. Since this represents about plus or minus 12 kc/s at carrier frequency it was obvious that a considerable improvement was necessary if audible hetrodynes were to be avoided. An ovened crystal was substituted having a frequency stability of .005 per cent and although this was far from ideal, few complaints have been received. Standard crystal controlled A.M. receivers type R1392B are used throughout. Linking each transmitter-receiver station with the Air Traffic Control Centre are two GPO landlines, separate lines being used for transmission and reception. These lines have a frequency response of about 300 to 2,500 c/s within 3db, and the outgoing line from Uxbridge carries a D.C. switching circuit for the operation of the transmit-receive relays at the remote station.

The splitting of the out-going speech currents to the four transmitters and the combination of the incoming speech frequencies from the receivers is effected by means of transformers.

Fig. 1 is a map showing the layout of the stations of this network, together with the calculated coverage, this being based on "line of sight" modified for refraction. This calculated coverage agrees closely with results obtained in practice, there being also shown on Fig. 1 a contour within which consistently good communication has been maintained with aircraft flying at between 5,000 and 10,000 feet.

The network (which is known in the Civil Aviation world as "Climax") proved so effective that in June 1949 it was brought into operational service for certain approved users, and in July 1950 was made available to all users on a frequency of 126.7 Mc/s and has continued in operation since that date.

The success obtained with the early operation of "Climax" resulted in a decision to cover the United Kingdom with a series of such networks. In 1949, a plan was drawn up providing for three such networks, based on Air Traffic Control Centres at Uxbridge in Southern England, Preston in Northern England and Prestwick in Scotland. The location of the stations of those networks is shown at Fig. 2, and it will be seen that in the South five transmitter-receiver stations are used, in the North four, and in Scotland three. The calculated coverage from these stations is such as to cover the whole of the United

Kingdom with the exception of the extreme north of Scotland. Economic considerations, coupled with the difficult terrain, lead to the decision not to attempt coverage of this area, although the internal air routes within Scotland and to the Scottish Islands are served on a route basis by V.H.F. transmissions from aerodromes and other stations. Unlike the "Climax" network the new stations are sited with a view to obtaining optimum V.H.F. coverage, and in the case of the three Scottish stations and one in Northern England, the Ministry were fortunate in being able to make use of the excellent sites of the Scottish Gee Chain, all located at considerable heights above the surrounding country.

Reduction of Frequency Spacing

In planning the new networks, it was desired to embody certain operational and technical improvements on the "Climax" system. Firstly, it was considered that the frequency spacing of the stations should be reduced. This arose from the need to use more than three transmitting stations in the Southern England network, and partly by the need to avoid imposing limits on the selectivity of airborne receivers. To meet this requirement a Specification was prepared for a high-stability crystal-oscillator unit to drive the T1131B transmitters. This called for a stability of .0003 per cent representing plus and minus 500 cycles over a wide range of ambient temperatures and supply mains voltage. The design of this unit will be described in a subsequent article. This unit permits the individual transmitters to be spaced at 10 kc/s instead of 15 kc/s as hitherto. It is intended at an early date to conduct experiments with a view to even closer spacing.

The high order of stability achieved with the new crystal oscillator units would normally call for a very high-grade and expensive frequency-meter at each transmitter site for checking purposes. In view of the considerable cost involved, it was decided instead to provide each site with three crystal oscillator units for each frequency used, these being held as transmitter in use, transmitter spare, and general spare. All three units are maintained with ovens at working temperature so as to be available for immediate use. For checking purposes a hetrodyne detector and frequency meter is provided to measure the different frequencies between the three units.

Multi-channel Working

Secondly, it was realized that one channel was insufficient to meet the growing requirements of Air Traffic Control, particularly since the new system would still further reduce the use of M.F. and H.F. for area control. The new networks were therefore planned on a basis of four channels in Southern England, and two in Northern England and Scotland; although ultimate expansion beyond this was borne in mind when the equipment Specifications were drawn up. As will be described later this plan has been modified to meet changed operational requirements. The use of more than one channel led to a number of technical problems, which made further field tests necessary. These fall into two categories, those associated with common aerial working (it being very desirable from the point of view of reliability, installation and design, that a common aerial be used for all transmitters on a site and similarly another common aerial for all receivers), and those associated with the operation of a number of V.H.F. transmitters and receivers in close proximity on the same site. Of these the latter proved more serious; in fact, in the course of experiments carried out to resolve technical difficulties, a solution was also found to the former problem. It was found, when a number of V.H.F. transmitters are operated in close proximity, that spurious signals are generated; these are in general due to non-linear elements in the vicinity of the transmitter aerials. The effect has been investigated by the Admiralty in the case of multi-channel working in warships, and is known for obvious reasons as the "Rusty Bolt Effect." These investigations have been dealt with at length elsewhere.[2] The effect was minimized by the use of wooden towers to support the transmitter aerials, and by the elimination of all unnecessary metal work from the immediate vicinity of these aerials. Even after these precautions were taken it was still not found practicable to operate the receivers in the immediate vicinity of the transmitters. The presence of powerful signals on a channel other than that to which the receiver was tuned gave rise to "cross-modulation" with consequent cross-talk between channels. During early experiments it was found that such "cross-talk" was serious when transmitters and receivers were separated by distances as great as ten miles. Such a limitation was, of course serious, since separate transmitter and receiver sites would have been necessary for every station, and quite apart from the prohibitive economic burden that this would impose, in many cases the terrain was such as to make it impossible to locate separate transmitting and receiving sites. The obvious solution to this problem was to avoid the presence of unwanted signals in the early stages of the receivers, by the use of highly selective tuned circuits. After a number of experiments this was achieved by the use of high-Q cavity resonators between aerial and receiver.[3] These present a high shunt impedance across the coaxial line at the desired frequency and a low shunt reactance at the unwanted frequencies. As an additional safeguard, a double-screened room was used to house the receivers; the mains supply and audio lines passing through the screens at one point with R.F. filters inserted at this point. It is of interest to note here a problem that arose while these experiments were being carried out, it was found that strong signals could be received with the R.F. Oscillator and I.F. stages of the R1392B Receivers inoperative. Non-linearity in the R.F. stages was causing rectification of incoming signals (in the absence of cavity resonators) and the resultant modulation component was transferred to the A.F. stages of the receiver through the impedance of the power supply. This effect was eliminated by an improvement to the anode supply decoupling. The use of cavity resonators also made possible the use of a common aerial for all receivers used at a station.

Common V.H.F. Aerial Working

Having achieved common-aerial working with the receivers it was clearly desirable that a similar technique should, if possible, be adopted in the case of the transmitters. Experiments showed that this could be done by use of the same cavity resonators, the loss of transmitter power being of the order of 3-4db, and this was considered acceptable in view of the considerable simplification arising from common-aerial working. To further reduce interaction between transmitters and receivers it was found desirable to separate the two aerial systems by at least 15 feet and to mount them with their major axes in line and spaced vertically. All these measures made possible the simultaneous use of four V.H.F. channels from the same site, using a common transmitting aerial and common receiving aerial mounted on the same mast. The only limitations to frequency allocations were a channel spacing of at least 400 kc/s, and the avoidance of three channels equally spaced; that is, if one channel be f and a second $f \pm \Delta f$ then the frequency $f \mp \Delta f$ is to be avoided as a further channel. The final aerial system adopted for the transmitter-receiver sites is shown in Fig. 3, four wide-band aerials being mounted on a single 120 ft. wooden tower, these being transmitter, receiver, transmitter spare, and receiver spare, respectively, there being, as stated previously, a vertical separation of 15 ft. between individual aerials. The aerials themselves are wide-band cage dipoles, designed to give satisfactory operation over the aero-

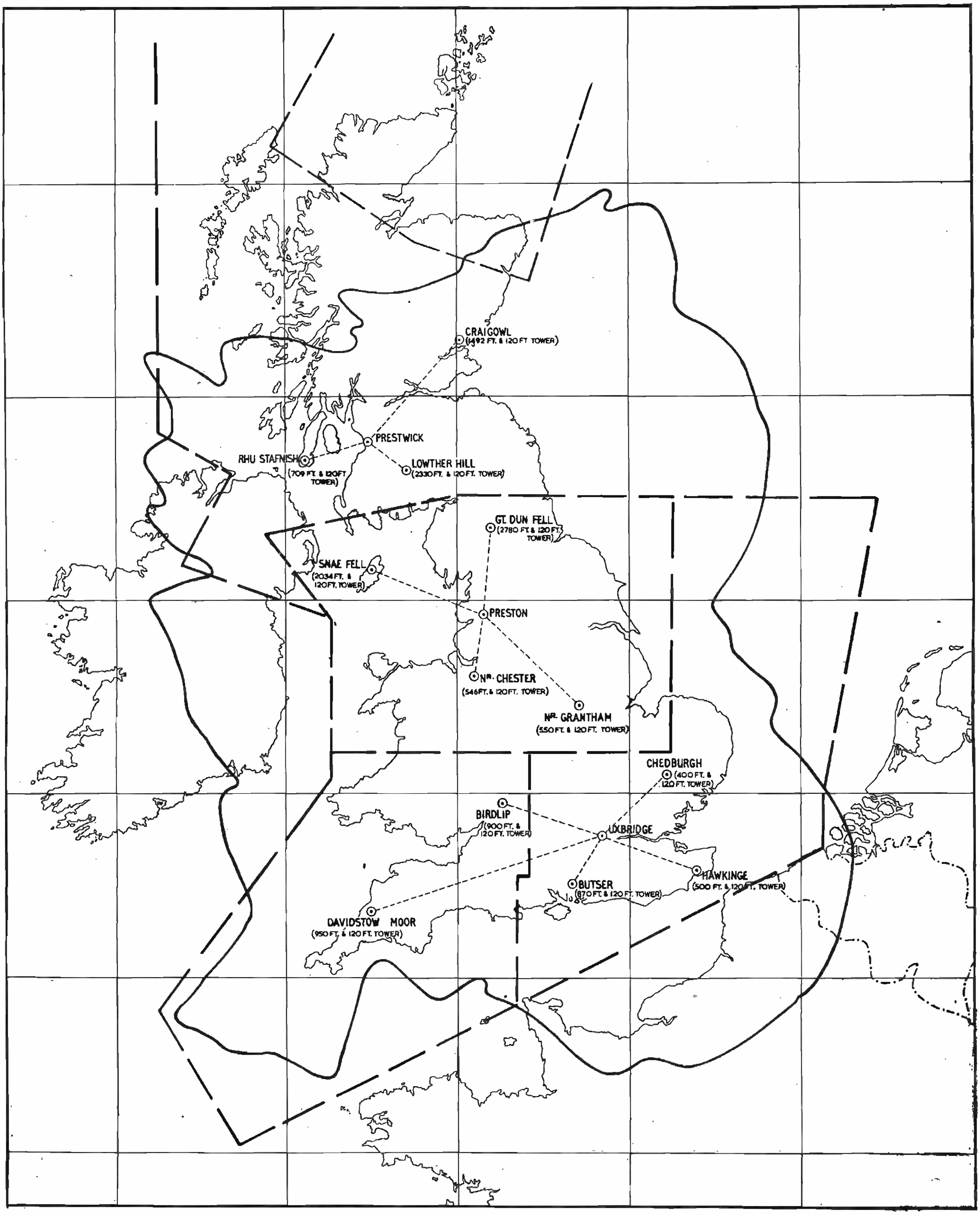

Fig. 2. Layout of the new Ministry of Civil Aviation V.H.F. area coverage network. This will provide direct communication facilities for aircraft flying over the United Kingdom

Legend : ▬▬ theoretical coverage at 5,000 ft. above sea level ; — — Flight Information Region boundaries

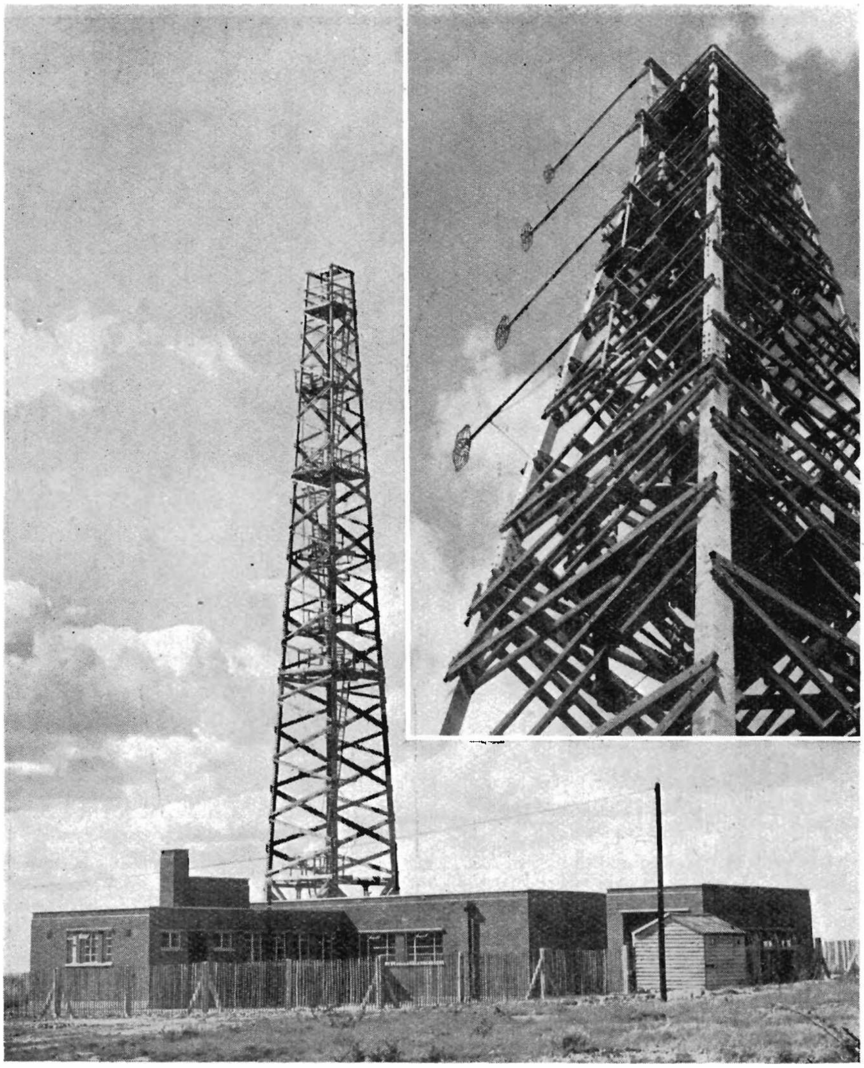

Fig. 3 (Left). View of the Butser Station at 870 ft. above sea level with its 120 ft. wooden mast. The inset shows the four wide-band aerials mounted in line with their axes vertical and spaced 15 ft. apart

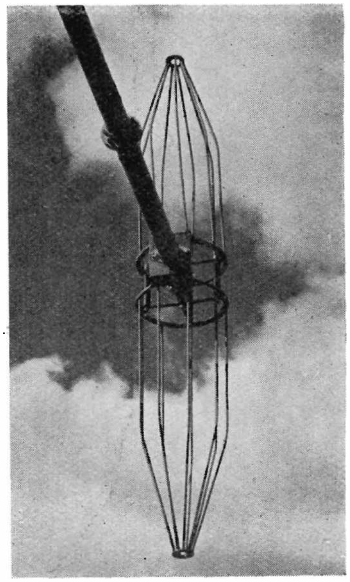

Fig. 4 (Below). Close-up view of the wide-band cage dipole with matching device in the mounting boom

nautical communication band of 118-132 Mc/s, a matching device being embodied in the mounting boom. Technical data on these aerials, which are shown at Fig. 4, has been given by A. H. Brown.[4]

Audio-Frequency Equipment

Thirdly, the audio-frequency equipment used in the new networks represents a considerable improvement over that used in the earlier "Climax" system. The development of this equipment to a Specification prepared by the Ministry of Civil Aviation was undertaken by Plessey's Ltd., and the equipment will be described in a subsequent article. The equipment at the Air Traffic Control Centre at Uxbridge is shown in Fig. 5. The chief improvements are—

(a) The use of up to four channels simultaneously, with provision for a later increase, if required, up to eight channels.

(b) Improved methods of "splitting" and "combination" at the Control Centre, with provision, if required, for up to eight transmitter-receiver sites per channel.

(c) Improved audio-frequency response characteristics.

(d) Use of compression and expansion in the audio-frequency amplifiers to ensure a consistently high level of modulation of the transmitters.

(e) Use of A.C. switching by 2460 c/s tone on the transmit lines.

(f) Complete flexibility of equipment at the Control Centre.

(g) Built-in audio frequency test equipment for checking of levels and frequency response throughout the system.

The Control Centres and transmitter-receiver sites are linked by GPO landlines routed through carrier circuits, having a frequency response of 300-2,800 c/s within 1 db.

As previously stated, the original plan called for four channels, each using five transmitter-receiver stations in the case of Southern England. However, since 1949 considerable evolution of air-traffic control procedures has taken place, particularly in the "channelising" of air traffic into "airways." These "airways" are defined by M.F. Radio Ranges and Beacons, and marked by 75 Mc/s Fan Markers. This has resulted in some modification of the original plan, particularly in the Southern area.

The network was brought into operation in February 1951 in the following form:—

Channel 1. 126.7 Mc/s. Using all five T-R sites and providing all-round area coverage for Southern England.

Channel 2. 118.9 Mc/s. Using the Butser site only, providing coverage for the "airways" leading southwards to the Continent and Channel Islands.

Channel 3. 120.3 Mc/s. Using the Hawkinge site only,

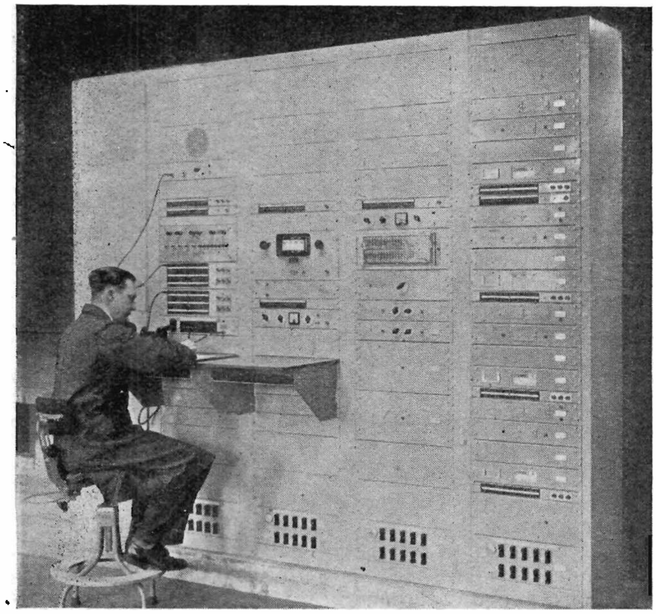

Fig. 5. Audio frequency and line terminal equipment at Air Traffic Control Centre, Uxbridge. An MCA engineer is carrying out audio frequency characteristic measurements at the test bay

providing coverage for "airways" leading eastwards to the Continent and Scandinavia.

Channel 4. 122.1 Mc/s. Using the Chedburgh, Birdlip and Davidstow sites, providing cover for "airways" leading northwards and eastwards to Scotland and the North Atlantic.

This does not, however, represent the final development of the system, its flexibility being such that further channels will be added when warranted by channel loading.

While it is yet too early to fully assess the operation of the system, the first reports indicate that, like "Climax", the service areas agree closely with calculated coverage and that effective area coverage is provided. Aircrews report a high degree of reliability and intelligibility, which makes possible a speedy interchange of air-traffic control messages at considerable distances from final destinations, which is a matter of some importance with the ever-increasing operational speeds of modern aircraft.

Acknowledgments

The developments described in this paper are part of the telecommunications programme of the Ministry of Civil Aviation and, in the case of the high-stability oscillator and audio-frequency equipment carried out in close co-operation with the Plessey Company under contract to the Ministry. A considerable number of colleagues took part in the original experimental work and in the subsequent installation of the systems described, and it is difficult to acknowledge their contributions individually. The author is grateful to the Director of Navigational Services (Telecommunications), Ministry of Civil Aviation, for permission to publish this paper.

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Electronic Colorimetry

By D. W. Thomasson, A.M.Brit.I.R.E.

THE development of electronic devices for colour analysis has been hindered by a strong prejudice in favour of the older visual methods of comparison, and by continued adherence to the trichromatic system of identification. The system suits the older method well, since it involves photometric measurements at those wavelengths where the sensitivity of the eye is greatest. It is less suitable for practical comparison work of a routine nature.

Consider the three spectral distribution curves of Fig. 1. All three coincide at the wavelengths of the spectral matching stimuli (0.7 μ, 0.546 μ, 0.436 μ) used in the trichromatic method. All three will therefore give the same trichromatic identification. To an observer whose eyes have maximum sensitivities at different wavelengths from these accepted as standard, the colours will look different.

This is unimportant to the research worker who requires a general comparison of the effective colours and illuminating efficiencies of various light sources or reflecting surfaces. It is very inconvenient when the object of the test is the establishment and maintenance of a uniform product colour.

The only solution in such cases is to plot the whole spectral curve, or, at least, increase the number of sampling ordinates so that the general form of the curve can be seen. Visual apparatus cannot be used for such measurements with any degree of reliability, the readings differing by up to 15 per cent with different observers.

Electronic colorimeters are, on the other hand, quite suitable for this sort of measurement.

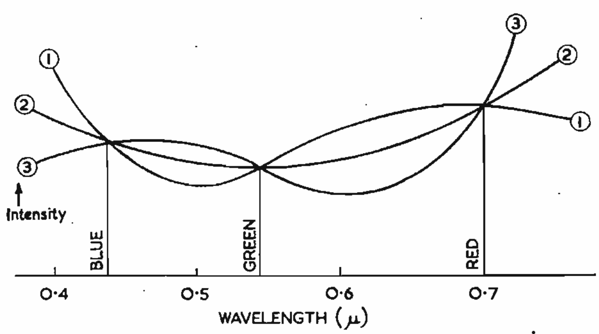


Fig. 1. Three spectral distribution curves having identical intensity levels at the spectral matching wavelengths, which may give different colour sensations

Essentials

The essential elements of an electronic colorimeter are:

(1) A calibrated photometer corrected for constant sensitivity over the visual wavelength range.

(2) A selective filter passing a narrow band of light wavelengths.

For measurements of reflexion coefficients, a light source must be added, and the photometer correction altered to compensate for the spectral distribution of the source.

Subdividing the essential elements, the photometer must include a photo-electric pick-up head, with its associated amplifier, an adjustable light filter for response correction, and some form of indicator. The calibration is best achieved by using some form of built-in standard. The selective filter may use a prism or diffraction grating associated with a slit passing a band of the dispersed light. Coloured glass filters are unsuitable, as they are liable to pass unwanted wavelengths outside the visible range, and are not easy to adjust.

Practical Problems

The most difficult problem is that of securing a constant sensitivity over the visual wavelength range, together

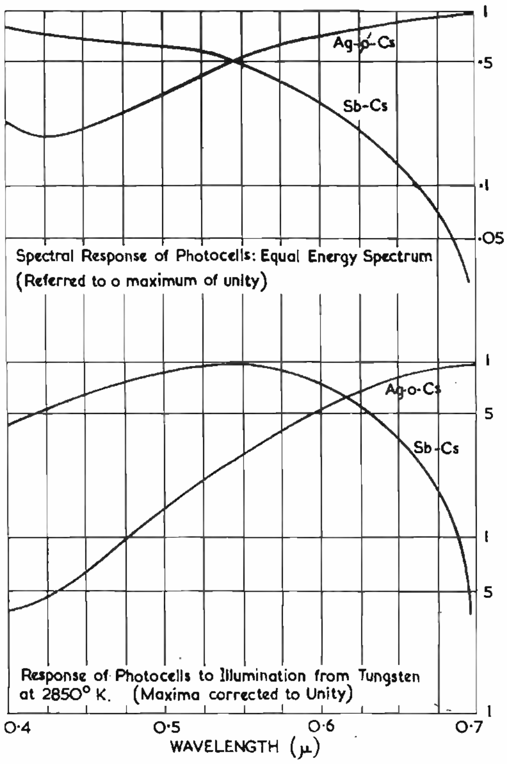


Fig. 2. Spectral response of photocells with Ag-O-Cs and Sb-Cs cathodes

with an adequate sensitivity level. Among photocells currently available, the most suitable are those having caesium-oxygen-silver and caesium-antimony cathodes. The spectral sensitivity curves of these two types are shown in Fig. 2, together with the overall sensitivity curves obtained with a tungsten light source at 2850° K.

It can be seen that the sensitivity varies considerably. The maximum overall sensitivity is that obtained at the wavelength of least sensitivity.

At the moment, only the Ag-O-Cs cathode is of much value, and even this requires a correction ratio of 11/1

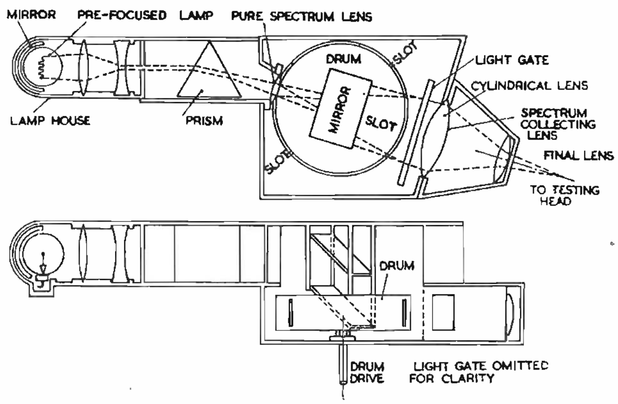


Fig. 3. Diagram showing general arrangement of illuminating head

with the tungsten source. Experimental work on a new photocell may solve the problem.[1] This cell has two cathodes, one of the Ag-O-Cs type, and one of the Sb-Cs type. The Ag-O-Cs cathode is deposited on one side of a partition dividing the cell into two separate evacuated sections, and this cathode is in the form of a semi-transparent layer. The Sb-Cs cathode is deposited on the other side of the partition, and is illuminated through the Ag-O-Cs cathode.

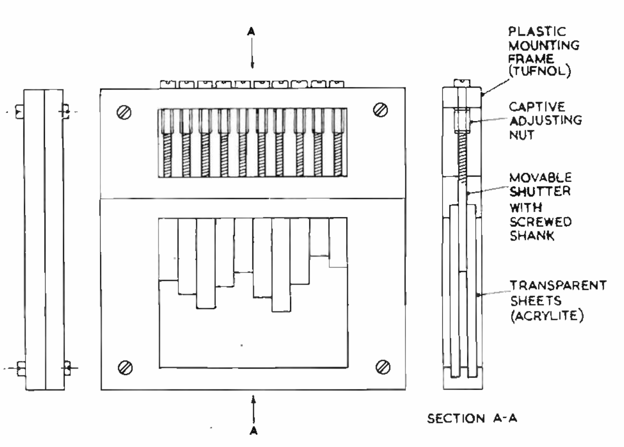
The outputs of the two halves of the cell are combined to obtain a much more even response than is possible with any known single cathode. The manufacture of the cell presents many problems, but the use of new techniques avoids the most serious difficulties.

Apart from the initial correction of the spectral sensitivity, it must be maintained constant during operation. This is made more difficult by changes in the light source spectral distribution with voltage variations and filament ageing. The only really satisfactory solution is to monitor the sensitivity continuously, facilities being provided for rapid sensitivity adjustment.

Automatic Colorimeter

The light source and selective filter for an electronic colorimeter for reflectivity measurements are shown in Fig. 3. The light from the lamp is focused into a narrow beam and passed through the prism, the dispersed rays being passed to the interior of a slotted drum. Rotation of the drum moves the slots across the dispersed rays, giving the required selective filter action. The rays passing through the slot are collected and passed to the testing compartment.

Fig. 4. Adjustable mask filter for modifying spectral distribution of light



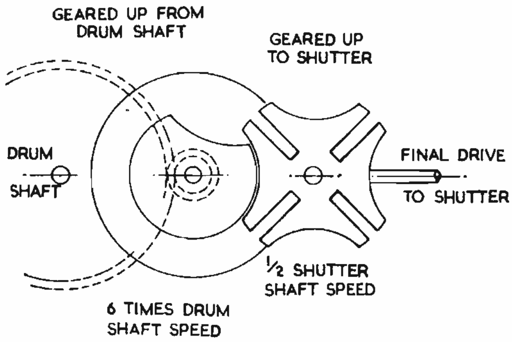


Fig. 5(a). "Maltese Cross" drive to shutter carrying standard

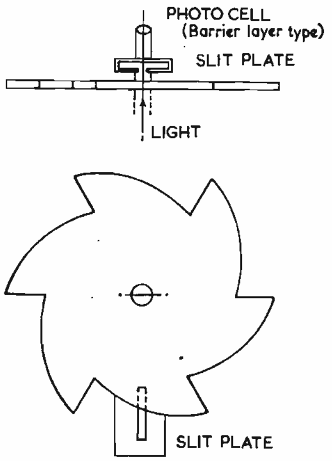


Fig. 5(b). Sweep generator. Six-toothed mask is mounted on drum shaft

Between the drum and the collecting lens is an adjustable mask, shown more clearly in Fig. 4. The height of the opening can be set by altering the position of ten metal blades, each of which has its own adjusting screw. The amount of light reaching the testing compartment in each position of the scanning drum is thus controlled, and the mask may be set up to obtain a constant photometer indication at all parts of the spectrum.

In this particular instrument,[2] the indicator is a cathode ray tube. The light reflected from the surface under examination is picked up by a photocell, the output of which is amplified and fed to the vertical deflexion plates. The horizontal deflexion is obtained by a photocell and mask type generator[3] (Fig. 5b).

To obtain the required standard calibration, a "standard white" surface is used. This is mounted on a rotating holder driven from the drum shaft through a "maltese cross" mechanism (Fig. 5a), so that the standard covers the specimen during alternate scans of the drum. Every third slot in the drum is omitted, and the light is cut off.

The photocell output thus goes through three alternate phases: the reflexion from the specimen: the reflexion from the standard: zero reflexion. The horizontal trace of the C.R.T. is completed once during each phase, and the resulting display is viewed through a special graticule scale (Fig. 6).

The "white trace" is set to the top line of the graticule by adjusting the mask in the light filter and the gain of the amplifier. The "black" trace is set to the bottom line by means of the Y-shift control. The "specimen" trace thus gives a standard indication of the spectral reflectivity of the surface being examined.

Identification

The colour may be identified by a code number taken directly from the graticule readings. In the case shown, the identification is 8986421000. There are 10^{10} possible identifications, about half of which are useful in practice.

The vertical scale is in antilogarithmic units, giving readings which approximate to the "sensation level" equivalent of the reflectivities.

Manual Version

The layout of a manually operated colorimeter using the same identification principle is shown in Fig. 7. There are ten sampling positions, selected by a rotary switch which sets up the necessary sensitivity levels. A cam on the switch shaft rotates the prism through an adjustable lever mechanism.

The indicator is a moving coil meter, the scale being calibrated in antilogarithmic fashion. The sensitivity adjustments are checked against a standard white surface.

Conclusion

The electronic colorimeter must eventually come into widespread use, ousting the visual method wherever comparisons of observed colour are required. The changeover is being hastened by a lack of expert colour matchers, yet there is still some resistance to the introduction of the new method.

Earlier inefficiency in electronic colorimeters is being overcome by new techniques, and it is to be hoped that this will overcome the prejudice. The advantages of the standard identification method will help here, and a reliable method of specifying colour will become available.

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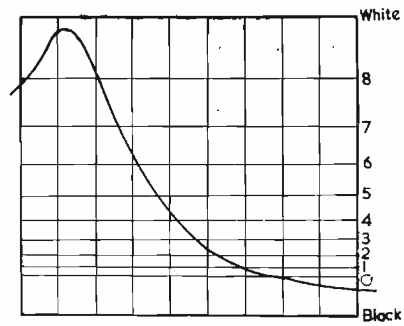
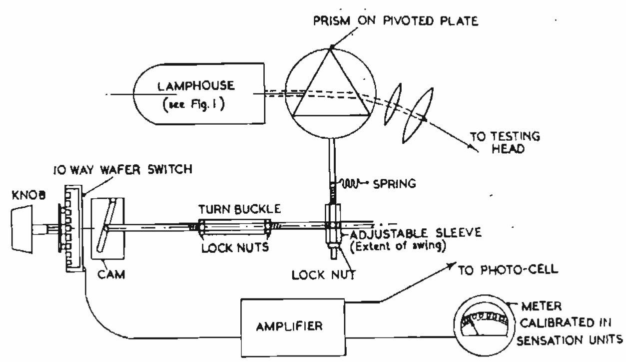


Fig. 6. Response curve on C.R. Tube screen as viewed through graticule. "White" and "Black" traces are set to coincide with top and bottom lines. Identification reads 8986421000

Fig. 7. General arrangement of manually-operated Colorimeter



THE A.M. AND F.M. TRANSMITTERS AT WROTHAM, KENT.

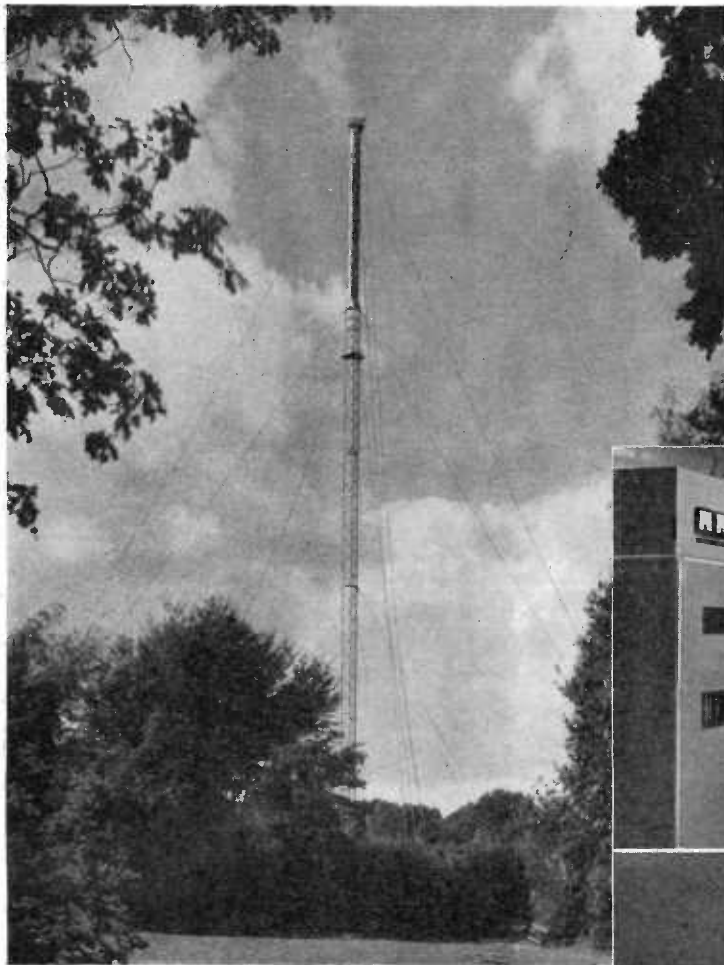
THE B.B.C. announced last month details of the new V.H.F. transmitting Station at Wrotham, Kent, about 20 miles south east of London. The Station consists of a single storey brick building, and a 470 ft. mast, the base of which is 730 feet above sea level.

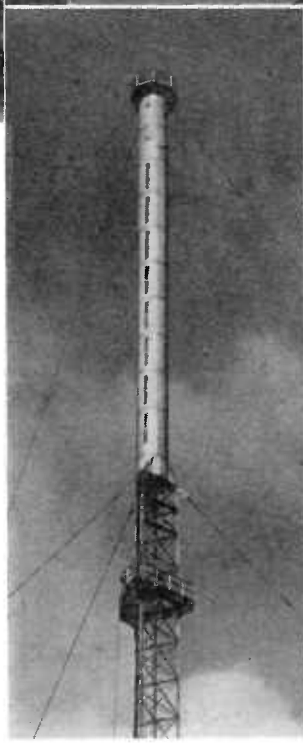
The F.M. transmitter, manufactured by Marconi's Wireless Telegraph Co. Ltd., has a power of 25kW and operates on a mean carrier frequency of 91.4Mc/s. (corresponding to a wavelength of 3.28 metres) with a maximum deviation of $\pm$75kc/s. It incorporates the Marconi 'F.M.Q.' system of frequency modulation, in which a quartz crystal oscillator is connected through a quarter-wave network to a balanced modulator, the susceptance of which varies with the modulating signal, and in turn varies the frequency generated by the crystal oscillator.

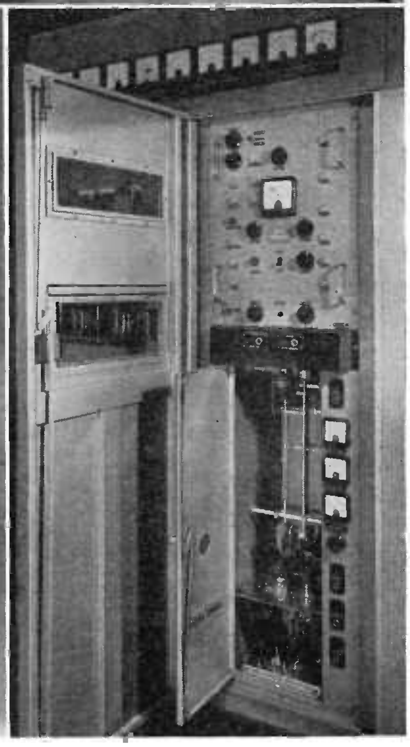
The output of the crystal oscillator is passed through three frequency doubling stages and one tripling stage to produce the carrier frequency of 91.4Mc/s. There then follow six stages of amplification. The first two are conventional push-pull stages and the remaining four are single-ended earthed-grid stages with coaxial-line tuning elements. The output stage consists of two BR128 valves in parallel, giving an output of 25kW.

The A.M. transmitter, also manufactured by Marconi's Wireless Telegraph Co. Ltd., has an unmodulated power of 18kW and operates on a carrier frequency of 93.8Mc/s., which corresponds to a wavelength of 3.20 metres. The drive equipment and the radio-frequency amplifiers are like those in the F.M. transmitter, except that the balanced modulator in the "F.M.Q." drive is made inoperative. The audio-frequency modulator has four stages, the final stage consisting of two ACT 14 valves operating in class B.

The mast consists of a lattice steel support mast 360 feet high, on top of which is a cylindrical section 110 feet long and 6½ feet in diameter, which with the slots in its surface forms the V.H.F. aerial system. The support mast has a triangular cross-section, each face being 9 feet across, and rests on a ball joint which permits some angular movement under wind pressure. The dead weight of the mast is 60 tons, and the maximum thrust at the base is 200 tons. The mast was designed and built by B.I.C. Construction Co., Ltd.







The accompanying photographs show:

(Top left) View of the completed 470 ft. mast.

(Top right) The transmitter hall. In the foreground is the 25-kilowatt F.M. transmitter, and beyond it is the 18-kilowatt A.M. transmitter. The kiosks, from which the transmitters are controlled, are behind windows in the wall on the right. The two doors between the transmitters give access to the air ducts forming part of the valve cooling-system.

(Bottom left) The V.H.F. aerial and part of the triangular support mast. The aerial, which is shared by both transmitters, consists of 32 slots in the wall of a cylinder 110 feet long and 6½ feet in diameter. The slots are arranged in 8 tiers with 4 slots in each tier.

(Bottom right) Close up view of one of the panels of the F.M. transmitter showing the "F.M.Q." drive. This consists of a directly modulated crystal oscillator and a series of frequency multiplying stages; at the bottom can be seen the amplifier stage, consisting of one C144 double tetrode and second R.F. stage, consisting of two TT16 tetrodes.

Aspects in the Design and Manufacture of Planar Grids for Triodes at U.H.F.

By W. J. Pohl, M.Sc.

TUNEABILITY over a wide range of frequencies, low operating voltage and ease of modulation are attributes which make the standard triode suitable for a very wide range of application at frequencies up to several thousand megacycles per second. It is well known that at centimetre wavelengths the electron transit time plays a very important part. The maximum frequency of oscillation may be considered to be proportional to $(i/a)^{1/3}$, where i is the current density in the grid cathode space, and a is the grid cathode separation.[1,2,3] If the frequency is to be increased above this value, either a must be diminished or i increased. The latter is restricted to a fixed value (greatly increased for pulse conditions) by the cathode emission. Hence a becomes a decisive quantity, which also affects the efficiency.[4] Furthermore a determines the grid pitch, which should not exceed a if a long tail in the characteristics of the valve is to be avoided. The grid pitch is in turn an important factor in the determination of the amplification factor.[5]

In general, the planar (as opposed to the cylindrical) electrode structure will be chosen in attempts to extend the useful operating range of a triode beyond 3,500 Mc/s. The reason for this, other than the constructional advantages of the planar structure, lies in the fact that the length of the electrodes of a cylindrical construction may only be a small fraction of one quarter of the operating wavelength.

The planar grid wires must be reliably tensioned, otherwise the expansion with temperature rise will cause wire buckling, and, at exceedingly close inter-electrode clearances, this results rapidly in short circuits. Excessive wire temperature may also give rise to troublesome primary grid emission.

These considerations indicate the importance of the relationships between the dimensions of a grid and its ability to dissipate power. In this article this matter is discussed in perspective with practical manufacturing problems. A recently developed method of producing planar ring frame grids carrying highly tensioned wires is reported.

List of Symbols

t = Temperature (as a variable).
l = Length (as a variable).
Q = Heat received per second by unit length of wire.
A = Cross-sectional area of wire.
K = Coefficient of thermal conductivity of the wire.
T_0 = Temperature of the grid frame.
α = Coefficient of linear expansion of the wire.
τ = Residual tension in the wire.
Y = Young's modulus of the wire.
Δ = Extension.
L = Length of wire.
W = Power (heat units per second) dissipated before start of buckling.
D = Grid aperture diameter.
p = Pitch of grid.
F = Residual force in the wire.
d = Diameter of the wire.
α_f = Coefficient of linear expansion of the frame.
T_R = Room temperature.
u = Radial displacement (as variable) of a ring frame on deformation.
ϕ = Polar angle specifying section of circumference of ring frame.
R = Radius of ring frame.
E = Young's modulus of the frame.
I = Moment of inertia of a cross-section.
M = Bending moment.
f = Stress in frame.
N = Weight of tension meter needle.
x, y = Linear dimensions of radial section of a ring frame.

Calculation of Maximum Wire Length

Let us examine the case of a single wire, stretched between the parallel faces of a cathode at about 800°C and an anode, usually between 200° and 350°C. The wire will receive power along its length, when the valve is operating, by electron bombardment, and also by radiation of heat from the cathode. The former power can be measured, and is constant along the wire, if fringing effects are ignored. The latter is not constant; any elemental part of the wire receives heat which is proportional to the difference of the fourth powers of the temperatures of the element and the cathode (Stefan's Law). The heat interchange between the wire and the anode follows the same law, but is negligibly small compared to the other two factors, because the grid wire temperature is never greater than about 500°C even at the centre, where the temperature is highest.

We may assert therefore that the fraction of the power thus received which is not disposed of by conduction of heat along the wire to the frame, is negligibly small. Under these conditions the temperature distribution along the wire, by considering the thermal equilibrium of an elemental section of the wire, can be shown to be represented by the equation

$$\frac{d^2t}{dl^2} = mt^4 + n \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where t and l are variables of temperature and length respectively, m and n are constants. This equation is difficult of general solution. We may however, at the cost of a small error, assume that the power received per unit length is constant along the wire.* Again by considering the thermal equilibrium of an element of the wire, we derive the relationship

$$\frac{d^2t}{dl^2} = -\frac{Q}{AK} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

taking the origin in the centre of the wire. Introducing the boundary conditions that $t = T_0$ when $l = \pm L/2$ and $\frac{dt}{dl} = O$ when $l = O$ we find that

$$t = T_0 + \frac{QL^2}{8AK} - \frac{Ql^2}{2AK} \quad \ldots\ldots\ldots \quad (3)$$

Thus the temperature distribution is a symmetrical parabolic curve, rising from T_0 at the ends to a maximum of $\frac{QL^2}{8AK} + T_0$ in the centre.

Let it be assumed that the grid frame has the same coefficient of thermal expansion as the wire. Then the increase in length of the wire over and above that of the frame, is

$$\Delta = \int_{-L/2}^{+L/2} \alpha(t - T_0)dl = \frac{\alpha QL^3}{12AK} \quad \ldots\ldots\ldots \quad (4)$$

* The author has calculated, by a series of successive approximations, the true temperature distribution in accordance with equation (1), for particular cases. The results show that the above assumption introduces only small errors in the calculated temperature distribution, not in excess of 3 per cent in the centre of the wire.

The residual tension in the wire will be reduced to zero when the expansion just equals the extension originally set in by the tension.

$$\triangle = \frac{\alpha Q L^3}{12AK} = \frac{\tau L}{Y}$$

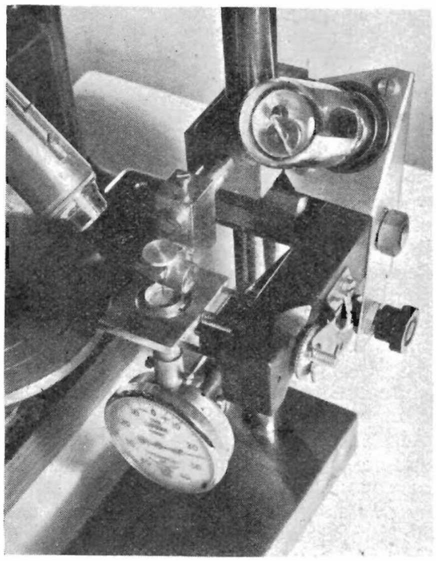


Fig. 1. Clock gauge method of measuring the tension of grid wires

The tension becomes zero and buckling commences when

$$Q = \frac{12\tau AK}{Y\alpha L^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Thus for a single wire, the total power which may be dissipated before buckling commences is given by

$$W = \frac{12K\tau A}{\alpha YL} \text{ or } \frac{12KF}{\alpha YL} \quad \ldots\ldots\ldots\ldots \quad (6)$$

For a grid of circular aperture, wire pitch p, the total power, when the longest wire commences to buckle, is

$$W = \frac{3\pi KF}{Y\alpha p} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

F may be measured on the finished grid by a method described later. This makes the above equations suitable for estimating the total power dissipation of a particular grid. It is easily shown that, when the grid to cathode clearance is of the order of 0.01 times the longest wire length, the additional power required to cause a grid cathode short, once the residual tension is taken up by expansion, is negligibly small. The measured grid dissipation at breakdown of a grid of known wire tension may therefore be used to check the validity of Equation (7). To compare such a measured value with the value given by Equation (7), the heat received by the grid by radiation from the cathode (not included in the measured value) must be taken into account. Taking this as the fraction

$$\frac{\text{heater rating} \times \text{area of grid wires projected on cathode*}}{\text{Total cathode cylinder radiating area}}$$

such a comparison has shown agreement between calculated and measured values to within 25 per cent. This discrepancy is not excessive when we consider that differences in wire manufacturing conditions can cause small changes in K, Y and α; these "constants" also vary slightly with temperature. Further, we have introduced an error of about 3 per cent or so in the fundamental assumption underlying equation (2), and, as will be seen later, there are likely to be errors in tension measurement up to 10 per cent.

In the design of a grid therefore. such errors must be taken care of by allowing an ample safety factor.

Equation (6) shows the limitation to the length of the longest wire. For a grid with a circular aperture (which is the most convenient form from a manufacturing point of view) the diameter of the grid aperture, and hence the power of the valve, is thus limited, and it is usually desired to make this as large as possible.

If a valve operates satisfactorily under certain conditions, we may design the grid for another if the new valve is to operate under conditions in which the power received by the wires, per unit area presented to the cathode, is to be the same in both valves. Using Equation (7), stipulating equal grid transparency, and taking into account the expansion of the frames, the relationship between the grid apertures of the two valves

$$D_2 = D_1 \sqrt{\left\{\frac{d_2K_2Y_1\alpha_1}{d_1K_1Y_2\alpha_2}\left[\frac{\tau_2 + E_2}{\tau_1 + E_1}\right]\right\}} \quad \ldots\ldots\ldots \quad (8)$$

is easily derived. The suffixes 1 and 2 refer to old and new valves respectively, and

$\epsilon = Y\ (\alpha_f - \alpha)\ (T_o - T_r)$ for each of the cases* T_o may be determined by experiment on a model, and, in the case of disk seal triodes, is usually limited by the maximum permissible temperature of a glass-to-metal seal.

Equation (7) may also be used to examine different wire materials from the point of view of suitability for tensioned planar grids. Such an examination has revealed that the most suitable tensioned grid using commercial

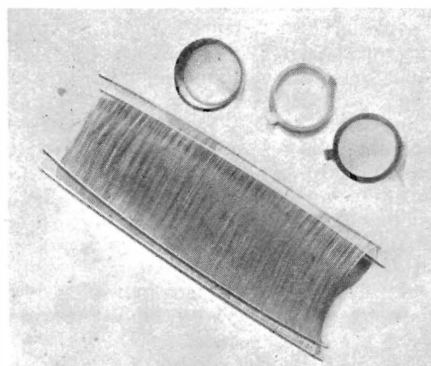


Fig. 2. Pre-formed grid mesh on wire "backbones"

materials should consist of a tungsten wire carrying a copper coat, thickness 15.5 per cent of the tungsten wire radius. Such a composite wire can dissipate theoretically 1.125 times the power of a plain tungsten wire having the same outside diameter and carrying the same residual tension in the tungsten. The copper acts only as a conductor of heat and can carry no residual tension.

A Method of Measuring Residual Wire Tension

A method used at Philips, Eindhoven, for comparative measurement of tension in the wires has been adapted to give absolute values of wire tension. The principle is as follows: A blunt needle of known weight is rested on the centre of the wire. The resulting vertical displacement of the wire is measured. For this a clock gauge is used whose feeler is screw operated. Contact of the feeler with the grid wire is registered electrically by a neon lamp circuit. A low power microscope facilitates

* This should be an over-estimate because the wire is at a greater temperature than the other surroundings of the cathode cylinder; even so, the value is usually less than 10 per cent of the total grid dissipation.

* D_1 and D_2 also represent the length of the longest wires, Equation (8) may therefore be used also for cases where the aperture is non-circular; or for strapped grids.

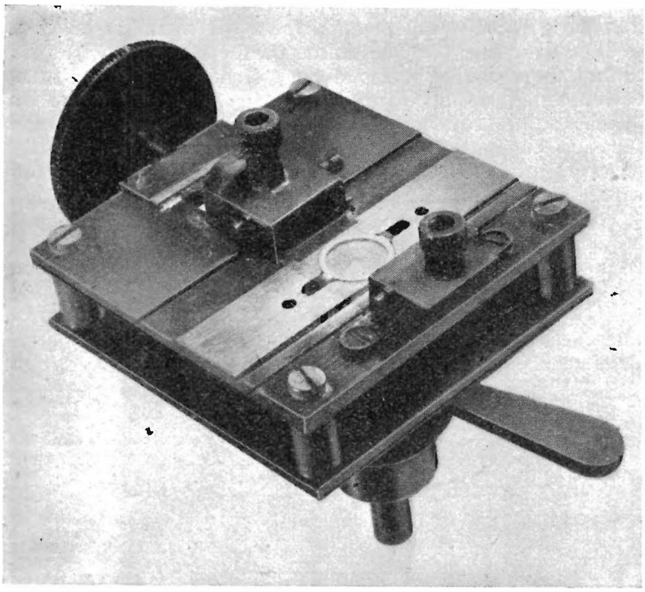


Fig. 3. Wire mesh held taut in the welding jig over the ring frame

the positioning of the grid, which is moved on a screw-operated platform. See Fig. 1.

By considering the equilibrium of forces at the contact point of the needle on the wire, and assuming the wire stretches according to Hook's Law, we deduce

$$\tau A = F = \frac{NL}{4\delta} - 2AY\left(\frac{\delta}{L}\right)^2 \quad\ldots\ldots\ldots (9)$$

where N is the weight of the needle and δ is the vertical displacement as measured by the clock gauge feeler. With the aid of this equation, a calibration curve can be drawn for any grid wire. The weight of the needle should be kept as small as practicable, otherwise the wire stress may exceed the limit of elasticity and an error would be introduced.

Mesh Grids

Mesh grids are normally used in cases where the residual tension is not relied upon to keep the wires in position, i.e. where electrode clearances are large enough to obviate the necessity of avoiding slight buckling. The mesh grid is mechanically stronger, and buckling of the longest wire is restricted by shorter wires. This is not taken into account in an approximate treatment by Wilchinsky[6] in which the grid is replaced by an equivalent sheet of uniform thickness and conductivity. Wilchinsky implies that the error involved by this replacement is small, but gives no proof to this effect. Such a sheet cannot be an exact equivalent because the length of path of (and the resistance to) heat flow varies, being least along radii parallel to the wires, and a maximum along 45° radii. In view of this, Wilchinsky's estimate of the maximum power dissipation of a mesh grid before buckling commences is likely to err on the optimistic side. The error becomes 100 per cent when his equation is transformed for the case of the parallel wire grid.

Using his results, and Equation (7), for comparing a mesh grid and a parallel wire grid, both of pitch p (other factors being equal) we find that the dissipation of power before buckling commences is the same in both cases. The parallel wire grid has the advantage of greater transparency, and can be more reliably tensioned. For these reasons it seems likely that it will be chosen for triodes which are to provide a maximum of power at wavelengths below 20cm or so.

An Outline of Manufacturing Problems

The most common U.H.F. triode grid is made by winding fine tungsten or molybdenum wires on to a rectangular molybdenum frame with a circular aperture. To provide a good thermal and electrical contact the wires are then copper or gold brazed to the frame.

At U.H.F., the outside diameter of a planar triode is limited by the concentric circuit, the dimensions of which must be in accordance with the required wavelength. When a new triode is developed it is usually desired to make the output power a maximum. For this reason the rectangular grid frame is not ideal, because in order to accommodate it inside the valve, some cathode area has to be sacrificed. The most suitable frame therefore is circular, in the form of a ring. Ring frame grids have been made by various methods, all involving a brazing process and not easily adapted to mass production. Further, the residual tension is limited by the low yield strength of the wires at brazing temperatures.

A great improvement can be made in this respect by extending the frame after brazing, whereby the wires are tensioned.* Unfortunately, by this means the short wires suffer a far greater elongation than the long wires; the former may fracture before the latter are properly tensioned. In the case of molybdenum wires this is not serious as ample extension in the region of plasticity is possible before fracture. But tungsten, in other respects a far more attractive wire material (see Eqn. 7), will break after an elongation of approximately only 1 per cent. For this reason the manufacture of highly tensioned tungsten grids on ring frames is somewhat difficult.

The general problem therefore with which the writer was faced was the design and manufacture, with a view to mass production, of planar grids on ring frames, having wires as taut as possible under the temperature conditions likely to be encountered. A method developed for attaching fine wires to ring frames by means of electrical resistance welding will now be described.

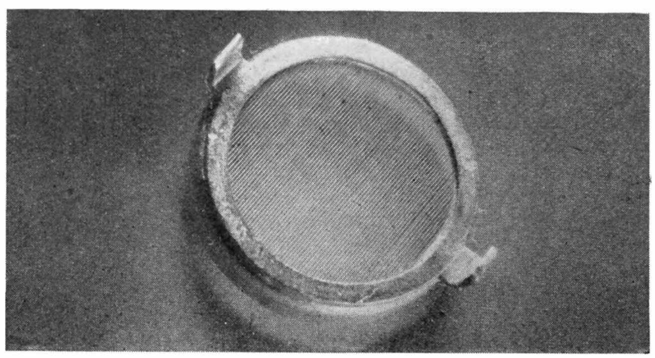
Manufacture by Electrical Resistance Welding

The method described below promises wide application, and is in pre-production on the *VX* 8047.

The grid wire is first wound with the required pitch on to a system of backbones. The wires are fixed to the backbones by the "notch and squash" method well known in the valve industry. The resulting structure is shown in Fig. 2. After winding in this way the backbone structure is cut and trimmed to give pieces such as are shown in Fig. 3. Such a piece is then laid into the welding jig where the two backbones are held in a groove and pulled apart, thus stretching the wires taut. Ring frames are then placed coaxially above and below

* This method was first developed at the G.E.C. Research Laboratories, Wembley. A notch is pressed into the frame along a centre line at right angles to the wires, thus forcing the two halves of the frame apart, and extending the wires. This is known as "stretching."

Fig. 4. Ring frame with grid wires welded on, after trimming



the wires, and the whole is resistance-welded together by a single pulse of current. The completed grid is then trimmed of loose wires outside the ring frame. A finished grid is shown in Fig. 4.

The clamps of the jig gripping the backbones must be so designed that the backbone wire is to some degree able to rotate, otherwise some wires may tighten before others. This might lead to fracture of wires at one end of the grid before those at the other end are taut. An even pitch will not be obtained unless the wires are entirely free when stretched; for this reason frames must come into contact with wires only when stretching is completed.

The electrode system used is shown in Fig. 5. The cup *A* contains a mercury copper amalgam (copper filings in mercury, pasty consistency) which is compressed during welding. It allows the upper electrode to align itself, and also ensures that it does not tilt over to one side during the weld, as would be the case with a ball type self-aligning joint. The paste must be loosened

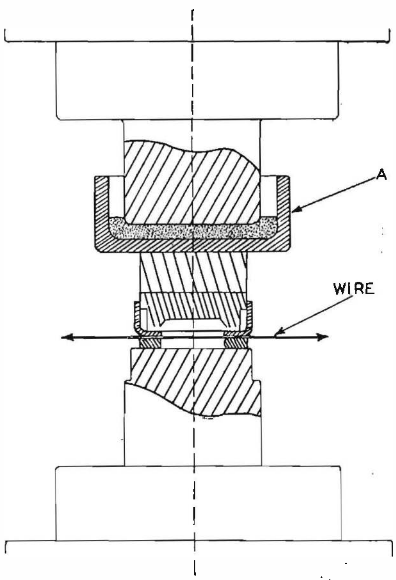


Fig. 5. The electrode system used for welding

periodically, say every fifth weld, otherwise the self-aligning properties will be lost and faulty welding will result. This highly conductive self-aligning electrode system is the only one out of a number that have been tried which will give consistently successful results. Considerable pressure is needed. For a grid of 11mm aperture diameter, and 35 sq. mm welding area, a force of approximately one ton is used. The welder used is a machine made by Sklaky Co., mechanically controlled and capable of 40kW pulse.

Both tungsten and molybdenum wire grids have been made in this manner. The latter are welded on to ring frames of rectangular cross-section, which may be stamped out from sheet metal. The frame is stretched by notching after welding. This cannot be done with a tungsten wire grid on account of the brittleness of the wire. Residual wire tension in this case is dependent entirely on stretching of the wires before welding. For this reason the frame has to be especially strong. Further, it must not be allowed to expand during the welding pulse otherwise contraction on cooling results in slack wires. Such expansion is avoided by arranging that the part of the frame which reaches a high temperature during the welding pulse is very weak compared with the part which remains cool, so that the latter prevents the former from expanding. This is achieved by making the weld on a thin flange protruding inwards from the main frame ring, as shown in Fig. 6. The frame of the tungsten wire grid cannot therefore be stamped out of sheet metal, but must be machined, and becomes necessarily more expensive on this account. Further, the great strength required of the frame necessitates a greater width of ring, thus partly offsetting the advantages gained by the use of tungsten wire.

Tension measurements on the molybdenum wire grid of 60 micron wire, aperture 11mm, frame 1mm wide, 1mm thick, gave average values of the order of 7.0×10^4 gm/mm². A tungsten grid of 50 micron wire, frame as shown in Fig. 6 gave values up to 8.7×10^4 gm/mm². These figures should be compared with a CV273 grid, unstretched using 29 micron directly wound tungsten

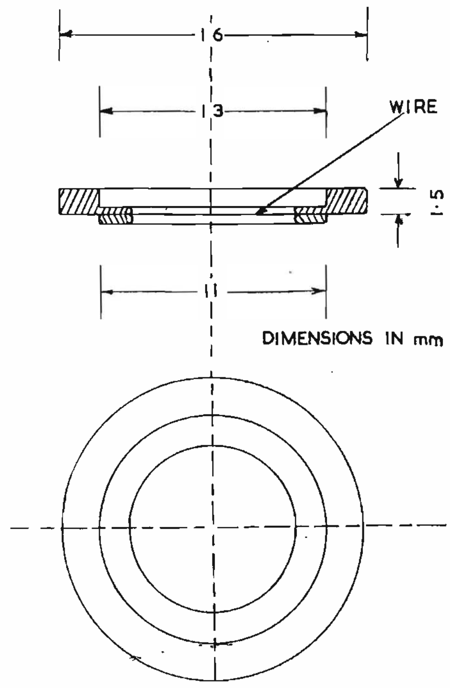


Fig. 6. Cross-section and plan of ring frame, showing the thin welding flange and the thicker strengthening section

wire on a rectangular frame. For this, difficulty was experienced in obtaining average values greater than 4.0×10^4 gm/mm². In making this comparison it should also be remembered that finer wire is able to withstand higher residual stresses.

Thus the welded grid combines the advantages of a circular frame and high residual wire tension with simplicity and cheapness of manufacture.

The coefficient of thermal expansion of the frame should be chosen in accordance with the yield strength of the wire at baking temperatures. Telcoseal alloy No. 1 (Telegraph Construction Co., Greenwich) has been found suitable for both tungsten and molybdenum wire grids on account of its low coefficient of thermal expansion between 0 and 500°C. It has been found helpful though not essential to nickel plate the frame to a thickness of two microns before welding. Nickel is known to "wet" tungsten and molybdenum, and the layer of nickel alloy which is formed helps to strengthen the weld.

The Design of Ring Grid Frames

As it is desired to retain the maximum residual tension in the wires, the grid frame must be designed accordingly. The pull of the wires tends to deform the ring into a plane oval, so that the longest wires particularly will suffer a reduction in residual tension. An examination using Euler's theory of columns shows that in all practical cases there is no likelihood whatever of direct buckling of the ring. Lateral deformation into an oval will take place first. The degree to which this is likely to occur will now be examined, with the object of enabling the frame width to be reduced to a minimum compatible with high residual tension in the longest wire.

An equation for the deflexion of a curved bar is developed by Timoshenko[7]. For a thin ring it is expressed by

$$\frac{d_2u}{d\phi^2} + u = -\frac{R^2M}{EI} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

where I is the moment of inertia of radial cross-section

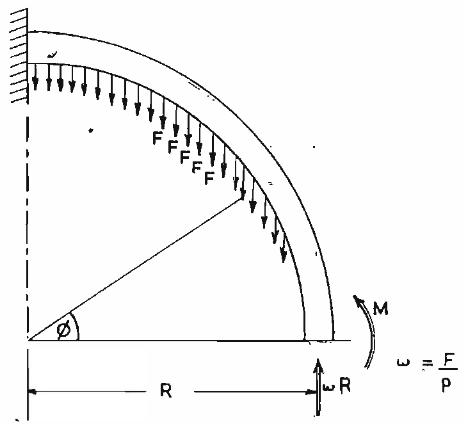


Fig. 7. Calculation of the bending moment M across a radial section of the frame

about axes such as yy in Fig. 8. We shall, at the cost of a small error, presume that the width of the frame is small compared with its radius, and that the frame is loaded by a large number of parallel wires spaced at pitch p and each exerting a force F so that the loading $\omega = F/p$ may be regarded as uniformly distributed. Using Castigliano's method to calculate the bending moment M across any radial section of the frame, (see Fig. 7) we find that

$$M = \frac{\omega R^2}{4} \cos 2\phi \quad \ldots\ldots\ldots\ldots \quad (11)$$

showing that when $\phi = 0$ and π, $M = \omega R^2/4$
and when $\phi = \pi/2$ and $3\pi/2$, $M = -\omega R^2/4$

Substituting this result for M into Equation (10) and solving the equation for the boundary conditions $\phi = 0$ and $\pi/2$, $du/d\phi = 0$ we find

$$u = \frac{\omega R^4}{12EI} \cos 2\phi \ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

so that for $\phi = 0$ and π, $u = \dfrac{\omega R^4}{12EI}$

$\phi = \pi/2$ and $3\pi/2$, $u = -\dfrac{\omega R^4}{12EI}$

The loss in tension in the longest wire is likely to be somewhat less than

$$\delta\tau = \frac{\delta F}{A} = \frac{2uY}{D}$$

In the manufacture of the welded grid this represents the loss of tension when the stretching clamps are released after welding. If this loss is not to exceed, say, 10 per cent of the total tension, then $\delta F/F = 0.1$, giving

$$I = \frac{AR^4Y}{0.6DpE} \quad \ldots\ldots\ldots\ldots \quad (13)$$

where $I = 4yx^3/3$

The above equation may be used as a rough guide for the design of the tungsten wire grid, the frame of which is not stretched by notching after welding. In practice, a thin flange and covering washer must be provided as shown in Fig. 6. In the molybdenum wire grid frame, which is stretched after welding, the tension in the wires is built up at the same time as the stress in the frame. The best and most economical design is one in which the greatest permissible stress in the frame f' and in the longest wire τ' are simultaneously established at the end of the notching process. From Equation (11) we find the maximum stress in the frame which will be found at $\phi = 0$ and π

$$f = \frac{\omega R^2 x}{I} + \frac{\omega R}{4xy}$$

The second term is in practice very small compared with the first, and may be neglected. Since $\omega = A\tau/p$

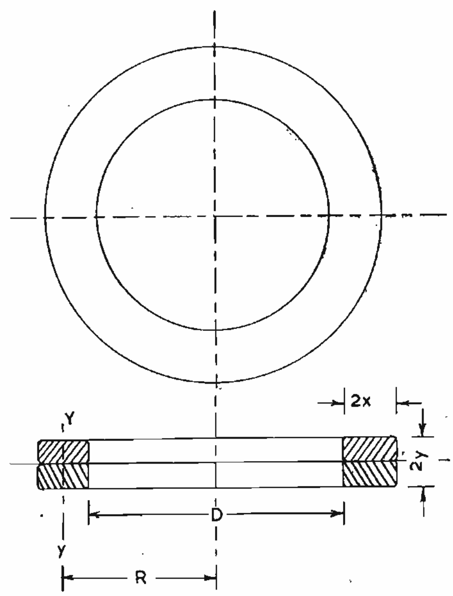
$$f = \frac{3\tau AR^2}{4x^2yp}$$

for a rectangular cross-section, so that

$$x = R\sqrt{\left[\frac{3A}{4yp}\left(\frac{\tau'}{f'}\right)\right]} \quad \ldots\ldots\ldots\ldots \quad (14)$$

This relationship may be used as a guide in the design of the molybdenum wire stretched frame. It shows that the ring frame of a stretched grid may be much weaker than that of an unstretched grid, which is to be expected. Theoretically the best place for notching is at $\phi = \pm\pi/4$ and $\pm 3\pi/4$ as here the stress is least. In practice the notches must be closer to the centre line otherwise the shortest wires receive no tensioning.

Fig. 8. Dimensions used in the calculation of deformation of the ring due to wire tension



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Piezo-electric Crystal Devices (Part 1)

By S. Kelly *

THE term "piezo-electric crystals" to most engineers implies only quartz crystals for frequency control, and to a lesser extent wave filters. This limitation, of course, has never been strictly true, and crystals of various types and forms are finding ever increasing uses; not only in the electronic field but throughout the scientific and industrial field as well. Piezo-electricity (or "pressure" electricity) is the name given to phenomena exhibited by certain materials in which pressure applied to the materials will cause them to become electrically charged, or conversely, in which an applied electric field causes them to deform mechanically. Piezo-electric phenomena are confined to crystalline substances, and more particularly to twenty of the thirty-two crystal classes. During the last decade, especially during the war years, a tremendous amount of research has been expended in the investigation of "artificially grown" piezo-electric crystals.

Difficulties of supply of natural quartz assumed major proportions during the second World War, and water soluble crystals were put forward as an alternative. The requirements were primarily a substitute for natural quartz as a frequency controlling element. Practically all artificial crystals are water soluble and therefore to a more or less degree are dependent on the humidity and temperature of the surrounding atmosphere; this does tend to limit the applications of water soluble crystals, although this defect can be overcome by methods to be described later. Frequency stability comparable to that obtained with quartz can only be obtained with crystals of high melting point and generally insoluble in water. Of all these crystals, quartz itself is the only one whose usefulness in frequency control is assured, and quartz appears to be the easiest to grow of all the insoluble crystals, but the difficulties associated with the successful development of quartz synthesis on a commercial scale are tremendous; pressures of several thousand atmospheres at high temperatures being required. However, by the end of hostilities certain crystals had been synthesized which could be used commercially as frequency controlling elements, subject to limitations. These were mainly a rather large frequency temperature coefficient, necessitating the use of temperature controlled ovens, the control being ± 0.2°C to a nominal temperature of usually 50°C, the temperature coefficient 4 to 8 parts per 100,000 degrees centigrade over a range of 0°C-90°C. The most suitable crystals were neutral potassium tartrate, ethylene diamine tartrate, and dipotassium tartrate.

Crystals for Transducers

Parallel with the development of crystals for frequency control, investigations were conducted to ascertain their usefulness as electro-mechanical and electro-acoustic transducers, and to-day there are three of these crystals in commercial use and a fourth under intensive development. These crystals are:—

Rochelle Salt
Ammonium dihydrogen phosphate (A.D.P. or P.N.) †
Barium Titanates
Lithium Sulphate (L.H.) †

Of these four, Rochelle Salt is by far the most widely used. Ammonium dihydrogen phosphate, which has only recently been made available in useful sizes, is rapidly gaining acceptance due to its relatively high sensitivity and ability to withstand high temperatures. Lithium sulphate is used chiefly as a thickness and sometimes as a volume expander. The titanates, somewhat similar in construction to high "K" capacitors, can be made to show a marked piezo-electric effect and can be made up into the familiar bender "Bimorphs," ‡ but their long-term stability is still in some doubt.

Rochelle Salt and A.D.P. crystals are grown by evaporation. Seed crystals, which are correctly oriented slabs cut from the mother crystals, are placed in tanks containing a solution of the required salt together with minute amounts of other chemicals which are used to control the habit formation of the crystal. The tanks, which are usually about 3 ft. by 2 ft. by 1 ft. are kept in a constant oscillatory motion through an angle of about 10 degrees, at four sweeps per minute by a crank system. The temperature of the solution is brought to about 55°C, at which temperature it is fully saturated. It is then cooled at a predetermined rate, resulting in a supersaturated solution which is the condition required for the seed crystals to grow. Extreme accuracy of temperature control is required, and any sudden changes in temperature inevitably result in the destruction of all the crystals in that particular tank. The controlling chemicals are required in order that the crystals are grown to yield the most economical quantity of correctly oriented elements. The growing process usually takes a month to six weeks, depending on the final temperature to which the solution is cooled; this latter point being dictated by the maximum size of crystal required or conditions of ambient temperature outside the growing tank. Crystals of several kilogrammes without any flaws or veils are quite easily grown by this method.

In the case of lithium sulphate, however, it is not possible to grow the crystals by evaporation, and a reflux condenser system is used in order to maintain the required degree of saturation. The amount of condensate withdrawn from the growing tank determines the degree of saturation in a unit of time and governs the rate at which the crystal grows. Lithium sulphate is a much more difficult crystal to grow than Rochelle Salt or A.D.P. and the maximum size of crystal is very much smaller. However, refinements in the methods are yielding continuously improved crystals.

Rochelle Salt

Rochelle salt is chemically sodium potassium tartrate with four molecules of water of crystallization. This salt is highly water-soluble and under suitable conditions large crystals can be grown from saturated solutions of the material. The crystalline form of the material belongs to the diagonal holoaxial class of crystals and has three independent piezo-electric constants. In addition, there are nine independent elastic constants and three independent dielectric constants.

The piezo-electric effects in Rochelle Salt are fundamentally shear effects. In particular, an electric field parallel to any of the crystallographic axes gives rise to a shear stress in the plane perpendicular to the field.

The resistivity of dry Rochelle Salt, that is, at relative humidities below 45 to 50 per cent, is generally greater than 10^4 megohm metres. Because of this extremely high resistivity, and the high dielectric constant, the low frequency cut-off of tranducers made from "X" cut

* *Chief Engineer, Cosmocord, Ltd.*

† "P.N.," "L.H." are registered trade names of Brush Development Co.

‡ "Bimorphs" is a registered trade name of Brush Development Co.

Rochelle Salt is less than 1/10 cycle per second at all temperatures from −30°C to 40°C.

Rochelle Salt crystals will begin to dehydrate when the relative humidity drops to about 30 per cent and will begin to dissolve at relative humidities above 84 per cent. The surface leakage becomes appreciable at relative humidities above about 50 per cent. Continued exposure of a crystal to conditions outside the range 35 per cent to 84 per cent relative humidity may be expected to lead to ultimate deterioration. Because the crystal has water of crystallization, it has an appreciable vapour pressure. Figure 1 shows the vapour pressure curve of Rochelle Salt plotted against temperature, together with vapour pressure of water vapour. If the vapour pressure of the crystal is greater than the vapour pressure of the moisture in the surrounding atmosphere the crystal will lose water and dehydrate, and the surface of the crystal reverts to the basic salt. This condition considerably reduces the piezo-electric efficiency of the crystal, and in this condition it is deliquescent and it becomes increasingly sensitive to the

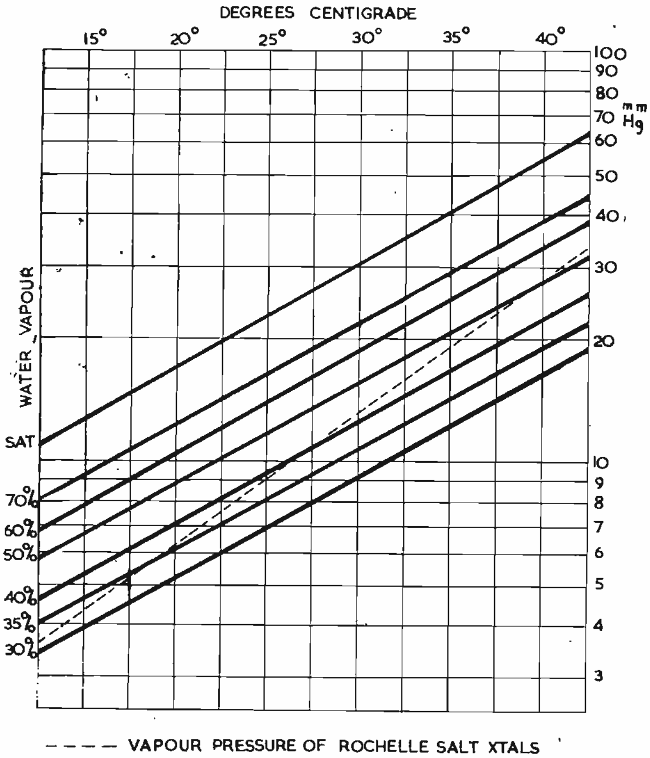


Fig. 1. Vapour pressure curve of Rochelle Salt and water vapour *vs.* temperature

humidity of the atmosphere. Above about 84 per cent relative humidity the crystal's surface will absorb moisture from the atmosphere and will eventually dissolve if it is kept for any period of time under these conditions. Fortunately, in most transducer applications, extremes of humidity are only of short duration, the average value lying within the safe range. Where the crystals are used in microphones, which for other reasons are hermetically sealed, the humidity restrictions do not, of course, apply.

In the early days of crystal device design, one of the greatest difficulties experienced with Rochelle Salt crystal elements was their apparent lack of reliability. Theoretically they should stand up to temperatures up to 55°C. In practice they were found to break down at as low as 35°C. This naturally imposed limitation on their use. Experiments carried out by Cosmocord Limited proved conclusively that these failures were due to varying and excessive moisture content in the crystalline structure.

The problem therefore was to protect each crystal from moisture in the air. The answer seemed to be a waterproof coating which would seal off the crystal from moisture, but there were certain difficulties in applying such a coating. First of all, the coating would have to be flexible, so as not to restrict the crystal's movement; otherwise the crystal would not function efficiently. Secondly the coating could not be allowed to alter to any great extent the dimensions of the crystal or this would affect delicate assembly work. Lastly, the coating would have to be capable of adhesion to the crystal. Obviously, a coating which did not adhere closely would strip off during assembly or during the crystal's working life. The requirements appeared to be mutually contradictory, a coating tough enough to keep out moisture, but at the same time extremely thin and flexible.

The final answer to the problem was a plastic coating of three-ply construction, the inner and outer layers of the coating consisting of a plasticized polyvinyl butyral resin which is a complete vapour barrier. The intermediate layer consisted of a combination of two different synthetic resins, suitably plasticized; and in addition, a primer coat between the three-ply coating and the actual crystal element, which serves as a waterproof adhesive.

Before this coating is applied, the crystals are conditioned in drying cupboards for at least 72 hours. These cupboards are specially designed to hold 3,600 crystals each. They are thermostatically controlled to a maximum temperature of 25°C. The air before entering the actual drying chamber first passes over silica gel which conditions the atmosphere to 40 per cent relative humidity.

When the crystals have been loaded onto frames and conditioned, they are dipped immediately as they come out of the conditioning cupboard. The method of dipping is as follows:

The crystals are suspended in clamps by their electrodes. The clamps are placed onto a frame which is then fitted to the machine and lowered into the solution. On an average each frame holds 120 crystals. The machine automatically withdraws the frames very slowly. Obviously if they are brought out quickly, drops of the solution will adhere to the crystals, and when the solution dries will leave bumps on the crystals. The withdrawal of the crystals is controlled by an ingenious device. Oil in a cylinder is forced through an adjustable needle valve which regulates the speed of withdrawal. This speed of withdrawal also determines the thickness of the coating. The most satisfactory speed has been found to be 2 mins. 24 secs. per inch of travel. Trouble occurred at first when the speed was controlled by this method because day to day changes in temperature altered the viscosity of the oil, thereby changing the speed. This was remedied by using a special purpose oil. Another factor to be considered is the viscosity of the solution itself. Therefore it is essential to control the temperature of the solution and to keep it at a constant heat which makes it ideal for coating the crystals. This is done by using elements to heat the tanks containing the solution which are thermostatically controlled, and keep them at a temperature of 28°C.

A very recent development in gramophone pick-ups is to suspend the crystal element in a plastic gel; this gel, besides conferring desirable mechanical properties to the element (the so-called "unbreakable crystal") also effectively hermetically seals the crystal and completely protects the unit from moisture. Tests made at 98 per cent relative humidity and 40°C over long periods of time indicate that units treated in this manner are completely water and moisture proof. It should be noted in passing that Rochelle Salt crystals will dissolve in their water of crystallization at temperatures above 55°C. Consequently, Rochelle Salt elements should never be subjected to temperatures in excess of 55°C and no attempt should be made to use them in applications at ambient temperatures above 45°C.

Between the two Curie temperatures (−18°C and 24°C) Rochelle Salt exhibits ferroelectric properties and the polarization field curves show hysteresis curves in a manner analogous to that shown by ferromagnetic materials. The result is that the dielectric constant of the material is the function of the field strength and also temperature. At very low field strengths the dielectric constant is much smaller than higher ones, and for field strengths below about 5 volts per cm the dielectric constant is about 200 at 0°C rising to approximately 1,500 at the Curie points. If the crystal is mechanically restrained in any manner the temperature capacitance anomaly is considerably reduced, and in the case of a bimorph the maximum change in capacitance with temperature is usually less than 3 to 1. Figure 2 shows the average of a group of bimorphs, with capacitance plotted against temperature. This curve was taken with the crystals freely suspended, and when they are coupled into electro-mechanical systems, which increases the loading, the temperature anomaly is still further reduced.

Ammonium Dihydrogen Phosphate (A.D.P. or P.N.)

Ammonium dihydrogen phosphate is a water soluble salt containing no water of crystallization. The crystalline form of the material belongs to the ditetragonal alternating class and has two independent piezo-electric constants.

The piezo-electric effects in A.D.P. are fundamentally shear effects. In particular, an electric field applied parallel to any of the crystallographic axes gives rise to a shear stress in the plane perpendicular to the field.

The volume resistivity of A.D.P. is sufficiently low that its influence on low frequency performance must be considered. As a consequence of the temperature dependence of the volume resistivity of A.D.P. the low frequency cut-off of A.D.P. transducers is also temperature dependent.

Ammonium dihydrogen phosphate transducers are relatively responsive to humidity changes if not protected by a moisture-proof coating. For an unprotected element, surface conductivity becomes appreciable at relative humidities above 45 per cent to 50 per cent and the material will become wet and start to go into solution at humidities above 94 per cent. The application of moisture-proof coatings previously described to an A.D.P. transducer, while not constituting 100 per cent protection from protracted exposure to conditions of high relative humidity, provides elements sensibly stable over long periods of time if the average relative humidity of 95 per cent is not exceeded. Alternatively, when used as supersonic transducers, protection against humidity effects is obtained by placing the elements in hermetically sealed containers filled with mineral oil. The maximum usable temperature with A.D.P. is 100°C.

Lithium Sulphate (L.H.)

Lithium sulphate is a water soluble salt containing one molecule of water of crystallization. The crystal belongs to the Polar class of the Monoclinic system, and has eight independent piezo-electric constants, thirteen independent elastic constants, and four independent dielectric constants.

The piezo-electric behaviour of lithium sulphate is complex in comparison with that of Rochelle Salt or A.D.P. Generally speaking both compressional modes and shear modes can be obtained with suitably oriented plates. In addition, the nature of the material is such that it exhibits the "hydrostatic piezo-electric effect"; that is, if a suitably cut lithium sulphate plate is subjected to a uniform hydrostatic pressure an electrostatic charge will be developed across its faces. The plates which find most application are Y cut plates with the major faces electroded and lying in the X-Z plane. Such plates behave basically as thickness expanders and also exhibit the hydrostatic piezo-electric effect.

The volume resistivity of lithium sulphate is greater than 10^{13} ohm metres, which is so large that the effects of volume conductivity on the low frequency response of lithium sulphate elements can be neglected in comparison with surface effects.

The water of crystallization in lithium sulphate is strongly bound in the material so that lithium sulphate exhibits no ill effects when exposed to conditions of low relative humidity or vacuum at moderate temperatures. Conditions of high relative humidity will lead to surface leakage effects and relative humidities in excess of 95 per cent will cause deterioration of the crystal.

The maximum safe temperature at which L.H. transducers can be used is 75°C.

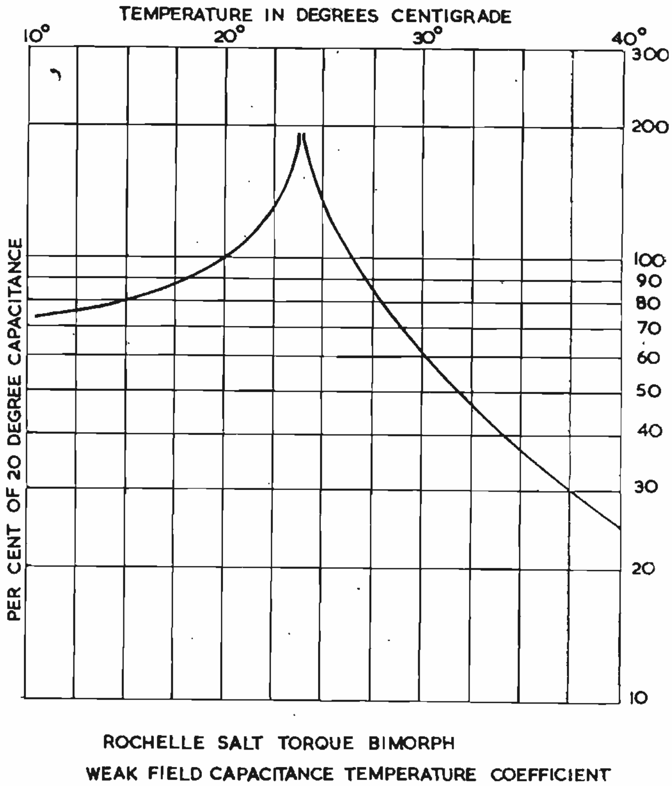


Fig. 2. Capacitance-temperature variation. Rochelle Salt Bimorph

Barium Titanate Ceramics

These transducers are the result of research into certain titanates, notably barium and strontium, in an attempt to provide high-K dielectrics with high dielectric strength for miniature capacitors. Unlike the crystals previously discussed, barium titanate has a multi-crystalline structure. It is basically a ceramic made up of a number of crystals of barium titanate (and sometimes additions of strontium or lead titanate) with their axes randomly distributed. They are fused at a high temperature, sometimes with the addition of small amounts of silica and other substances used as a binder. The material exhibits ferroelectric properties and, like Rochelle Salt, the permittivity is dependent on temperature. Figure 3 on page 103 shows a representative sample. There is a very large peak in permittivity at the Curie temperature, below which it drops rapidly. Below the Curie temperature the material exhibits hysteresis phenomena with greatly increased losses in strong fields. These phenomena are not present at temperatures above the Curie point and in the case of prepolarized ceramics which have been exposed to these high temperatures, the piezo-electric effect permanently disappears, although repolarizing will restore it. The Curie

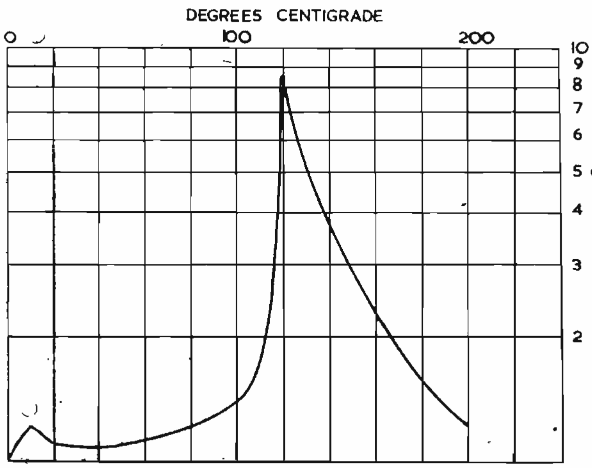


Fig. 3. Capacitance-temperature variation, Barium Titanate

temperature of barium titanate is about 120°; if some of the barium is replaced by strontium the Curie temperature will be reduced, and for a ratio of 70 : 30 barium/strontium, the Curie temperature is 0°C. The substitution of lead for some of the barium raises the Curie point although the permittivity drops somewhat. If such ceramics are maintained under an electric bias they will show a linear electric response to a vibrating force. The ceramic shows two electric modes, one is a compressional mode parallel to the electric field and is almost comparable to a quartz X cut, the other has a lateral compressional mode which can be used in the conventional bending assemblies similar to the Rochelle bender bimorphs.

It was found several years ago, during measurements of the dielectric strength, that the ceramic became permanently polarized and showed apparently permanent piezo-electric effects. Usually these effects are very small, but by suitable processing they can be made usefully large.

The dielectric constant of the ceramic is about 7 to 10 times that of Rochelle. The stiffness is approximately twice, and the ratio of voltage output per unit force is seven times worse than Rochelle, giving an overall efficiency of about −20db in respect of Rochelle when used in conventional assemblies. In order to bring the mechanical impedance to reasonable limits ceramics must be manufactured in extremely thin portions, usually about 0.005in. to 0.010in. The standard bimorph is about 1in. long by 1/16in. to 1/32in. wide and about 0.025 thick. The two elements forming the bimorph are cemented together with a conducting cement, the two outer surfaces being electroded in the normal manner and the electric connexions made by means of silver foil. Because of the high capicitance of the elements it is possible to use the two elements in series and even then the electrical impedance of the unit is only about 10-20 per cent of an equivalent Rochelle bimorph. The assembled bimorphs can then be used as conventional bender elements providing the necessary precautions required in the handling of very fragile ceramics are observed. Before these ceramics can be used commercially entirely new techniques of fabrication and assembly will have to be evolved. With all the present forms of conventional ceramic structures, the frequency response of transducers using them is restricted to a range of about 50 to 5,000/6,000 c/s. Long term developments now taking place show promise that this range will be considerably increased, and the mechanical and electrical properties improved to a point where in a few years' time ceramics may become a possible rival to Rochelle. It must be emphasized, however, that at this point ceramic transducer manufacture is an art rather than a science, and is in no way comparable to Rochelle except in freedom from deleterious effects of humidity and temperature of unprotected elements.

The various forms of titanate transducers at present available in commercial quantities are poly-crystalline in nature (unlike, say, Rochelle Salt or A.D.P., which are composed of only one crystal) and are rendered piezo-electric by electrical polarization after the elements are fired and usually after fabrication. The piezo-electric effect of titanate transducers is destroyed permanently if the transducer is raised to a point above the Curie temperature, although re-polarizing will usually return the titanate to the piezo-electric state.

One very disconcerting trouble is the inability to predict the life of a ceramic. Although the initial sensitivity of the ceramic element drops by 20 per cent in all cases in the first two or three weeks after polarizing, some ceramics fail after one or two months of use, and some are still active after 18 months to two years. We are, however, confident that with some refinements in the present method of manufacture they can expect a life of at least 18 months. A maximum limiting temperature with present production titanates is 70°C.

Crystal Fabrication

The magnitude and character of the piezo-electric effect in any crystalline material is greatly dependent on the orientation of the applied force or electric field with respect to the crystalline axis of the material. These axes constitute a co-ordinate system established by crystallographers for the purpose of simplifying discussions on crystals.

While in a sense these co-ordinate systems are arbitrary, they are at the same time so chosen as to coincide as far as is possible with the "natural" axes of the crystal, and in such a manner that the symmetry properties of the crystal are most easily described in term of their axes.

Piezo-electric devices are constructed using slabs of material cut from the crystal and never the whole crystal itself. These slabs are known as "cuts" and are identified by the axis perpendicular to the largest face of the cut. Thus if a plate is cut with its major face perpendicular to the "X" crystallographic axis, it is known as the "X" cut, etc. For certain purposes, cuts are made at other angles than perpendicular to the axes, i.e. the "zero temperature coefficient" cuts of quartz, and these cuts are given identifying names which are more or less descriptive of their origin.

Single Plates

The simplest piezo-electric element is the shear plate. This is a rectangular plate of piezo-electric material of such a nature that a voltage applied to its major faces produces shearing stresses in the plane of the plate.

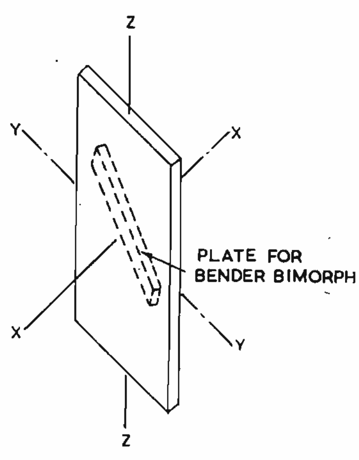


Fig. 4. A Rochelle Salt crystal showing the X, Y and Z axes

The X and Y cuts of Rochelle Salt and the Z cut of ammonium dihydrogen phosphate are the principal sources of shear plates for present day piezo-electric transducers. Figure 4 illustrates an X cut shear plate in the virgin crystal. The three axes X, Y and Z are shown in relation to the crystal structure and these symbols are used in all subsequent illustrations to denote their respective axis. Figure 5 shows an

X plate cut from the crystal. An application of a voltage in the X direction results in shear stresses set up at 45° angle to the Y and Z axes. Suppose that the corners of the plate are cut away to leave the dashed outline in Figure 5. It is evident that this element will expand along one axis and contract along the other if a voltage is applied to major faces. Such a plate, cut from a shear plate at 45° angle will form an expander element. A simple mounting of an expander block is easily obtained by fixing one end of the element to a base plate. The recti-linear mechanical load or drive can then be applied to the opposite end.

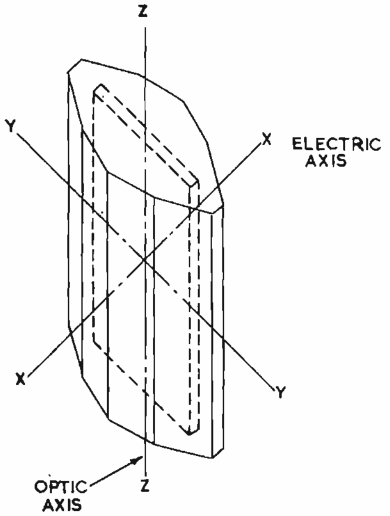


Fig. 5. An X-plate cut from the crystal shown in Fig. 4

It is important to observe that such an expander element undergoes extension and contraction in the directions of both its length and width dimensions. This has several consequences. First, it complicates the problem of mounting the element since any mounting which restrains motion in the width direction will affect the behaviour of the element, particularly the resonant frequency. Secondly, the existence of both length and width vibrations makes the behaviour of the element dependent to some extent on its length to width ratio.

Bimorph Crystal Elements

Piezo-electric shear plates can be used very advantageously in many situations because of their simplicity and small size. The mechanical impedance of these units, however, is somewhat high and the voltages which can be produced in simple shear or expander cuts, from, say, a microphone diaphragm, etc., are generally too small to be useful. To secure a reasonable mechanical or electrical output from these elements alone required auxiliary lever arrangements. It is immediately apparent that these will be unsatisfactory at high frequencies because of the lever's mass, to say nothing of the complications in design, thus nullifying the simplicity of crystal systems. These undesirable features of expander and shear plates can be eliminated by the combination of elements known as a " Bimorph ".

A bimorph is, in essence, a mechanical transformer operating on the principle of the bi-metallic strip. It will be remembered that in the bi-metallic strip large motions are produced by the unequal temperature expansion of two dissimilar thin metal strips firmly connected together. In a bimorph, the unequal expansions are, however, not provided by temperature changes, but by the use of two " mirror " expander or shear elements cemented together and connected in such a fashion that one element expands (or shears) in one direction, while the other element contracts (or shears) in the opposite direction.

(To be continued)

A Pulse Width Discriminator for Television Frame Synchronization

By A. N. Hunter, B.Sc., A.Inst.P.*

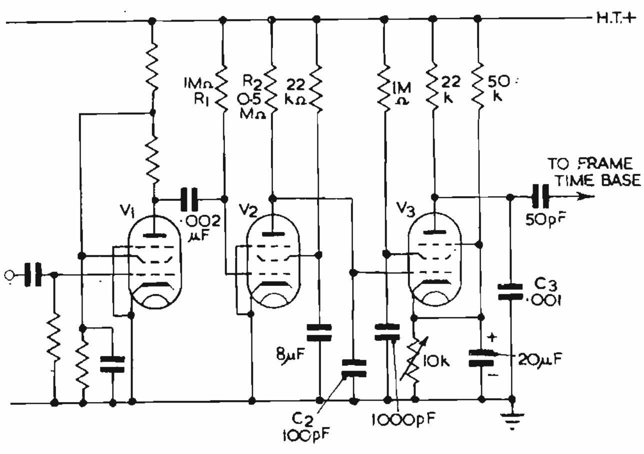
THE circuit described has been in use for twelve months in the author's television receiver and achieves perfect interlace with complete freedom from critical adjustment. It is therefore particularly suitable for home constructed receivers. Although separate pentodes have been used for $V1$ and $V2$ the circuit behaves satisfactorily with a double triode with separate cathodes, such as the 6SN7.

The output of any conventional synchronization separator giving negative pulses, such as is indicated for $V1$, is coupled to the grid of a switch valve $V2$. $V2$ is normally held hard on by returning the grid leak $R1$ to H.T. positive. Thus in the quiescent condition the capacitor $C2$ is discharged. On the arrival of a synchronizing pulse, $V2$ is cut off for the pulse duration and so generates an exponential waveform at its anode. Owing to the different duration of the two kinds of pulses the amplitude of this " sawtooth " will be four times as high for the frame as for the line pulses. This makes it easy to discriminate between the two sizes of "sawtooth" by means of the amplitude discriminator $V3$.

The output of $V2$ is directly coupled to the grid of $V3$ and this valve has a bias which may be varied through $R3$. Setting this bias so that the smaller " sawteeth," due to the line pulses, cannot get through, we have steep negative pulses at the anode corresponding to frame synchronizing signals. These pulses are used to trigger the frame time base.

The sides of the synchronizing pulses from $V1$ are certainly steep enough to define the commencement of the " sawteeth " to a microsecond or so. With the time constant of 50 microseconds specified for $R2C2$ the frame output from $V2$ attains about 60 volts with a H.T. supply of 250 volts. Allowing for the exponential form this means an average slope of about one volt per microsecond. If $V3$ has a grid base of 5 volts the pulse generated at its anode will fall in 5 microseconds and has an amplitude of 100 volts or so. This time represents the greatest possible variation in triggering the frame time base and is quite undetectable in the line spacing.

The capacitor $C3$ was added in order to stretch the back edge of the synchronizing pulses from $V3$. If preferred, $V1$ may be directly coupled to $V2$ by simply connecting $R1$ across the coupling capacitor $C1$ so as to preserve the D.C. level.



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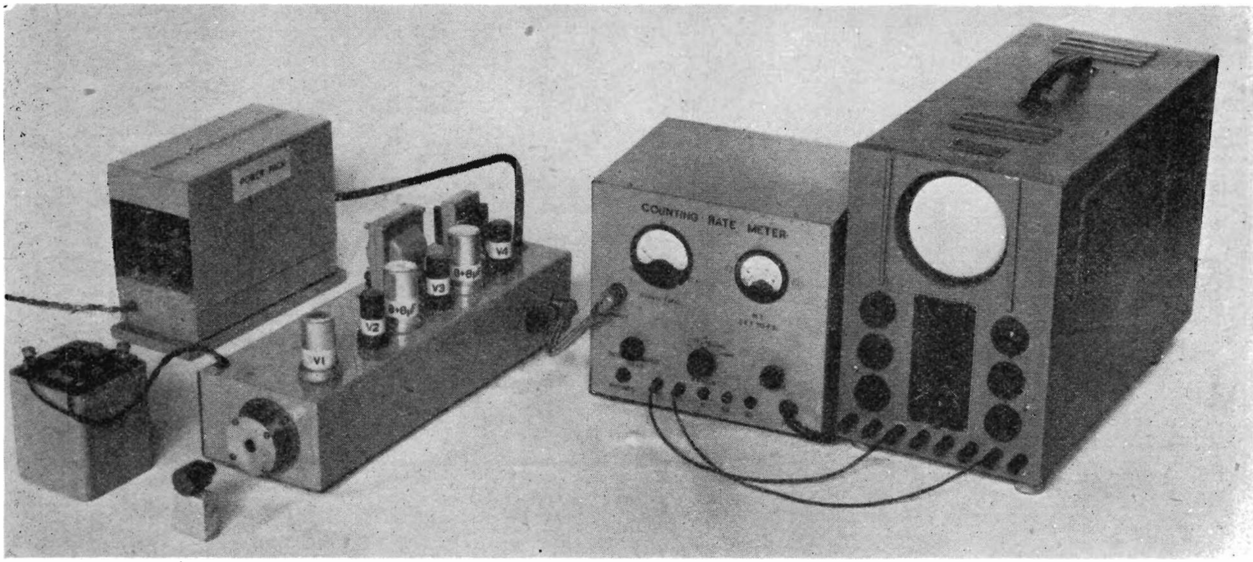


An ALPHA PARTICLE COUNTER for Students' experiments

By R. L. Woolley, M.A., A.Inst.P.*

THE apparatus described is for honours students' use in studying the α-activity of Thorium C and its products. It is convenient for this purpose as it is robust and stable, and its controls are simple. It can be constructed entirely from standard radio equipment, with large tolerances on almost all components, and very little trimming of component values is required.

Alpha-particles are detected by their ionization in a chamber 2mm deep. The ions from the track of one α-particle are collected by a strong electric field and the resulting voltage pulse is amplified and shaped by a four-stage amplifier with a gain of about 10^6. The pulses are next passed through a discriminator to remove background noise, and then counted by a Kipp relay counting-rate meter.

The ionization-chamber and amplifier are built in one unit and the discriminator and counting-rate meter in another. In addition a cathode-ray oscillograph and a power pack giving 300V, 50mA are required. A general view of the apparatus is shown in Fig. 1 (above).

Ionization Chamber and Amplifier

Details of the ionization chamber are given in Fig. 2. It is constructed entirely of brass, except for the insulators shown, which are carefully machined to fit with enough friction to hold the electrodes firmly. The front wall of the chamber is a wire gauze of 1mm mesh, maintained at about + 1,000V. The ends of the gauze wires should be covered with solder, to avoid corona leakage to the central electrode. The ions collected from the track of any α-particle which enters the chamber are driven by the electric field on to the central electrode.

The first valve V_1 (Fig. 3) is very important as it determines the background noise level. An EF50 or an RL7 is found most suitable. It is worth trying several valves, as the noise of different valves of the same type may differ by a factor of two or more. Considerable noise may be caused by bad contact between the valve pins and the socket; but with care this may be avoided with both ceramic and paxolin valve sockets. D.C. heating is used for V_1 and V_2 to avoid hum from mains harmonics. A signal-to-noise ratio of about 20:1 is obtained.

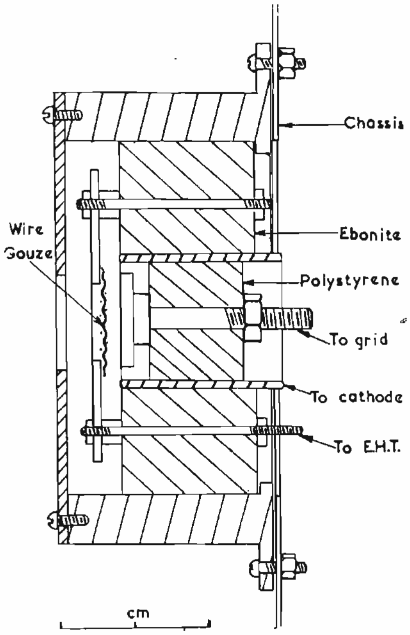
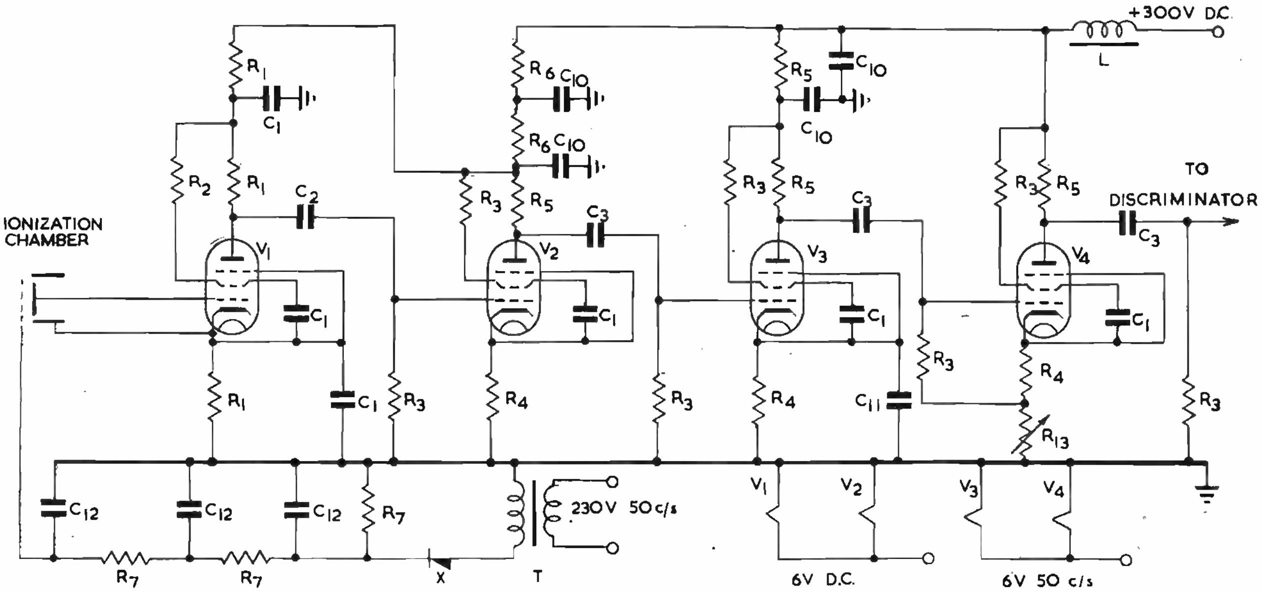


Fig. 2. Vertical section through ionization chamber

6AC7 valves are used for the three remaining stages as these are more robust than EF50's. A short time-constant coupling is employed between the first two stages to sharpen the α-pulse to about 50μS. The remaining stages have longer time-constants in order to transmit the pulse without distortion. In the present model the output is taken to the discriminator through a shielded cable, but unshielded wire may be used.

The chassis measures 45 × 15 × 10cm, and is constructed of 20 S.W.G. tinplate with internal screens between stages. Heater and H.T. leads and inter-stage couplings are taken through ½in. holes drilled through the inter-stage screens. All components except grid resistors and E.H.T. filter resistors are mounted on resistor racks.

* St. Andrews' University.



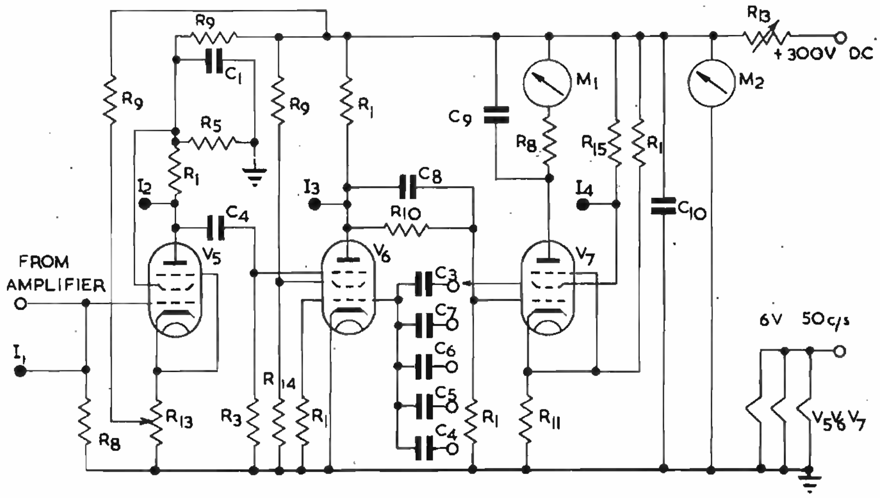


Fig. 3 (above) and Fig. 4 (right). Schematic of the complete equipment

COMPONENT VALUES

½ watt:—R_1,R_{16},R_{17}, 100 kΩ; R_2, 400 kΩ; R_3, 200 kΩ; R_4, 1 kΩ; R_5, 30 kΩ; R_6, R_{14}, 10 kΩ; R_7, 5 MΩ; R_8, 1 MΩ; R_9, R_{15}, 50 kΩ; R_{10}, 150 kΩ; R_{11}, 20 kΩ.
1 watt:—R_{12}, 30 kΩ. R_{13}, 0-10 kΩ.
250V wkg.:—C_1, 0.5 μF; C_2, 200 pF C_3, 0.01 μF; C_4, 100 pF; C_5, 300 pF; C_6, 1,000 pF; C_7, 3,000 pF; C_8, 10 pF; C_9, 16 μF (paper); C_{10}, 8 μF (electrolytic. C_{11}, 25 μF (electrolytic 25V wkg.) C_{12}, 0.5μF (1,000V wkg.).
L, 10 Henries. T, 1-3 ratio, e.g., Ferranti AF3 transformer with primary capacitor removed.
X, metal rectifier. M_1, 0-100 μA.
M_2, 0-250V. I_1, I_2, I_3, I_4, inspection sockets on front panel.
V_1, EF50; V_2, V_3, V_4, 6AC7; V_5, V_6, V_7, EF36.

Discriminator and Counting-Rate Meter

The circuit is shown in Fig. 4. The chassis measures 25 × 20 × 25cm.

The discriminator consists of an over-biased pentode V_5 with adjustable cathode bias. V_6 and V_7 form a Kipp relay. V_6 is normally conducting and V_7 biased beyond cut-off, but a negative pulse on the suppressor of V_6 will cause V_7 to conduct and V_6 to be cut off for a period of order $R_{15}C_4$ (or whichever capacitor is selected). Thus the average anode current of V_7 is a measure of the number of α-particles arriving per second. This is recorded on the meter M_1. The *R-C* filter across the meter reduces the effect of statistical fluctuations in the rate of arrival of pulses, especially at the higher counting rates.

The Kipp relay is in correct adjustment when the anode currents of V_6 and V_7 are correct. This adjustment is made after assembly. First adjust R_{14} till the anode current of V_6 is 2.0mA.

Then short-circuit C_9, remove V_6 from its socket, and adjust R_{10} till the anode current of V_7 is also 2.0mA. The reading of the meter depends on the H.T. potential, so that for accurate work, if mains fluctuations are likely, it is desirable to fit a potentiometer R_{13} and a small voltmeter M_2 with which the H.T. potential may be kept at about 250 V.*

Five ranges are provided, obtained by changing the time-constant of the Kipp relay, corresponding approximately to full-scale readings of 15, 50, 150, 500 and 1,500 counts per second. The pulses may be observed aurally by a pair of 'phones inserted in series with the anode load of V_5. The meter may be calibrated in terms of mains frequency with the aid of a C.R.O. as follows:— apply a 50 c/s deflexion to the Y plates and adjust the time-base frequency to any desired multiple or sub-multiple of 50 c/s by observing the appropriate stationary pattern. This known frequency may now be fed to the counting-rate meter by taking the signal from the time-base capacitor and feeding it into I_1 or I_2 according to its sign.

When using random pulses during counting, instead of periodic pulses as in calibrating, a small correction must be made to allow for the random pulses lost while the Kipp relay is on (i.e., V_7 conducting). Let *i* be the average current flowing through M_1 at an average count-rate of *n* per second, and let *I* be the average anode current through V_7 when it is conducting. It follows that V_7 is conducting for a fraction of i/I of the total time, and hence the

* Alternatively the control grid resistance of V_6 could be increased to about 1 megohm and connected to HT+ instead of earth, and M_2 omitted. This would compensate for H.T. fluctuations, as the duration of flip would then be inversely proportional to the H.T. voltage, and the product of current × time would be approximately constant. This device was suggested to the author by Mr. D. M. Mackay.

number of pulses missed will be $ni/(I-i)$ per second, and the true count-rate will be $ni/(I-i)$ per second. Here $I = 2mA$ and at full scale $i = 100\mu A$. Hence there is a 5 per cent correction at full scale, and proportionately less at smaller deflexions.

Typical Experiments

Study can be made of the α-activity of thorium active deposit from a ¼ millicurie radiothorium source (obtained from the Radiochemical Centre, Amersham). The active deposit is collected by recoil on a negatively charged brass block as shown in Fig. 5. The amplifier gain is first adjusted to give a maximum pulse height of about 30 V, monitored by a C.R.O. at I_1. The discriminator bias is then set so as just to cut out the noise and to give zero count-rate when the α-source is removed.

(a) A short exposure of 15 minutes to the radio-thorium source gives nearly pure thorium B. The ensuing growth and decay of thorium C may now be observed over a period of 48 hours with the source at a fixed distance (3cm) from the chamber.

(b) The ranges of the two groups of α-particles and their relative numbers may be deduced by counting the number of particles collected at different ranges.

(c) The ion-density along the track of an α-particle rises to a maximum near the end of the range. This variation of ion-density may be observed on the C.R.O. as a corresponding variation of pulse height with range. In addition, if a source is placed 4cm from the chamber, the short-range particles are near the end of their travel and give pulses nearly double the size of those of the long-range particles. By raising the discriminator bias the long range particle pulses may be completely cut off and the short-range particles counted separately.

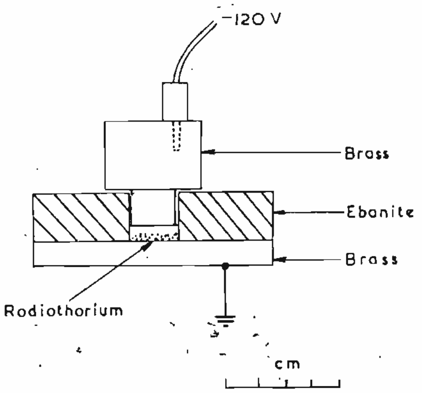


Fig. 5. Vertical section through radiothorium source

(d) The stopping power of thin metal foils may be measured.

Acknowledgments

Most of the assembly and testing of the apparatus was carried out by Mr. R. C. Eades, B.Sc. and Mr. A. J. MacInroy, B.Sc. Mr. H. Cairns has assisted in many ways and in particular suggested the use of an inter-valve transformer to provide the E.H.T. supply.

Use of a Cathode Ray Oscillograph as a Harmonic Generator

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

In order to determine the relative phases of the harmonic components of a complex voltage waveform, the apparatus described below was constructed. Apparatus for harmonic analysis, in general, only provides information in respect of the magnitudes of the harmonic components under test. For the determination of relative phase, one method requires a source of voltage of the same order of magnitude as the unknown component, of the same frequency, and of variable known phase. The procedure is to apply, in series, both known and unknown harmonics to the harmonic analyser; the analyser having initially been tuned to the test frequency. The phase of the known harmonic is adjusted until the analyser registers either a maximum or a minimum. In the former case the test harmonic will, at this setting, be in phase with the known harmonic, and in the latter 180° out-of-phase. This latter procedure is preferable since it allows for the " meter scale multiplier " switch on the wave analyser to be reduced, thereby providing greater accuracy in virtue of the increased sensitiveness at low values of input voltage. The phase shifting control is, initially, calibrated in terms of phase angle.

Fig. 1. " Negative " print of mask used for third harmonic generation

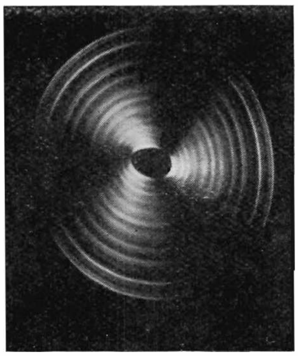
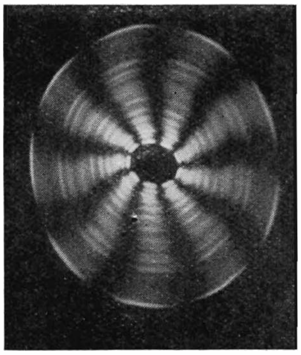


Fig. 2. Similar mask for ninth harmonic generation



General Arrangement of Apparatus

In principle the light reaching the cathode of an emission type photo-cell is varied sinusoidally at a harmonic frequency, the output voltage of the cell appearing across a load resistance being utilized, as outlined above, as the phase reference voltage. A mask of a type illustrated by the photographs of Figs. 1 and 2, is used to cause variation of the light excitation at harmonic frequencies.

For equal deflexional sensitivities, two equal voltages in phase quadrature, applied to the deflecting plates of a cathode ray oscillograph, produce a circular trace on the screen, caused by synchronous rotation of the electron beam. The trace acts as the light source in the harmonic generator. A mask having, say, five radial arms, placed between the screen of a tube and the photo-cell, gives rise to an output voltage of five times fundamental frequency. Furthermore, a sinusoidal distribution of the shading on the mask, circumferentially, produces a sinusoidal output from the photo-cell. The masks are photographic negatives, mounted in a frame permitting adjustment into a position of symmetry with respect to the circular trace. The photo-cell output is fed to the output potentiometer o-o', via an R-C amplifier and a parallel-T network, tuned to eliminate all 50 c/s. " pick-up." Pavlat and Gilson,[1] have outlined a circuit using a C.R.O. and a mask, in the form of a silhouette cut from cardboard. Their apparatus however, is designed to produce waveshapes, for medical purposes, of outlines not readily obtained by means of electronic circuitry.

The phase of the output wave is varied by time displacement of the electron beam, caused by shifting the phase of the voltage applied to each pair of deflecting plates by the same amount. The 50 c/s. input is fed to

* *A. Reyrolle & Co., Hebburn-on-Tyne.*

points *b* and *d* of the phase-shifting bridge *abcd*. The bridge output goes to a potentiometer *ef*, supplying the quadrature device *ghj*. From *ghj*, two voltages, in quadrature, are applied symmetrically to the deflecting plates of the C.R.O. The potentiometer *ef*, though not essential to the operation of the circuit, is necessary during production of the photographic negatives for the various frequencies. Details of circuits for the production of circular traces may be found in the numerous works of reference on the C.R.O., some of which are listed at the end of this article.

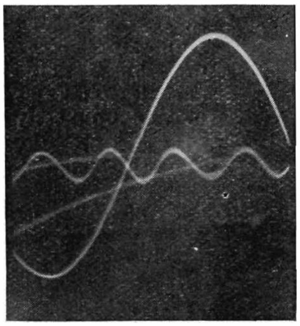


Fig. 3. Fifth harmonic output of the generator, expressed as a Lissajou figure

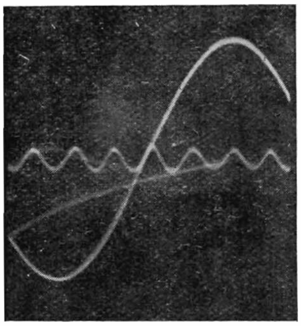


Fig. 4. Seventh harmonic output, in phase

Method of Producing the Masks

A circular trace may be modulated by applying, between grid and anode of the C.R.O., a voltage having a frequency that is an integral multiple of the fundamental. In order to produce photographic negatives for use as masks, the procedure adopted was to photograph the modulated circular trace, with a short time exposure, at the same time varying the trace diameter with the potentiometer *ef*. Figs. 1 and 2 illustrate masks, made by this method, for third and ninth order harmonics.

The modulating voltage, in all cases, was supplied by a dynatron oscillator, having a near-sinusoidal output waveform. In practice, it was not found too difficult to maintain the oscillator output constant in phase, during the period of exposure. If the phase varied slightly, the effect was to cause the "arms" of the mask to curve in either a lagging or a leading sense. A slight tendency towards this is apparent in the mask for the ninth harmonic (Fig. 2). Slight phase variation of this nature, however, does not appreciably alter the output waveform. This is particularly true if the circular trace, during operation of the apparatus, is de-focused, so that it embraces a radial distance of approximately one centimetre on the mask. This is the main reason why it was found desirable to vary the diameter of the modulated trace during exposure.

The effect of small variations in waveform, due to variations in shading, at any diameter, thus tend to cancel out with small variations at other diameters.

Calibration and Operation

During operation it is possible to obtain variation of output by alteration of the brilliance control of the C.R.O. Rather more satisfactory, however, is to maintain constant brilliance, and provide for output variation with the potentiometer *o-o'*.

Calibration may be effected by using a double beam type of C.R.O. as an indicator. A potentiometer is used to apply a fraction of the input voltage at *bd* to give deflexion of one beam. The generated harmonic, applied to cause deflexion of the second beam, is automatically synchronized with the first trace, since it is derived from the same source. By setting up a scale of degrees, along the X-axis of the screen, positions of the pointer of the resistor *bc* may be plotted against the phase of the harmonic, with respect to the fundamental sine wave. An alternative, and more satisfactory arrangement, is to supply the potentiometer *ef* from one of the phases of a three-phase phase shifting transformer. This instrument has the advantage of having a uniform scale of degrees with rotation, over 360° if required, in contrast to the cramped and restricted scale of the phase shifting network. For purpose of calibration and subsequent use, the instant when both the reference wave and the harmonic are passing through zero, increasing in a positive sense, is taken as 0°, and the "in-phase" condition. Figs. 3 and 4 show the wave-forms obtained of the fifth and seventh harmonic outputs respectively. The former illustrates the "180° out-of-phase", and the latter the "in-phase" condition.

The maximum voltage available for any harmonic was of the order of three volts. This was quite adequate for the purpose for which the apparatus was constructed. Higher order outputs could be obtained simply by the use of an additional stage of amplification.

Masks were constructed for harmonics from the third to the eleventh, inclusive. With no additional difficulties, masks for the thirteenth harmonic and upwards could be made using the same technique. An Admiralty pattern medium voltage tube, (W 1071/ACR 1) electrostatically focused and deflected, was used. Almost any tube will serve, however, the main consideration being that the trace should be bright enough to ensure adequate illumination for the photo-cell. The light detector used was a Baird, type VA11 photo-cell, with 200 volts H.T. The complete circuit arrangement is indicated in Fig. 5, points "*ef*" being shown supplied by a phase-shifting bridge.

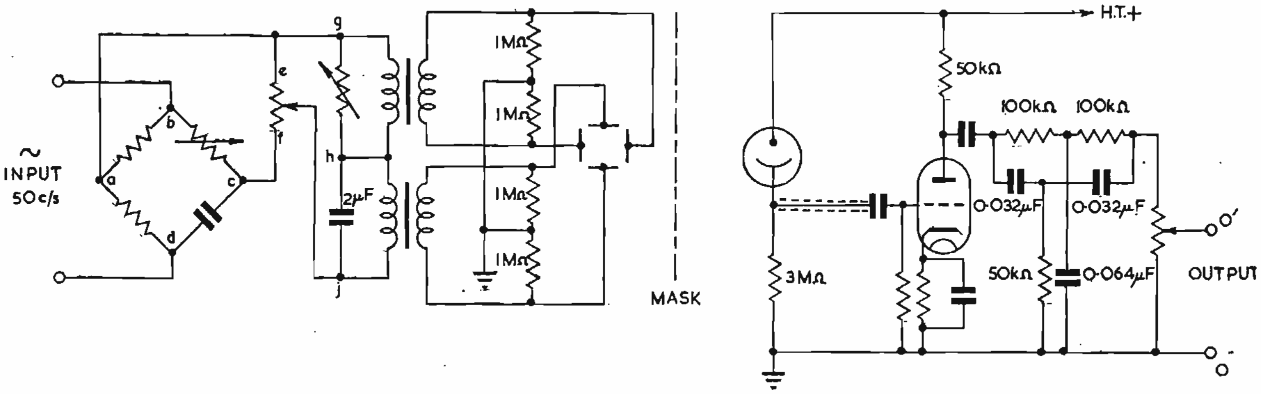


Fig. 5. Complete circuit arrangement

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An Electrometer Impedance Convertor

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

THE use of the 954 acorn and similar valves, operated under reduced potentials in order to achieve low grid current has become a well-known method of obtaining a high input impedance for electrometer applications.[1,2,3] The signal can be applied either to the control grid or to the suppressor. The former method leads to a lower input capacitance, as the grid is screened from the anode, but does not provide as low a grid current as the latter (which is stated to be 10^{-14}—10^{-15} amp.). In order to obtain a linear response to the applied signal, and to reduce the dependence of the input impedance on the signal it is usual to apply amplification to the output of the electrometer stage, and to feed the amplified output back in opposition to the signal on to the low impedance end of the grid resistor. In this way the operating potential of the electrometer grid scarcely changes and the input impedance is not varied by the signal. Examples of this use of feedback are to be found in the papers of Graham, Thode and Harkness[4] ($G3$ injection), and Downing and Mellin[5] ($G1$ injection); the circuits were used in conjunction with a mass spectrometer and an ionization gauge respectively. The application of 100 per cent feedback means that the E.M.F. appearing at the output of the amplifier is equal and opposite to the signal applied to the electrometer grid, but the output E.M.F. can readily be measured as the amplifier provides sufficient current to operate a meter. Hence the appellation "Impedance Convertor," rather than amplifier.

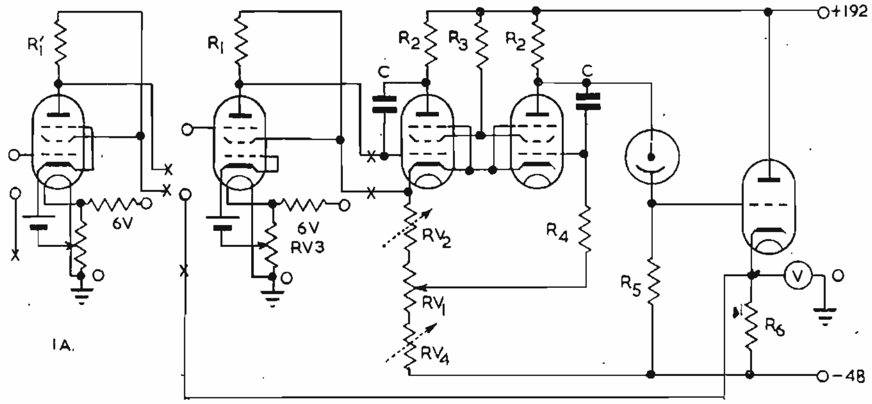

Fig. 1. Circuit for battery operation using G3 input. Fig. 1a. Modification of first stage when using G1 input.

Component Values (These apply to both figures)

R_1	24k ohm (wirewound)	R_8	1k ohm (wirewound, to carry 150 mA.)
(Fig. 1a)	100k ohm ,,	R_9	280 ohm ,, ,, ,,
R_2	100k ohm ,,	RV_1	50k ohm Helical potentiometer shunted with 150 ohms.
R_3	160k ohm ,,	RV_2	9×100 ohms tapped at 100 ohm steps.
R_4	100k ohm (carbon)	RV_3	500 ohm.
R_5	1M ohm (wirewound)	RV_4	15k ohm variable in series with 30k ohm fixed.
R_6	160k ohm ,,	RV_5	50 ohm to carry 150mA.
R_7	150 ohm ,,		
C	500 pF.		

The circuits of Fig. 1 and 2 show how the operating potentials for the electrometer stage can be derived from the cathode of the succeeding amplifier stage when either $G1$ or $G3$ injection is used.* It is only necessary to modify the anode load in order to keep on the linear part of the grid base of the amplifier valve. This arrangement makes the electrometer one of the resistances in a bridge across the amplifier cathode and earth, the output of the amplifier is thereby made much less sensitive to changes of the high tension supply than would have been the case if the electrometer anode potential was derived from a potentiometer across the supply.

In order to obtain the amplified signal in the correct phase for degenerative feedback it is necessary to follow the electrometer stage either with one stage of amplification and a phase invertor (as in Fig. 1), or to use two stages of subsequent amplification. In order to determine how much amplification was necessary, some measurements were made on a 954 operating with 4V on the heater, and the anode load returned to the source of screen potential. Using $G1$ injection, with 3V bias, and 100k ohm anode, the anode current at 30V high tension was 12μA and the stage gain was 2.2. At 20V H.T. the gain fell to 0.5. Using $G3$ injection and 30k ohm anode load and 4.5V cathode bias, the anode current at 20V H.T. was 110μA and the stage gain 0.7. These potentials are higher than those recommended by Nielsen, but the grid current was certainly not more than 10^{-13} amp. It appears that for most purposes adequate feedback is obtained if the electrometer stage output is amplified by a few hundred times and in this case it is sufficient to use a single high-gain pentode as amplifier, and to phase-invert the output. Even when two stages of amplification are used it is necessary to employ pairs of valves or twin valves in order to reduce the dependence of the system on the heater temperature (cf. Miller[6] and also the convertor described.[4])

The temperature of the cathode of the electrometer determines the contact potential between cathode and grid, and so the system is sensitive to variations in the low tension supply. The effect is less marked when $G3$ injection is used, for $G1$ is then strapped to the cathode. It is possible to apply a compensating E.M.F. into the cathode circuit by feeding a suitable portion of the heater potential into the cathode circuit as bias. Then over a limited range the bias alteration can be made to cancel the effect of the cathode temperature change following an alteration in the heater potential. This device has long been used in electrometer circuits.[7,8] It is necessary to adjust the potentiometer across the heater by trial and error until small changes of heater potential do not permanently alter the output reading. The bias is brought up to the required

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* *Prov. Patent*

value (usually about 4V) by insertion of a small battery in the cathode lead.

Following the phase invertor a VR105 gas discharge valve can be used to reduce the potential by approximately 110V, and so allow a cathode follower to operate with its output about zero potential. The output is fed back to the low impedance end of the input, and is measured by a suitable meter. It is necessary to correct the variations introduced by the cathode follower itself on account of changes in its cathode temperature. This can be done either by returning the indicating meter to a second cathode follower whose cathode potential is set at zero by connecting its grid to a slightly negative potential, or simply by increasing the proportion of heater potential fed into the electrometer cathode circuit as bias. There is, however, an argument for using the second cathode follower in a mains-operated equipment because the resistance between the zero potential tapping and the negative line, if made common to the electrometer cathode circuit and to the output, leads to positive feedback which limits the lowest resistance which can be used in the meter circuit. The use of the second cathode follower obviates this difficulty by providing a low impedance return to negative for the meter circuit.

operated circuit the cathode of the reference cathode-follower is set to zero with respect to earth by adjustment of the grid potentiometer *RV*5 (Fig. 2). The compensating potentiometer *RV*3 is set about midway, and the balance controls *RV*1 (and *RV*2) are operated so that a voltmeter across the anode loads of amplifier and invertor valves reads zero. A high value helical potentiometer is used for *RV*1 and it is shunted with a low resistance. In this way the difference of potential between individual turns is kept low and the setting is less disturbed by mechanical shock. The D.C. level is adjusted by means of *RV*4, while balance is maintained by use of *RV*1, until the output cathode-follower is at zero with respect to earth (and therefore to the cathode of the reference cathode-follower). The feedback loop is restored, and it only remains to adjust *RV*3. This should be done with a resistance in the grid circuit about equal to that which will be used most frequently. The output reading is observed at intervals and the direction and rate of the unidirectional change is noted. A known change in the setting of *RV*3 is next made and the rate of change of output reading again observed after resetting the balance. After repeating this once it is possible to calculate approximately where to set *RV*3, and the final adjustment is soon reached. By careful setting of *RV*3 it is possible to eliminate that part of the output reading instability which arises from changes in the heater circuit. The arrangement is rather insensitive to changes of H.T. on account of the use of a bridge circuit. The residual instability when battery supplies are used depends upon the value of the input resistance, with 10^9 ohms the short-term variation observed was 100μV, and over an hour the output reading changed by between 0.2 and 2mV. When an input resistance of 10^{11} ohm was used the short-term instability increased to about 1mV, which, of course, depends on the meter damping, but the drift was not changed.

Circuit Details

The 954's used as electrometer valves were selected, but most proved to be acceptable provided sufficient bias was applied, about 4V was generally ample. The test was made using a 10^{11} ohm input resistance, 1.5V was applied across a 1k ohm resistance in series with the low impedance end of the high resistance and the feedback loop, and the feedback E.M.F. was observed, or alternatively the difference between the battery E.M.F. and the feedback appearing at junction of the 1k ohm and the input resistance was measured directly. If the difference was less than 0.02V the valve was accepted; this corresponds to an input impedance of nearly 10^{13} ohms as a minimum.

All the resistances following the input circuit are wire-wound in order to reduce noise and temperature coefficient. For battery operation 6.3V heater valves are used as it was considered that their high conductance, unipotential cathodes, and freedom from microphony are sufficient to justify the higher drain on the L.T. supply (0.9A). The 954 is connected in series with 20 ohms to reduce its heater P.D. to 4V. CV138's are suitable as amplifier and invertor, and a 9001, triode connected, as cathode follower. The total H.T. supply required is 240V, tapped at 48V.

For mains operation the 954 is shunted to reduce the P.D. developed across it by a 150 mA stabilized supply, and 12V 0.15A valves are used as amplifier, invertor, and twin cathode follower. 12SH7's may be used in the former two positions and a 1633 (or 12AH7) as the latter. A 240V supply may be employed both as H.T. source and to heat the valves in series with a suitable resistance, as when properly adjusted a 1V change of this supply is equivalent to only 7 mV of signal, the supply does not have to be extremely stable. One side of the 954 heater, at about 50V positive with respect to the negative of the supply, is made the zero potential point. The capacitors *C* serve to reduce the bandwidth and prevent high frequency oscillation.

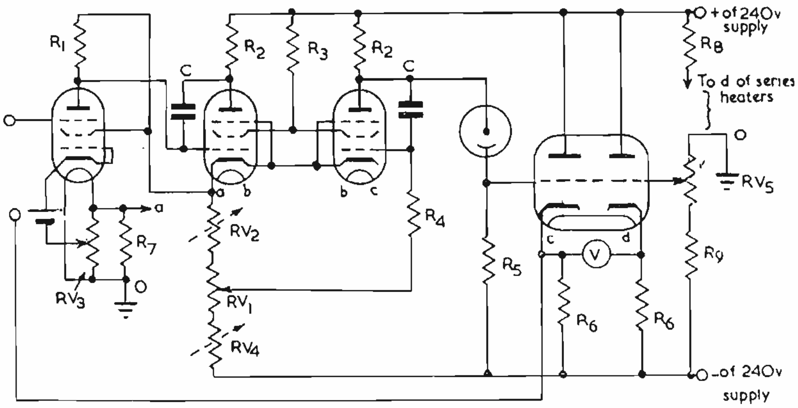

Fig. 2. Circuit for operation from 240V 150mA supply. The one side of the 954 heater and R7 is connected to the top of RV5, the other side (at a) is connected to the heater of the following valve, and so through to d, which is returned to the bottom of R8

Adjustments and Performance

In order initially to set up the circuit the feedback loop is disconnected, and the input grid is earthed. In the mains-operated circuit (continued above).

Applications

The low grid current and linear response renders the circuit suitable for the measurement of ionization currents, for measurement of bioelectric potentials using micro-electrodes, and for hydrogen ion determinations using a glass membrane electrode.

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A Note on Cathode Resistance Stabilization of C.R.T. Gun Current

By Hilary Moss, Ph.D.

WHEN making life tests on C.R.T.'s under conditions of static grid drive, it is almost always most desirable to achieve substantial constancy of total cathode current. Measurements on screen fatigue, for example, are difficult to interpret unless the beam current has been constant. Continuous manual adjustment of grid bias to achieve this end is often impracticable. It is obvious, however, by analogy with valve circuits, that insertion of a cathode bias resistor to develop auto-bias, must result in increased current stability. This arrangement also avoids the need for a separate bias supply. The purpose of this note is to deduce an expression defining the increase in current stability so produced.

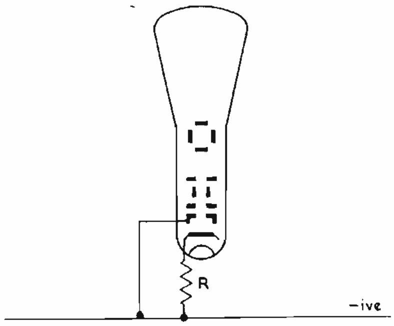


Fig. 1. Cathode ray tube working under auto cathode bias conditions

The simple circuit connexion is shown in Fig. 1, while Fig. 2 shows a typical modulation curve for a C.R.T.—this being the grid volts/cathode current relationship. E_c is the grid cut-off voltage, and E_d the grid drive (i.e., the modulus of the difference between the cut-off voltage and the actual grid voltage). The tube working point is thus at P. The author has shown elsewhere[1] that the modulation curve of Fig. 2 can be closely approximated by the equation

$$I_c = 3 \, . \, E_d^{7/2} \, . \, E_c^{-2} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where I_c, the total cathode current, is in microamperes for E_d and E_c in volts.

If the grid bias for the tube were derived by a cathode resistor as in Fig. 1, then the working point on Fig. 2 is found by drawing the load line through origin 0. Its slope is clearly α where $\cot \alpha = R$. The intersection with the curve at C is then the working point.

Fig. 3 is an enlarged view of the left-hand portion of Fig. 2 and in addition includes two modulation characteristics, (a) and (b). Characteristic (a) is the static curve for a tube of cut-off E_c on initial test. We suppose that after running for some period the cathode activity increases and in consequence a larger cathode current can be obtained for the same grid drive.* Thus the new modulation curve is (b), on which every ordinate is k times that on curve (a). (This assumption as to the effect of increased cathode activity is closely in accord with the facts. The cut-off voltage E_c, being almost entirely a function of the tube geometry, and depending but little on the physics of the cathode surface can be considered constant).

* *This frequently happens in practice with oxide coated cathodes and constitutes the phenomenon known as " ageing."*

The Stability Factor

If the tube were operating under fixed bias conditions with a constant grid drive of E_d (Fig. 3) then it is clear that the change in cathode current on ageing would be FD. But under auto cathode bias conditions of Fig. 1 the initial working point is D and the final working point not F but C. Thus the change in cathode current is CX. It is now natural to define the ratio FD/CX as the " stability factor ", since this quantity expresses the improvement effected by use of auto bias.

Evaluation of the Stability Factor

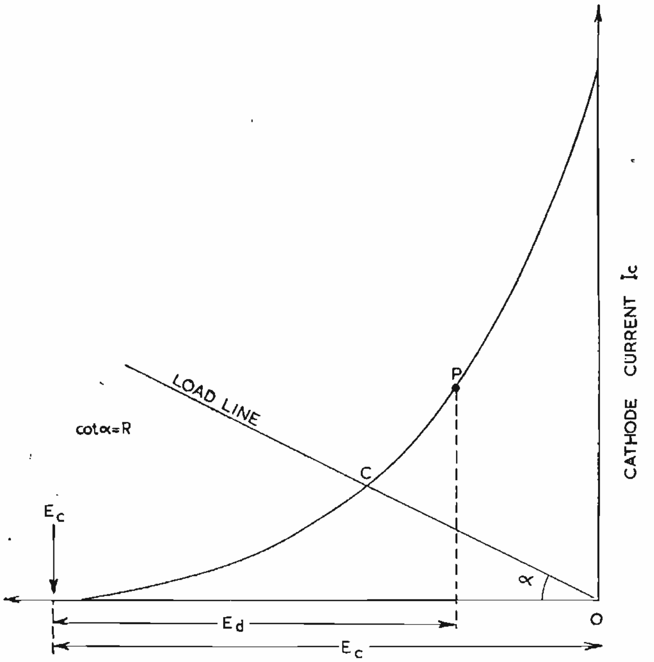
Refer always to Fig. 3. We wish to calculate the value of FD/CX.

Firstly we see immediately that

$$FD = 3 \, . \, E_d^{7/2} \, . \, E_c^{-2} \; (k - 1) \quad \ldots\ldots\ldots \quad (2)$$

To find CX we work in the boundary HCD. Now since HC is only small, we may consider HCD a triangle.

Fig. 2. Typical modulation curve for a C.R.T. Grid volts are plotted against cathode current



Using the facts that $CX = HX \, . \tan \theta = XD \, . \tan \alpha$ and that $HD = HX + XD$ we readily find

$$CX = \frac{HD \, . \tan \alpha \, . \tan \theta}{\tan \alpha + \tan \theta} \quad \ldots\ldots\ldots\ldots \quad (3)$$

Again we note that $HD = E_d - E_d'$. But points H and D both correspond to equal cathode currents. Thus

$$3 \, . \, k \, . \, E_d'^{\,7/2} \, . \, E_c^{-2} = 3 \, . \, E_d^{7/2} \, . \, E_c^{-2}$$

so that

$$HD = E_d \left\{ 1 - (1/k)^{2/7} \right\} \ldots\ldots\ldots\ldots \quad (4)$$

Finally to evaluate $\tan\theta$ we merely need to differentiate the equation to the modulation curve. This yields

$$\tan\theta = \frac{21}{2} \cdot k \, . \, E_d'^{\,5/2} \, . \, E_c^{-2} \quad \ldots\ldots\ldots\ldots (5)$$

Substituting the results of (4) and (5) into (3) and remembering by definition of the load line that $\tan\alpha = 1/R$, gives after some reduction

$$S \equiv \frac{FD}{CX} = 2 \, . \, R(k-1) \frac{\left\{\frac{21}{2} \, . \, k^{2/7} \, E_d^{5/2} \, E_c^{-2} + 1/R\right\}}{7 \, . \, k^{2/7}\left\{1 - (1/k)^{2/7}\right\}}$$

We now set $k = 1 + \epsilon$, where $\epsilon \to 0$ (this corresponds to a small change in emissivity)

Thus

$$S = \frac{2 \, . \, R \, . \, \epsilon\left\{\frac{21}{2}(1+\epsilon)^{2/7} \, E_d^{5/2} \, E_c^{-2} + 1/R\right\}}{7(1+\epsilon)^{2/7}\left\{1 - 1/(1+\epsilon)^{2/7}\right\}}$$

and in the limit as $\epsilon \to 0$ this yields the stability factor S as

$$S = \frac{21}{2} \; R \, . \, E_d^{5/2} \; E_c^{-2} + 1 \quad \ldots\ldots\ldots\ldots (6)$$

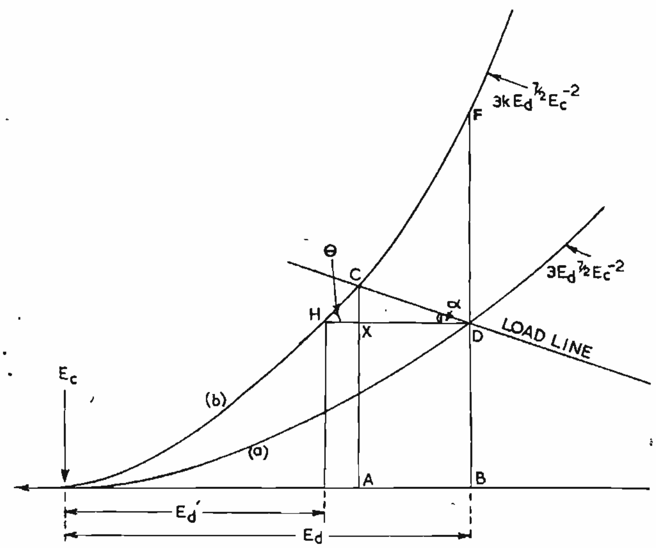


Fig. 3. Enlarged portion of Fig. 2 with modulation characteristics (a) and (b) added

In this expression R is in meghoms for E_d and E_c in volts. Finally from Fig. 3 we see that the cathode current at the working point D is equal to $3 \, . \, E_d^{7/2} \, . \, E_c^{-2}$ and that this must equal $(E_c - E_d) \tan\alpha$, i.e.,

$$3 \, . \, E_d^{7/2} \, . \, E_c^{-2} = (E_c - E_d)/R \quad \ldots\ldots\ldots\ldots (7)$$

Using this relation in (6) then yields

$$\text{Stability factor } S = \frac{7}{2} \cdot \frac{E_c}{E_d} - \frac{5}{2} \quad \ldots\ldots (8)$$

This is the relation sought. To determine the stability factor one merely draws the load line on the modulation characteristic. The intersection gives the working point and this immediately fixes E_d. From (8) the stability factor is then found at once.

Fig. 4 plots the stability factor and working current as a function of cathode bias resistor R for various cut-off voltages. Fig. 4 was obtained by plotting a number of modulation curves of the form of Equation (1) and drawing on them the appropriate load lines. Increasing the bias resistor naturally raises the stability factor, but a limit to this process is set by the reduction in cathode current so caused. However, it is apparent that useful

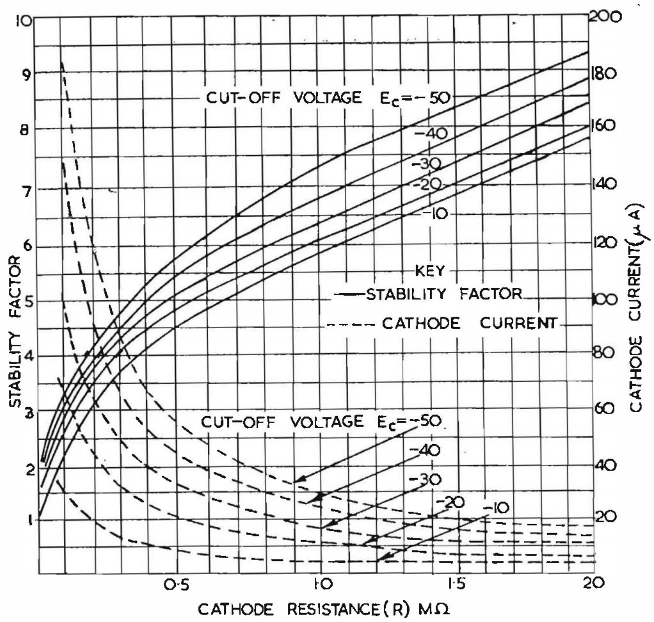


Fig. 4. Stability factor and cathode current vs. cathode resistance value for various cut-off voltages

improvements in stability can be obtained at beam currents of the order of 50 μA.

An obvious extension of this technique is to return the grid of the tube to a fixed positive source, so balancing the cathode bias developed across R. This permits high values of R to be used without restricting the cathode current, so that the stability can be made very high. Practical limits are set, however, by the tube leakage and the necessity for corresponding stability in the source of positive voltage to which the grid is returned.

REFERENCE

[1] "The Electron Gun of the Cathode Ray Tube"—Part 2. *Journ. Brit. Inst. Radio Engineers 6*, 99–129, 1946.

Kew "A" Watch Tests to end

ON March 1 the Kew "A" Tests, for 67 years an international criterion of accuracy in watches, will come to an end. New tests at the National Physical Laboratory will be made by means of equipment capable of recording errors as small as five thousandths of a second. A quartz-oscillator clock will provide the standard of time required and an electronic device will measure the errors with accuracy. New cold rooms and constant pressure equipment will be available for the tests.

The history of the Kew "A" Tests provides a measure of the advances in watch design and production which have taken place since their inauguration. Until 1915 tests were carried out by "eye and ear" comparison against a weight-driven pendulum clock, and it is doubtful whether the accuracy achieved was better than one second a day. In that year the use of a recording chronograph enabled variations of five-hundredths of a second in twenty-four hours to be detected. Several years later the inception of radio time-signals from Greenwich Observatory and the installation of an electrically operated "free" pendulum clock, provided further improvement in accuracy.

In recent years the performance of precision watches approached that of the recording equipment used, so that more accurate and impersonal methods of testing have become necessary. The new testing equipment will provide standards of precision which will be of great assistance to the British watch-making industry.

Notes from the Industry

New Radio Industry Council. The Radio Industry Council, reconstituted under a plan adopted by the old Council last year, held its first meeting on Thursday, January 25, when Mr. J. W. Ridgeway, O.B.E., was elected Chairman and Mr. G. Darnley Smith, Vice-Chairman.

The new Council consists of 16 members, four being nominated by each of the constituent associations (B.R.E.M.A., R.C.E.E.A., R.E.C.M.F. and B.R.V.M.A.), and nominations are for one year only.

Among other innovations under the new constitution are an Executive Committee consisting of eight members, two being nominated by each constituent, and a committtee of Secretaries of the R.I.C. and constituent associations with the Director, R.I.C., as Chairman.

The new Executive Committee, which will meet monthly to conduct all the ordinary business of the R.I.C., consists of: Mr. P. D. Canning, Mr. G. Darnley Smith, Mr. M. M. MacQueen, Mr. G. A. Marriott, Mr. F. S. Mockford, Mr. L. H. J. Phillips, Mr. W. F. Randall, and Mr. J. W. Ridgeway.

Television by Wire. The Rediffusion Group of broadcast relay companies, which relay the B.B.C. and selected foreign broadcast programmes to over three million people, announced recently that they have developed practical systems of television rediffusion which they are installing at home and abroad.

Viewers will have interference-free television and a choice of broadcast programmes brought to their homes for a weekly charge. This will include hire of the receiver, full maintenance and replacements.

Rediffusion have spent over £100,000 in the last 15 years in research and experiments on "television by wire" systems. One of these, a communal television aerial system, has been in operation in London flats and hotels since 1937, while another will supply simultaneous distribution of more than one television programme in addition to a choice of broadcast programmes.

This announcement brings hope to the eight million people living either in geographical "black spot" reception areas, or in parts of the country not covered by the television development programme which aims to cover 85 per cent of the population by the end of 1954.

Exports of British Radio Equipment in November, 1950, were valued at £1,943,613, the highest monthly figure yet and as much as the annual value of radio exports before the war.

Total value of exports for 11 months of 1950 was £15,987,217, exceeding the figure for the whole of 1949 by more than £3,600,000.

The Televiewers Association, which now incorporates the South Coast Televiewers Association is progressing with its plans to establish interference detector units in many fringe areas, and the project has the G.P.O.'s support. The detector used at Lancing for the last two years has proved a great success in reducing interference to a minimum.

The Association is now receiving applications for membership from all parts of the country, and anyone interested should get in touch with the Honorary Secretary, at 1 Carlton Mansions, Belle Vue Road, London, N.W.4.

Electronic Manual for Radio Engineers. We regret that a mistake occurred on page 75 of the February issue of ELECTRONIC ENGINEERING, when the price of the above mentioned book was quoted as 57s. net. The correct price is 85s. net.

Widney-Dorlec Display Unit. A display unit of the Widney-Dorlec cabinet system has been arranged by Hallam, Sleigh & Cheston, Ltd., of Bagot Street, Birmingham 4, who will be pleased to arrange for its exhibition throughout the country by the engineering society. The unit was recently used at the Television Society's exhibition. Organizing secretaries of associations wishing to have this system exhibited should get in touch with Hallam, Sleigh and Cheston, Ltd.

The Fifth Radar Association Reunion will take place at the Royal Empire Society Hall, Northumberland Avenue, Trafalgar Square, London, on Saturday, March 10, 1951. Tickets, 8s. 6d. each, including buffet, are obtainable from the Radar Association, 83, Portland Place, London, W.1.

Mullard Valve Replacement Guide. A new edition of the well-known Mullard Valve Replacement Guide has recently been issued and is available from wholesalers at 2s. 6d. net.

While the previous edition of this popular book covered all receivers marketed between 1933 and 1939, the new edition includes all receivers introduced between 1933 and 1949, both years inclusive. The dealer thus has at his disposal, in a compact and convenient form, lists of the valve complements of practically every commercial set at present being used in this country.

The receivers are listed in alphabetical order of maker's name, and the post-war models are grouped separately from the pre-war models. Where applicable, appropriate Mullard replacement valves are listed for all receivers manufactured between 1933 and 1939. For those valves for which no Mullard equivalent is available, the original valve type and make is quoted, and is printed in italics.

Receivers manufactured after 1939 are listed with their original valve complements, irrespective of make. Suitable Mullard replacements, if available, can be quite easily selected from the comprehensive Equivalents List printed on tinted sheets at the end of the book.

PUBLICATIONS RECEIVED

E.M.I.—ELECTRIC AND MUSICAL INDUSTRIES, LTD. This delightfully produced brochure covers the work carried out by the E.M.I. group of companies in the field of television. It covers cathode ray tubes, cameras, outside television sets, etc. Electric and Musical Industries, Ltd., Hayes, Middlesex.

TINPLATE HANDBOOK is a booklet by W. E. Hoare containing most of the facts and information necessary for buyers and users of tinplate, and includes an English-French-German-Spanish glossary of the technical terms of the trade. Steelmaking and tinning processes are summarized, while the major uses of the principal grades of tinplate are indicated, and testing methods are briefly described. This booklet can be obtained free of charge, from the Tin Research Institute, Fraser Road, Greenford, Middlesex.

SILICONE NOTES ON DOW CORNING SILICONE RESIN DC 935. This is a new silicone resin which is claimed to be more flexible and flame-resistant than other silicone resins, and the notes on it include a specification. Midland Silicones, Ltd., 49 Park Lane, London, W.1.

RADIO MATERIALS CATALOGUE is well produced and clearly illustrated, and has been compiled to cover the cables, insulated wires, capacitors, etc., specifically developed for radio and electronic applications. Only standard types are included, but modifications can be made for individual requirements. British Insulated Callender's Cables, Ltd., Norfolk House, Norfolk Street, London, W.C.2.

RADIO FREQUENCY CERAMICS is a profusely illustrated catalogue of the components, etc., made for radio frequency and other purposes by Bullers, Ltd., 6 Laurence Pountney Hill, Cannon Street, London, E.C.4.

N.S.F. RADIO AND ELECTRICAL PRODUCTS is a catalogue of engineering Data Sheets on the switches, capacitors, resistors and other products manufactured by British N.S.F. Co., Ltd., Keighley, Yorks.

G.E.C. COLD PRESSURE WELDING describes the work done in the G.E.C. Research Laboratories on cold welding and gives details of many new developments. It is well produced with clear illustrations, and may be obtained from the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

WIGGIN NICKEL ALLOYS NO. 329 is a new publication by Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham 16. It contains a variety of articles dealing with the uses of nickel-containing materials in industrial heat-treating and process equipment, including the use of nickel equipment in the production of phenol-formaldehyde resins.

HUNT'S CATALOGUE C.2663 covers a selection of types of capacitors for radio and electronic equipment manufactured by A. H. Hunt, Ltd., of Bendon Valley, Garratt Lane, Wandsworth, London, S.W.18. Copies of this well produced catalogue are available to bona fide equipment manufacturers.

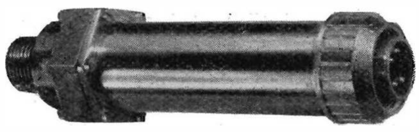
VACTITE RESISTANCE WIRES AND TAPES is a leaflet describing the alloys of high electrical resistivity made by this company. These comprise three different alloys which are made to meet a wide variety of needs for high resistivity materials. Vactite Wire Co., Ltd., 75 St. Simon Street, Salford 3, Lancs.

ON HANDLING "PERSPEX" is a reprint of an article printed in "Art and Industry" in May, 1950. It is profusely illustrated to show the many applications of this material. Imperial Chemical Industries, Ltd., Plastics Division, Welwyn Garden City, Herts.

GUIDE TO INDUSTRIAL FILM MAKING is a brochure published by the British Engineers' Association and the British Electrical and Allied Manufacturers' Association. Its aim is to aid manufacturers in assessing the factors affecting the costs of producing films and the supplementary charges likely to arise therefrom. This informative booklet can be obtained from either the British Engineers' Association, 32 Victoria Street, London, S.W.1, or the British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W.C.2, price 2s.

ELECTRONIC EQUIPMENT

A selection of the more interesting apparatus, components and accessories compiled from information supplied by the manufacturers



Barrel-type Pressure Pick-ups

(Illustrated above)

THESE pick-ups are primarily intended for the measurement of dynamic pressures from 1,000 to 50,000 lb./in.^{2} The pick-ups consist of a thin hollow-walled cylinder of beryllium copper, around which are wound four resistance elements. Stresses in the hollow portion are therefore registered as a change of resistance in the windings due to strain.

The intrinsic natural frequency of the pick-ups is very high, the limiting factors being the length of connexion from the source to the pick-up and the nature of the gas or fluid the pressure of which is to be measured.

Other types of pick-ups for pressures down to 1 inch of water are also available in this range of strain gauge pick-ups.

J. Langham Thompson & Co.,
Springland Laboratories,
Stanmore Hill,
Middx.

3-Speed Record Changers

RADIOGRAMOPHONE Development Co., Ltd., announce that all their radiogramophones and record players are now fitted with 3-speed record changers. Models are provided with two plug-in pick-up heads, one for use when playing normal 78 R.P.M. records and the other for long-playing 45 and $33\frac{1}{3}$ R.P.M. records. Both pick-ups are of the ultra lightweight high-fidelity type with sapphire stylus—specially designed for low record wear.

Radiogramophone models 1046 G3 and 850 G3 and record player model RPA5 are equipped for the automatic playing of eight 10-inch or 12-inch records (not mixed) at $33\frac{1}{3}$ or 78 R.P.M. Seven-inch 45 or $33\frac{1}{3}$ R.P.M. records can be played singly. For export, radiogramophone models 1046 G3 and 1048 G3 and record player model RPA6 incorporate a similar record changer which has the additional feature of facilitating automatic playing of ten 7-inch $33\frac{1}{3}$ or 45 R.P.M. records.

Radio Gramophone Development
Co., Ltd.,
Bridgnorth,
Shropshire.

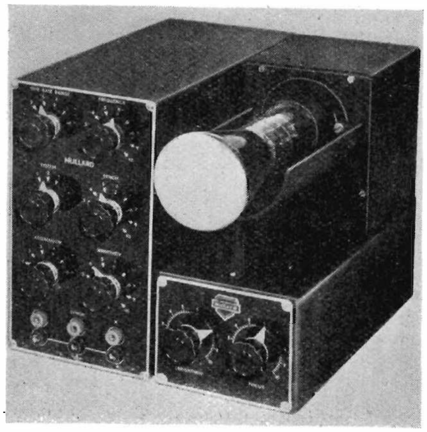
Moldseal Paper Capacitors

HUNT'S have developed a new housing to replace the waxed cardboard covering commonly used on standard types of paper tubulars.

In this new construction, the units are moulded in a special material developed by Hunt's, which provides a complete hermetic seal and ensures long shelf-life without deterioration in insulation resistance. Moldseal capacitors have a neat and clear appearance and are suitable for operation at temperatures up to 71° C. Types for use at higher temperatures will be available shortly.

Moldseal casing is already applied to Midget Metallized Paper, Type W99, and Miniature Metallized Paper, Type W48, and Foil and Paper, Types L51 and L51A are now being added to the Moldseal range. Comprehensive ranges of capacitors are available for D.C. and for A.C. operation and prices are economical.

A. H. Hunt, Ltd.,
Benson Valley,
Garratt Lane,
Wandsworth,
London, S.W.18.



Mullard Time Base/Amplifier and C.R.T. Unit

(Illustrated above)

A CATHODE Ray Tube Unit B100, with an associated Time Base/Amplifier Unit B101, recently introduced by the Equipment Division of Mullard Electronic Products, Ltd., has been specially designed to meet the needs of educational establishments where a moderately-priced instrument is required for the demonstration of A.C. theory and the various applications of cathode ray oscillography in modern research.

Although of moderate price, the two instruments combined electrically embody most of the features of the higher priced oscillographs normally used in industry and research. Among the wide range of demonstrations that can be made with this combined unit are: half and full-wave rectification, magnetic hysteresis, harmonics, frequency determination, Lissajou figures, smoothing, etc. It can also be used for a great variety of tests in the laboratory.

Another important feature of this combined instrument is that the amplifier section of the B101 unit can be used as a general-purpose voltage amplifier without modification. The frequency response is from 25c/s to 30kc/s and a stepped attenuator, in conjunction with a continuously-variable gain control, gives a control of gain from zero to a maximum of approximately 1880db.

Used in conjunction with the B100 Cathode Ray Tube Unit, the vertical amplifier of the Time Base/Amplifier Unit gives a maximum sensitivity of 25mV/cm over a time base frequency range from 25c/s to 30kc/s. The horizontal amplifier of this unit provides a sensitivity of 100mV/cm.

The Mullard B100 Cathode Ray Tube Unit is a simple instrument with its own supply unit. It embodies a 3in. C.R. Tube, which is exposed so that the effect of magnetic deflexion can be demonstrated. Both the vertical and horizontal deflexion sensitivities are approximately 0.2mm/V.

Mullard Electronic Products, Ltd.,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Signal Flasher Units

(Illustrated below)

NEW signal flasher units have been added to the Bulgin range of components.

The flashers are automatic units for switching alarm devices such as signal lamps, bells, buzzers, cyclically, to increase urgency of warning, and they are reliable and consistent. The heater-power is 1.8W peak, 0.9W average. Models are made with 4V and 6V heaters, for use in 4V, 6V, 12V low voltage supply uses, with bulbs of: 4V (of any wattage up to 4); 6V (0.3A, 1.8W on 12V or of any wattage up to 4 upon 6V supply); or 8V (0.4-0.5 A, use with 4V flasher upon 12V supply).

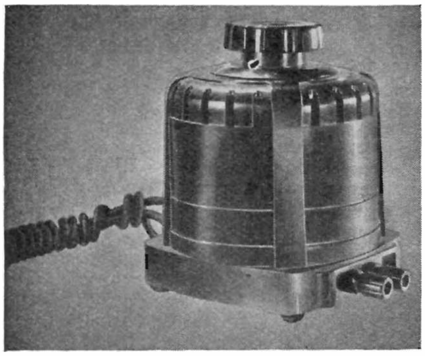
The clip-on models are particularly adapted to fix to standard Bulgin Signal Lamps, having tubular bodies, to increase the urgency of indication of such light-signals.

The illustration shows flasher list No. S.584, with bulb, for 4V operational test on top, and signal lamp D.9 underneath ready wired and connected together. The units are, of course,

usually sold separately, and wired up by the user.

Cycling times average 2-3 secs., but adjustment is provided to give 1-5 secs. cycles approx. In use, the light will first show steadily, but will quickly commence flashing, to draw stronger attention to itself if its warning is, e.g., ignored, or if no requisite action (following its signal) be taken.

A. F. Bulgin & Co., Ltd., Bye Pass Road, Barking, Essex.



New Range Variable Transformers

(Illustrated above)

PHILIPS variable transformers, built on the auto-transformer principle, are now made in 10 different types varying in output from 130VA to 2080VA. Those having a capacity of 130-520VA are housed in a "Philite" casing while the heavier types with 1040VA and higher have a metal casing.

With these transformers, which are fitted with a graduated scale and a knob, a secondary voltage can be obtained that is variable from 300V to 20 per cent above the nominal primary voltage; the maximum output with any secondary voltage is limited by the permissible secondary currents listed in the table below, which may not be exceeded.

The efficiency of the variable transformers is high, the graduated scale permits exact regulation to the fraction of a volt, and owing to the low voltage loss there is constant regulation.

They are of simple but robust construction and, if properly used, should have a very long service period.

Type for 220V Mains

Output VA	Secondary V	Secondary A	No-load Losses W	Type Numbers Build-in Type	Type Numbers Bench Type
130	0-260	0.5	5.6	84512	84513
260	0-260	1	6.8	84514	84515
520	0-260	2	9	84516	84517
1040	0-260	4	17	84518	84519
2080	0-260	8	25	84520	84521

Philips variable transformers are extremely suitable for regulating the intensity of illumination of shop-windows, stage lighting, etc.; and whether incorporated as an integral part of an apparatus or used on their own, have a wide field of application in research, testing and repair departments. In combination with valve rectifiers they can quite easily be used to give an efficient and continuously variable D.C. supply unit.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

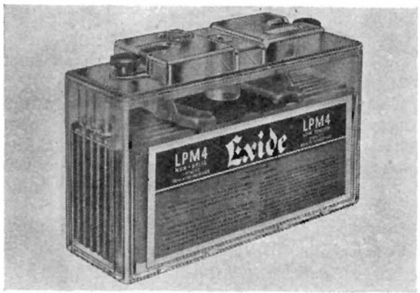
New Exide Unspillable Cell

(Illustrated below)

THE latest addition to the range of radio cells and small accumulators manufactured by Chloride Batteries, Ltd., is the new Exide unspillable LPM4 in moulded polystyrene container.

This cell was designed principally for "Walkie-Talkie" apparatus although it should also prove equally suitable for certain domestic radio receivers.

The polystyrene container offers many advantages, particularly in countries overseas. It remains unaffected by wide variations in temperature, thus ensuring a long life for the cell even under tropical conditions. Moreover, this tough, transparent material retains its attractive appearance throughout the life of the cell.



The separators are constructed of Lignex—a highly absorbent wood fibre material that greatly reduces the quantity of freely mobile acid in the cell. This type of separation, combined with the specially designed lid, prevents acid spillage in service, even on inversion. These cells can be supplied and stored in a dry condition, thus eliminating the necessity of frequent freshening charges and the possibility of deterioration while in stock.

The cell has a voltage of 2, with a capacitance of 30Ah at the 20 hour rate. The charge rate is 2 amperes.

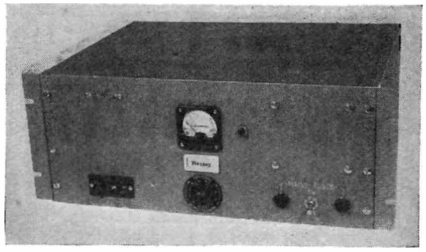
Chloride Batteries, Ltd., 6-10 Whitfield Street, London, W.1.

Aerial Multicoupler Wide Band Amplifier

(Illustrated top right)

DESIGNED to International Aeradio Specification, the Aerial Multicoupler Wide Band Amplifier, Type PV.14, introduced by the Plessey Company, Ltd., Ilford, Essex, permits the operation of up to ten communication receivers, within the frequency range 2-20Mc/s, from one common aerial system without loss of strength of individual signals or cross modulation effects. It consists of an amplifier, preceded by a high-pass filter attenuating incoming signals below 2Mc/s, which feeds ten cathode follower stages designed to work into 75 ohm unbalanced loads.

The amplifier section consists of two identical sections each of two EF91 valves in parallel and driving five cathode followers, type ECC91. The coupling between the amplifiers and cathode followers gives attenuation of signals above 20 Mc/s, and the output response has been kept within ±3db throughout the pass range. While the amplifier will



handle signals up to 250mV without overloading or the cross-talk factor becoming excessive, the attention paid to keeping the noise factor within the amplifier to a minimum also allows signals of the order of 1μV to be handled.

Mains consumption is approximately 130 watts, and the supplies catered for include 110 volts, 60c/s, as well as the standard 200-250 volts, 50c/s of this country.

The unit is suitable for international rack-and-panel mounting.

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

Five Ton "Hydroram" Arbor Press

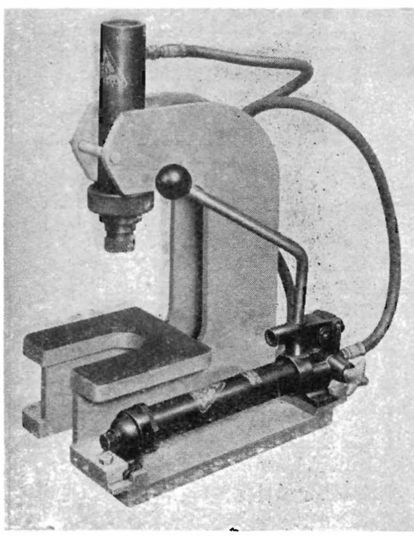
(Illustrated below)

CHAMBERLAIN Industries, Ltd., have recently introduced a 5-ton hydraulically operated arbor press into their range of accessories for the Hydroram repair kits.

The arbor press is robustly fabricated from mild steel. The standard Hydroram pump and ram unit can be fitted easily to provide the power source, and the press is suitable for holding all classes of light assembly work covering bending, straightening, clamping and shearing.

Provision is made for fitting special tools to the accurately machined work table, which is 7½in. square, while the base is provided with fixing holes for rigidly bolting the press to a work-bench or table. The maximum ram stroke is 6in., with a maximum retraction of 6½in.

Chamberlain Industries, Ltd., Staffa Works, Staffa Road, Leyton, London, E.10.



BOOK REVIEWS

Recent Advances in Radio Receivers

By L. A. Moxon. (Modern Radio Techniques Series). Cambridge University Press. 1949. IX + 183 pp. 18s.

SINCE 1938 considerable progress has been made in radio receiver technique to meet some exacting specifications of radio receiver design. The author, who himself has contributed to the advance by original research work, presents in his book some aspects of the progress made.

Three specific receiver problems are discussed in the book. Firstly, the problem of reducing the internal noise level of a receiver to as low a value as possible; secondly, the problem of obtaining a faithful response of a receiver to impulses of very short duration; and thirdly, the general tendencies in the design of broadcasting, television, and communication receivers. The subject-matter is presented under the following chapter headings: concept of noise factor, theory and practice of amplifier design for minimum noise factor, noise factor of mixers, measurement of noise factor; intermediate-frequency amplifiers; trends in practical receiver design, some new kinds of receiver; and some new circuit tricks. An appendix contains design formulae for intermediate-frequency amplifiers.

The author, drawing on a rich fund of practical knowledge and of first-hand research experience, has admirably achieved his aim in giving a coherent and clear picture of the problems under discussion. A welcome feature of the book is the emphasis placed on describing basic physical concepts rather than discussing solutions of specific problems.

This is an important book for electronic engineers engaged in designing valves and receiving circuits in the short-wave ranges. The book is also warmly recommended to advanced students of electronics and to research workers who wish to bring their knowledge up-to-date.

R. FEINBERG

Electronic Equipment Construction

300 pp. Placed by the Office of Naval Research, Washington, D.C., and issued by Stanford Research Institute, California, U.S.A. Available from the Department of Commerce, Office of Technical Services, Washington, D.C. Price $7.00.

THIS book is a compendium of recent advances in construction techniques and components designed to facilitate servicing and maintenance of electronic equipment. It has been compiled by a team of scientists from the Stanford Research Institute who have visited companies and Government establishments both in the United States and England, in order to get the widest coverage on their subject. It is fully illustrated and furnished with tables setting out all available information on the performance of the product described and examined by them.

The book falls into three main sections dealing with components, construction techniques and activities of typical organizations respectively. In addition, there is a section devoted to Research and Development requirements. While the first three sections give a complete survey on what has been achieved in this field, the latter section deals with the gaps which still have to be filled in before the progress which has been made can be fully exploited in practice. Nevertheless, what has been done to reduce size, weight, production costs and maintenance requirements is impressive, and the book, which is unique, fills a need for a summarization of all techniques and components available up to date to the electronic engineer. It is valuable also as a guide to possible sources of supply, and the lay-out of the book permits a ready choice of methods and products most suitable to any particular task.

Outstanding features in the book are the summary on printed circuits and compacted components. In their purpose to present the numerous practices and ideas in aggregate the authors have certainly succeeded and the book "may well provide a source of future major advances" by being not only a text book, but also a stimulus to the reader.

Mention should be made of the fact that the work of this project was done under the auspices of the Office of Naval Research.

P. P. HOPF

1950/51 F.B.I. Register

23rd Edition. 852 pp. Published for the Federation of British Industries by Kelly's Directories, Ltd., and Iliffe and Sons, Ltd. November, 1950. Price 42s.

THE F.B.I. REGISTER is unique among industrial directories published to promote Britain's export trade in that it provides a substantial cross-section of the most important producers of British goods in a very wide range of industry. It is the only authorized directory of this association of British manufacturers and the information contained in it is compiled by the publishers in close collaboration with the F.B.I., it being a requirement that only goods of members' own manufacture are referred to in it. The book is compiled and classified for quick reference with major instructions and cross-references in English, French and Spanish.

In its new form the 1950/51 F.B.I. Register now comprises seven sections: (1) Products and Services: which is a classified Buyer's Guide listing over 6,000 F.B.I. member firms under more than 5,000 alphabetical trade headings; (2) Advertisements (3) Addresses: an alphabetical directory of all F.B.I. member firms with their full addresses, telegraphic addresses, telephone numbers, list of products, and in many cases their home and overseas branches, agencies, etc.; (4) Trade Associations: classified (a) by trade categories and (b) alphabetically with full addresses; (5) Brands and Trade

Names: listed alphabetically for rapid identification of the products concerned and their manufacturers; (6) Trade Marks: showing reproductions of several hundred registered trade marks classified by trade categories for easy finding of sources of manufacture; (7) Addenda: covering the products and addresses of new members elected since the main sections went to Press.

Collins Wireless Diary 1951

Incl. 128 pp. technical data and figs. Collins. 1950. Price: 3s. 8½d. or, with pencil, 4s. 3½d.

COMPLETELY revised last year and with minor corrections to date, this diary is notable for its valuable compendium of technical data, which is just what the practising engineer needs to carry in his pocket.

Much practical data is given on general physical and mechanical properties, including a table of the elements. Lists are given of conventional symbols, units and dimensions, Greek symbols and Metric prefixes. Useful mathematical tables cover various powers of numbers, exponential and hyperbolic functions, logs., antilogs., trigonometrical ratios and formulæ.

General radio topics include lists of abbreviations and graphical symbols (not all, unfortunately, to B.S. 530:1948, and this section could profitably be expanded), a 17-page glossary of telecommunication terms (mostly agreeing with B.S. 204:1943) and a chart of the electromagnetic wave spectrum. After a discussion on the classification and allocation of radio wavelengths follow several pages detailing the principle long wave, medium wave, European and short-wave World stations, British television channels, and amateur channels, prefixes and codes. Useful wire tables are given for copper, fuses and resistance winding. *R*, *L* and *C* fundamentals, data and calculations are well summarized (especially the inductance formulæ) and A.C. and R.F. circuit formulæ are recorded. Formulæ are quoted for the design of attenuators and A.F. amplifiers. The following topics are described in general notes and circuits: negative feedback; tone control; power supplies; loudspeaker acoustics and matching (including a turns-ratio chart); reproduction from gramophone records (including a simple pre-amplifier circuit for modern magnetic pickups); microphones; propagation of electromagnetic waves, production of the carrier wave, modulation; principles of radio reception; eight pages on television (with particular reference to Alexandra Palace and pictures of the two B.B.C. Test Cards).

Several complete circuit diagrams of interest to home constructors cover a 5W and a 15W quality amplifier, T.R.F. and superhet tuner units, and an amateur telegraphy transmitter to cover octaves from 1.7 to 28Mc/s.

Three particular items of data have been found most useful from day to day by the present reviewer. Firstly, the two reactance and resonance charts for A.F. and R.F. (but why a distinct gap between them from 10-100kc/s?). Secondly, a decibel conversion table into voltage and power ratios. Thirdly, the comprehensive (low-power) valve basing tables (15pp.). These include International Octal and all British bases, old and new, "standard"-sized and miniatures. Each base connexion scheme is identified by a code number and filament ratings are given, the type lists and basings being included on the same page as far as possible. The old B4, B5 and B7 types are usefully collected as a simultaneous equivalents list. A few small air-cooled transmitter valves and television magnetic C.R.T.s are also summarized.

J. C. Finlay

The D.S.I.R. Annual Report 1948-49

260 pp. Published for the D.S.I.R. by His Majesty's Stationery Office. 1950. Price 5s. 6d.

THE D.S.I.R. Annual Report for 1948-49 begins with the Report of the Advisory Council which states a broad outline of policy, and also contains a great mass of information on researches in progress and completed.

The Advisory Council points out two matters of special concern. So many problems of admitted importance are brought up for consideration that it is difficult to ensure that due effort is devoted to each one. The Advisory Council also states that it is essential to be constantly on guard against undue dispersion of scientific effort.

The Council again draws attention to the lack of balance in the programmes of research, stating that not enough time and effort was being devoted to basic research. A number of examples are given of how basic research in past years is now bringing the answers to practical problems.

The section called "Summary of Work" mentions researches in a very great number of different subjects ranging over practically the whole field of industry. In the compass of one book it is not possible to explain the subjects fully, and detailed information can in most instances be obtained only from published technical information or direct from the Station or Research Association.

Forest Products Research 1948

46 pp. Published for the D.S.I.R. by His Majesty's Stationery Office. 1950. Price 2s.

"FOREST Products Research 1948" deals with the work carried out at the Forest Research Laboratory during the year. It covers testing of new hardwoods, entomological research and radio frequency timber drying.

In the section on the last mentioned item, the general investigation of the possibility of seasoning timber by radio frequency has been concluded. It is unlikely that this method, owing to practical and economic considerations, will be applicable to seasoning timber in bulk. but it might prove useful when applied to dimension stock valuable enough to make speed of drying rather than cost the main consideration.

Engineers' Dictionary Spanish/English, English/Spanish

By Louis A. Robb. 664 pp. 2nd Edition. John Wiley and Sons, Inc., and Chapman and Hall, Ltd., London. 1949. Price £5.

THE second edition of this technical dictionary is well bound and clearly presented in good print. It appears to cover all engineering terms, and should prove a useful volume in a firm with Spanish business, although the price is rather high.

MEETINGS THIS MONTH

INSTITUTION OF ELECTRICAL ENGINEERS

Unless otherwise stated, all meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, at 5.30 p.m.

Date: March 1.
Lecture: The London-Birmingham Television Radio-Relay Link.
By: R. J. Clayton, M.A., D. C. Espley, O.B.E., D.Eng., G. W. S. Griffiths and J. M. C. Pinkham, M.A.

Measurements Section

Date: March 13.
Lecture: The Testing of Fine Wires for Telecommunication Apparatus.
By: R. C. Woods and J. K. Martin.
Lecture: The Use of an Electrostatic Wattmeter for Magnetic-Loss Measurements.
By: J. K. Choudhury, M.Sc.Tech., and Arvon Glynne, M.A.
(Joint Meeting with the Radio Section).

Radio Section

Date: March 7.
Lecture: Design Considerations for a Radiotelegraph Receiving System.
By: J. D. Holland.
Date: March 13.
See Measurements Section Meeting.

Informal Meeting

Date: March 12.
Discussion: Electronic Power Control of Motors.
Opened by: E. W. Forster, B.Sc.

District Meetings

Date: March 14. Time: 7 p.m.
Held at: The Electricity Showrooms, Southern Electricity Board, 37 George Street, Oxford.
Lecture: The Use of the Synchrotron and Other Particle Accelerators in Atomic Research.
By: C. H. Collie, M.A., B.Sc.

Cambridge Radio Group

Date: March 6. Time: 8.15 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Discussion: Is there an Optimum Speed for a Gramophone Record ?
Opened by: G. F. Dutton, Ph.D., B.Sc.(Eng.).

North-Eastern Centre

Date: March 12. Time: 6.15 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-on-Tyne.
Lecture: Standardization and Simplification in the Electrical Industry.
By: J. T. Moore, B.Sc.
Lecture: An Organization for Internal Standardization in a Large Manufacturing Company.
By: P. J. Daglish, B.Sc.

North-Eastern Radio and Measurements Group

Date: March 5. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Informal Lecture: The Nervous System as a Communication Network.
By: J. A. V. Bates, M.A., M.B., B.Chir.
Date: March 19. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: The Acoustics of Studios and Auditoria.
By: W. Allen.

North-Western Measurements Group

Date: March 20. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: The Use of an Electrostatic Wattmeter for Magnetic-Loss Measurements.
By: J. K. Choudhury, M.Sc.Tech., and Arvon Glynne, M.A.

South Midland Radio Group

Date: March 19. Time: 6 p.m.
Held at: James Watt Memorial Institute, Great Charles Street, Birmingham.
Informal Lecture: The Magnetic Tape Recorder.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).

SOCIETY OF INSTRUMENT TECHNOLOGY

Date: March 27. Time: 6.30 p.m.
Held at: Manson House, Portland Place, London, W.1.
Lecture: Magnetic Amplifiers.
By: D. A. J. Maddock.

Midland Section

Date: March 16. Time: 7 p.m.
Held at: Arden Hotel, New Street, Birmingham.
Lecture: An Electronic Process Controller.
By: J. R. Boundy, B.Sc., A M.I.E.E., and S. A. Bergen, M.B.E., A.M.I.E.E.

SECRETARIES OF ASSOCIATIONS

INSTITUTION OF ELECTRICAL ENGINEERS

The Secretary, Institution of Electrical Engineers, Savoy Place, W.C.2.

Cambridge Radio Group

G. E. Middleton, M.A. University Engineering Laboratory, Cambridge.

North-Eastern Radio and Measurements Group

G. A. Kysh (Asst. Sec.), Carliol House, Newcastle-on-Tyne, 1.

North-Western Radio Group

A. L. Green (Asst. Sec.), 244 Brantingham Road, Chorlton-cum-Hardy, Manchester, 21.

South Midland Radio Group

W. H. Brent, B.Sc., Regional Director's Office, Midlands Region (G.P.O.), Civic House, Great Charles Street, Birmingham, 3.

BRITISH INSTITUTION OF RADIO ENGINEERS

The General Secretary, 9 Bedford Square, London, W.C.1.

West Midlands Section

R. A. Lampitt, A.M.Brit.I.R.E., 20 Northfield Grove, Merry Hill, Wolverhampton.

INC. RADIO SOCIETY OF GREAT BRITAIN

General Secretary, New Ruskin House, Little Russell Street, W.C.1.

BRITISH SOUND RECORDING ASSOCIATION

Richard W. Lowden, " Wayford," Napoleon Avenue, Farnborough, Hants.

TELEVISION SOCIETY

Lecture Secretary: T. M. Lance, 180 Bromley Road, Beckenham, Kent.

Engineering Group

G. T. Clack, 10 Tantallon Road, Balham, London, S.W.12.

RADAR ASSOCIATION

The Secretary, 83 Portland Place, London, W.1.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

W. H. Fox, A.M.I.E.E., Engineer-in-Chief's Office (T. P. Branch), Alder House, E.C.1.

INSTITUTION OF ELECTRONICS

Lecture Sec.: W. Summer, 31 Beech Road, Bournville, Birmingham, 30.

North-West Branch

W. Birtwistle, 17 Blackwater Street, Rochdale, Lancs.

SOCIETY OF RELAY ENGINEERS

T. H. Hall, M.Brit.I.R.E., 23 Dalkeith Place, Kettering, Northants.

SOCIETY OF INSTRUMENT TECHNOLOGY

L. B. Lambert, 55 Tudor Gardens, London, W.3.

INSTITUTION OF POST OFFICE ENGINEERS

Date: March 6 Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: The Provision and Maintenance of Long Distance Circuits, London Trunk Transmission Control.
By: E. H. Jeynes, A.M.I.E.E., and J. E. Isherwood.

Informal Meetings

Date: March 20. Time: 5 p.m.
Held at: The Conference Room, 4th Floor, Waterloo Bridge House, S.E.1.
Lecture: The 2000-Type Selector and its Problems.
By: J. O. Thompson, B.Sc., A.M.I.E.E.

RADIO SOCIETY OF GREAT BRITAIN

Date: March 30. Time: 5.30 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: High Selectivity 'Phone Reception.
By: R. H. Hammans.

INSTITUTION OF ELECTRONICS

Date: March 28. Time: 7 p.m.
Held at: College of Technology, Manchester.
Lecture: Some Uses of Electrical Capacitance in Industrial Measurement.
By: A. Green, B.Sc.

Midlands Branch

Date: March 6. Time: 7 p.m.
Held at: The Warwick Room, Imperial Hotel, Temple Street, Birmingham 2.
Lecture: Radioactive Tracers: Their Uses in Research and Industry, with particular reference to their potentialities for Industrial Control.
By: I. S. Hallow, B.A.

Southern Branch

Date: March 16. Time: 6.30 p.m.
Held at: Southampton University College, Southampton.
Lecture: A Physicist Looks at Biology.
By: W. Summer, A.Inst.P.

BRITISH SOUND RECORDING ASSOCIATION

Date: March 16. Time: 7 p.m.
Held at: The Royal Society of Arts, John Adam Street, W.C.2.
Lecture: The Design of a Long Duration Recording and Reproducing Equipment.
By: R. W. Lowden.

THE ENGINEERS' GUILD

Metropolitan Branch

Date: March 8. Time: 6 p.m.
Held at: Caxton Hall, Caxton Street, S.W.1.
Discussion: The Engineer and the Public.
Opened by: H. Nimmo, M.I.C.E., M.I.Mech.E., M.I.E.E.

BRITISH INSTITUTION OF RADIO ENGINEERS

Date: March 29. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.
Lecture: Nuclear Scintillation Counters.
By: J. B. Birks, B.A., Ph.D.

North-Western Section

Date: March 1. Time: 7.15 p.m.
Held at: College of Technology, Manchester.
Lecture: A Survey of Television Development and its Problems.
By: H. J. Barton-Chapple, B.Sc.

Merseyside Section

Date: March 1. Time: 7 p.m.
Held at: Electricity Service Centre, Whitechapel, Liverpool.
Lecture: The Use of Foster's Theorem in Circuit Design.
By: E. Williams, Ph.D.

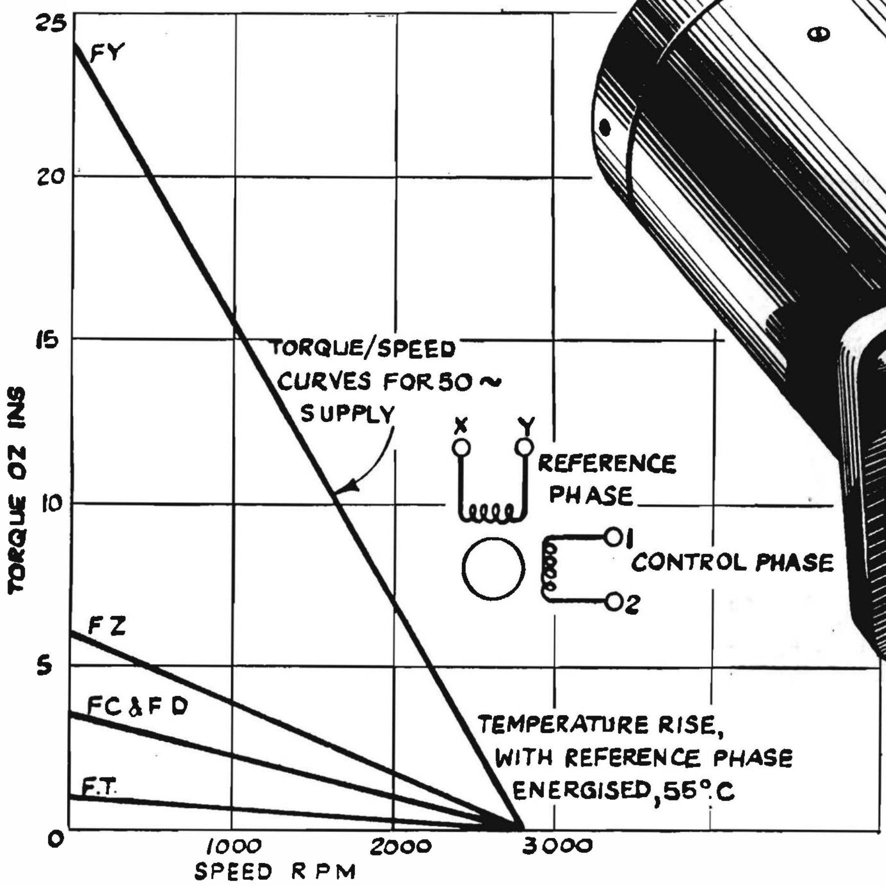
TELEVISION SOCIETY

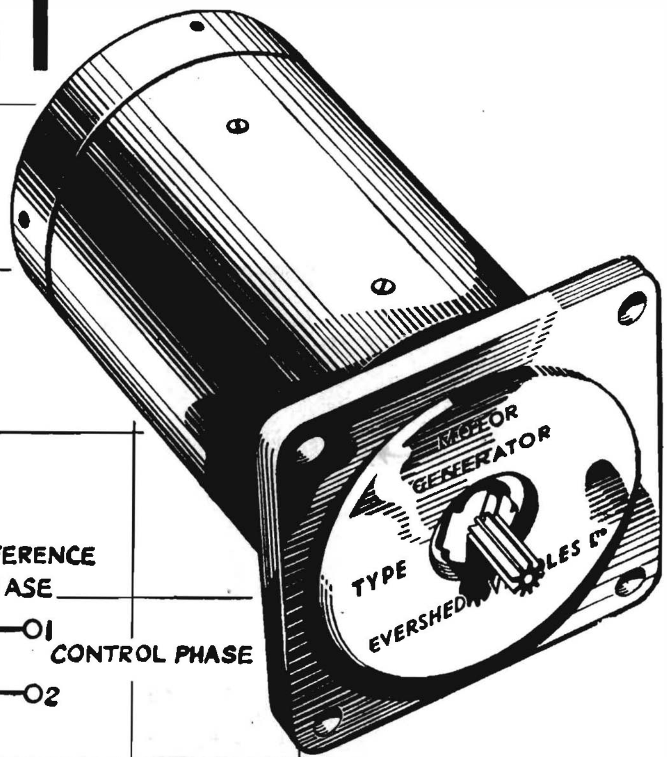
Date: March 7. Time: 6.45 p.m.
Held at: The Gaumont British Theatre, Wardour Street, W.C.2.
Subject: The Beveridge Report and the Future of British Television.
By: C. Ian Orr-Ewing, O.B.E., M.P.
Joint Meeting with the British Kinematograph Society.
Date: March 30.
Held at: The Waldorf Hotel, Aldwych, London, W.C.2.
Annual Dinner.

DATA SHEET No. 2.

EVERSHED SPECIAL DUTY F.H.P. MOTORS

TYPICAL A.C. SERVO MOTORS FOR ELECTRONIC CONTROL





Motors wound for 50-240 volts working, 50 and 60 C.P.S.

Antihunt induction generator may be fitted to all motors, giving 0.75 V./1000 R.P.M.

All motors rated for a temperature rise with reference phase energised of 55°C.

Send for the Evershed Small Motors' Data Book. EE 22.

FRAME SIZE	MOMENT OF INERTIA OZ. INS.²	REFERENCE PHASE WATTS.	CONTROL PHASE WATTS.	OUTPUT WATTS.
F.T.	.10	—	—	—
F.C.	.18	8.6	11	2.5
F.D.	.2	8.6	11	2.5
F.Z.	.27	12.0	12	4.5
F.Y.	.6	35.0	35	17.0

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ACTON LANE WORKS · CHISWICK · LONDON · W4

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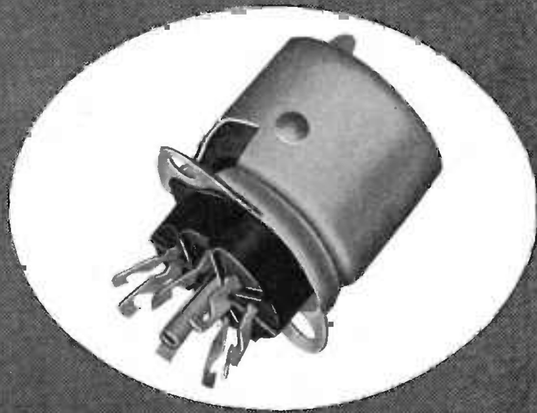

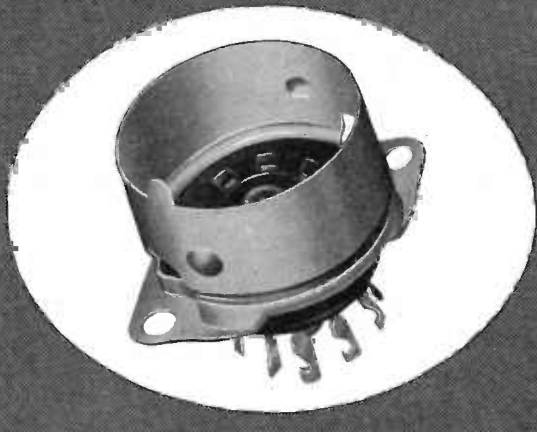

Frequentite is the most suitable insulating material for all high frequency applications. Seventeen years ago we introduced the first British-made low-loss ceramic, and consultation with us before finalising the design of new components is a wise precaution.

STEATITE & PORCELAIN PRODUCTS LTD.

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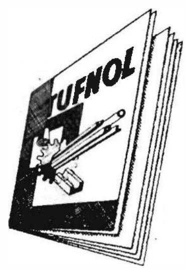
S.P.72

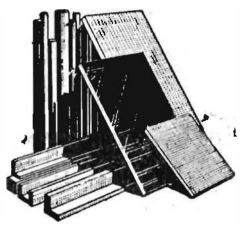
Though Tufnol is constantly seeking fresh worlds to conquer—these insulating collector bearing rings are not in fact a new use of this unique lightweight yet shock-proof material. As part of the apparatus in a steel works which swivels through 180° and charges the furnaces with steel ingots, they maintain electrical contact with the fixed bases through copper rings housed in their grooves. Throughout Britain, in heavy and light industry, Tufnol is used by resourceful engineers who see new and often unexpected uses for it. When you consider that it is half the weight of aluminium, structually strong, mates sympathetically with metals, has high electrical insulating properties, and stands up to searching tests of chemical corrosion, atmospheric exposure and grinding wear — its possibilities become apparent. Tufnol comes to you in pre-fabricated sheets, tubes, rods, bars, angles and channels or in specially moulded shapes. Easily and accurately machinable, it will certainly give full reign to your imagination.

Tufnol bushes increase the life of pickers in textile looms and, furthermore, do not wear the spindles along which they are continually moving.

DOWN-TO-EARTH FACTS ABOUT TUFNOL . . .

are contained in the series of informative handbooks devoted to its various uses. If you think you have a NEW use for Tufnol (and it is not unlikely), our Technical Staff will enjoy working with you on it. In any case why not write to us TODAY?





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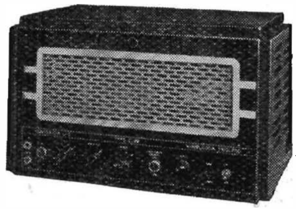
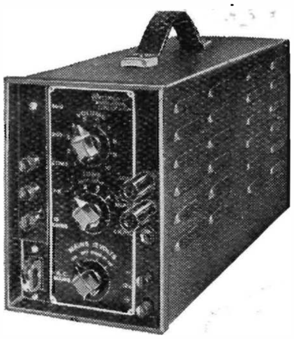


"FIFTY and THIRTY WATT" CINEMA AMPLIFIERS

as illustrated for single or double P.E.C. input with separate adjustable bias. Full range of tone controls to suit all needs with built-in Exciter Supply if required.

PRICES range from **34½ gns.** to **42½ gns.**

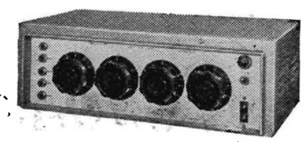


TYPE C.P. 20A AMPLIFIER

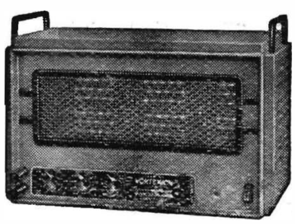
For AC Mains and 12 volt working giving 15 watts output, has switch change-over from AC to DC and "Stand-by" positions. Consumes only 5½ amperes from 12 volt battery. Fitted with mu-metal shielded microphone transformer for 15 ohm microphone, provision for crystal or moving iron pick-up with tone control for bass and top. Outputs for 7.5 and 15 ohms. Complete in steel case with valves.

PRICE **£28 . 0 . 0.**

FOUR-WAY ELECTRONIC MIXER



This unit has 4 built-in balanced and screened microphone transformers, normally of 50-30 ohms impedance. It has 5 valves and selenium rectifier supplied by its own built-in screened power pack, consumption 20 watts. Suitable for recording and dubbing, or large P.A. installations since it will drive up to six of our 50 watts amplifiers whose base dimensions it matches. The standard model has an output impedance of 20,000 ohms or less, and any impedance can be supplied to order. PRICE **£24 . 0 . 0.**



OTHER MODELS IN OUR RANGE OF AMPLIFIERS

"SUPER-FIFTY WATT" - - - - -	PRICE	**36½ gns.**
"THIRTY WATT" - - - - - - - -	,,	**30½ gns.**
"10-15 WATT RECORD REPRODUCER"	,,	**25½ gns.**

These are fitted in well-ventilated steel cases with recessed controls, as illustrated.

Full details upon request

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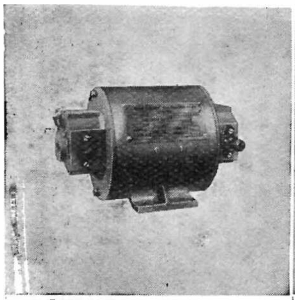
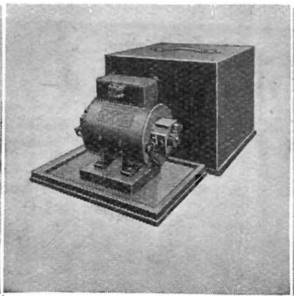
Telephones : LIB 2814 and 6242-3 **Telegrams : "Vortexion Wimble, London"**

The AUTHORITY ON *Power Equipment* *for* ELECTRONICS



LOW VOLTAGE ROTARY TRANSFORMER. 12 volts to 600 volts 200 m.a.



STANDARD RADIO AND TELEVISION ROTARY CONVERTER with filter and sound-proof cabinet. 230 volts A.C. Single Phase output.

MINIATURE ROTARY TRANSFORMER. 24/36 volts D.C. input. 60 watts output.

HIGH FREQUENCY MOTOR-ALTERNATOR. 200 watts 400 cycles output from 220 volts D.C.

For details and technical specification of Power Equipment for all Electronic purposes including the equipment illustrated, write for fully illustrated and descriptive lists 3 R.C. and 16 H.F. In prototype stages let your designers meet ours.

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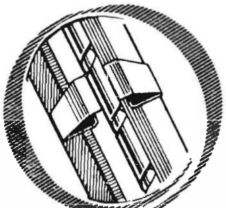
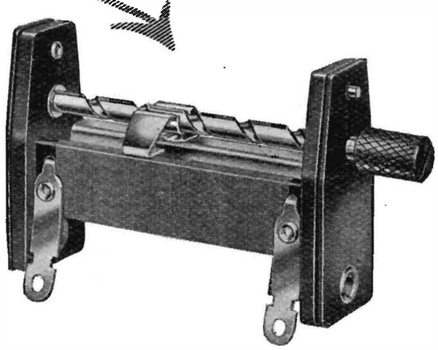
E.D.C. 19

VARIABLE- BUT DEPENDABLE



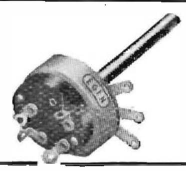


The value of the new EGEN midget pre-set variable resistor to the television and electronics designer and radio engineer has been enhanced by a new double slider, giving greater stability and making accurate adjustment easier. It has a rating of 2½ watts and is designed for panel or chassis mounting; available in any value from 10 ohms to 25,000 ohms.

R.E.C.M.F. Exhibition — STAND No. 26

- *Size 2" x 1⅛" x ⅞".*
- *Worm drive for smooth action.*
- *Rachet action prevents over-winding.*
- *Silver-plated solder tags.*

This new resistor can be supplied in groups mounted to a common panel, suitably engraved, if required.



—and a better carbon potentiometer
The complete electrical stability of the EGEN POTENTIOMETER is achieved by a specialised method of carbon deposition. Perfect mechanical action further contributes to its outstanding reputation for reliability.

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The variable condenser has a range of 100$\mu\mu$F which is extended to 1100 $\mu\mu$F by ten increments of 100$\mu\mu$F, all adjusted with accuracy so that the decade is absolutely direct reading in $\mu\mu$F, no corrections or calibration being necessary.

Electrical Standards for Research and Industry

Testing and Measuring Apparatus for Communication Engineering

LIST No. C 880

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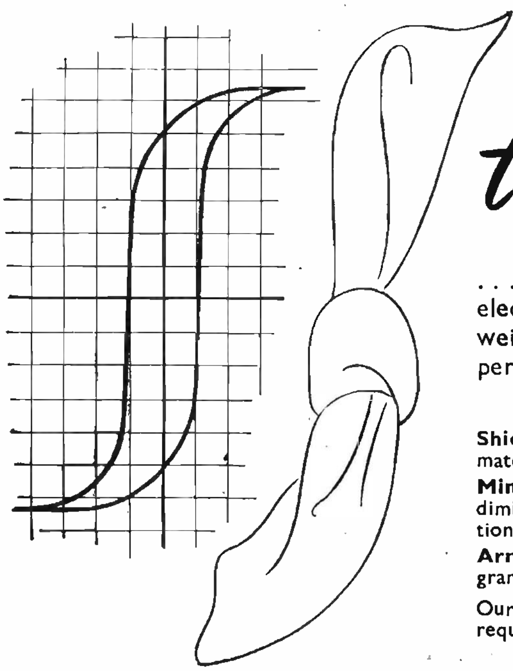

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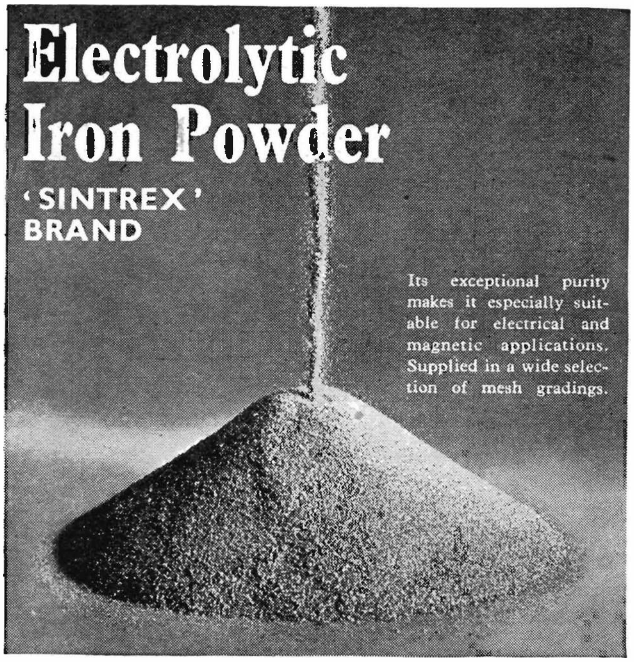

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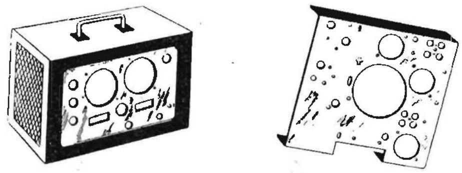

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WHY IT PAYS TO USE

Ersin Multicore Solder

Radio Manufacturers and Service Engineers all over the world prefer to use *Ersin Multicore Solder* in their factories and workshops. Even in the U.S.A. where more cored solder is produced than anywhere else in the world, many leading firms insist on British made *Ersin Multicore*, despite the freight charges and import duties which raise its cost above that of the locally made single-cored product. Below are some of the reasons why *Ersin Multicore* has attained such world-wide popularity.

FOR MANUFACTURERS

Ersin Multicore Solder is the only solder containing 3 cores of non-corrosive Ersin Flux. Ersin is a high grade rosin which has been subjected to a complex chemical process to increase its fluxing action, whilst still retaining the non-corrosive properties. Ersin Flux makes precision soldering quicker and more economical —it not only prevents oxidation during soldering, but actually cleans the surface to be soldered, removing any oxide from the metal.

Three cores of flux ensure flux continuity throughout the length of the solder wire. There are no lengths without flux—that means no wasted solder, no wasted time, and freedom from 'dry' or H.R. joints.

The correct proportions of flux to solder are always assured—no extra flux is required. Three cores of flux provide thinner solder walls, giving instantaneous melting —an important factor in speeding up repeat soldering operations.

Soldered joints made with Ersin Flux do not corrode even after prolonged exposure to any degree of humidity. This has been tested under climatic conditions ranging from the Arctic to the Tropics.

Only the finest virgin tin and lead are used in the manufacture of *Ersin Multicore*, giving complete freedom from impurities.

CUTS PRODUCTION COSTS

The economies effected by using *Ersin Multicore Solder* play an important part in cutting production costs and keeping down the price of radio equipment. You get more joints per lb. of *Ersin Multicore*—there is no waste. Soldering with *Ersin Multicore* is quicker, too, and every joint is a perfect electrical connection. This saves time in your inspection department—fewer sets are rejected on test.

These lengths of ERSIN MULTICORE SOLDER all weigh the same. By selecting the finest gauge, the maximum economy of material is obtained.

FOR FACTORY USE

Ersin Multicore Solder is made as standard for factory use in 5 alloys and 9 gauges, and is supplied on nominal 7 lb. reels. Other Alloys and Gauges can be supplied to special order. Bulk prices on application.

ALLOYS. This table shows the Melting Points of the three principal Alloys used in Electronic and Telecommunication industries.

Alloy	Colour Code	Sol.	Liq.	Bit. Temp.	USES
60/40	Red	183°C	190°C	230°C	High quality work
45/55	Crimson/Buff	183°C	227°C	267°C	Hand soldering
40/60	Green	183°C	238°C	278°C	radio and electrical

GAUGES. Approximate number of feet per lb.

Standard Wire Gauge	Diam. in inches	Diam. in M/ms.	ALLOY 60/40	45/55	40/60
10	0.128	3.251	25.2	23.5	23.0
12	0.104	2.642	38.1	35.2	34.9
13	0.092	2.337	48.7	45.3	44.5
14	0.080	2.032	64.4	59.2	58.6
16	0.064	1.626	100.5	94.3	92.1
18	0.048	1.219	178.5	167.8	163.5
19	0.040	1.016	257.5	240.4	235.5
20	0.036	0.914	318.0	302.5	291.0
22	0.028	0.711	526.0	492.0	481.0

FOR SERVICE ENGINEERS

Most service engineers safeguard their reputation for quality by using only *Ersin Multicore Solder*, which gives them a guaranteed standard of sound, precision soldered joints.

The repair of old receivers may involve making connections to highly oxidised tags. The extra speed of the non-corrosive Ersin Flux—contained in the 3 cores of *Ersin Multicore Solder* —will enable satisfactory joints to be made quickly. There is no waste with *Ersin Multicore*, the correct proportions of flux and solder are always present, and as the flux does not tend to run out of the cores, there is always a supply available for the next joint.

Ersin Multicore Solder is made in 4 specifications for Service Engineers, packed in the well-known Size One Carton, which provides the most convenient method of carrying solder in the Service Engineer's Kit. The wire is drawn out through a hole in the top and cannot become tangled.

SIZE ONE CARTONS. Contain 60/40 High Tin Television and Radio Quality or 40/60 Radio and Electrical Alloy.

Catalogue Ref. No.	Alloy Tin/Lead	S.W.G.	Approx. length per carton	Retail Price Subject s.	d.
C 16014	60/40	14	16 feet	5	0
C 16018	60/40	18	41 feet	5	0
C 14013	40/60	13	15 feet	5	0
C 14016	40/60	16	29 feet	5	0

Specification C16018 is particularly recommended for soldering television equipment.

MULTICORE SOLDERS LTD.

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